COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

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THE GEOLOGY AND MINERAL RESOURCES OF THE CHILLAGOE AREA, QUEENSLAND

BY

F. DE KEYSER, Bureau of Mineral Resources,

and

K. W. WOLFF, Geological Survey of Queensland.

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BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

Director: J. M. RAYNER.

This Bulletin was prepared in the offices of:

Bureau of Mineral Resources, Geological Branch: Chief Geologist, N. H. FISHER.

Geological Survey of Queensland: Chief Government Geologist, A. K. DENMEAD

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CONTENTS

SUMMARY 7
INTRODUCTION 9
Situation and access 9
Climate 9
Fieldwork 10
Geography 11
Previous investigations 11

REGIONAL GEOLOGY

STRATIGRAPHY 11
PRECAMBRIAN 12
Dargalong Metamorphics 12
Metamorphism and metasomatism 15
Age 15
Post-Metamorphic intrusions 16
Boundary with the Palaeozoic 16
PALAEOZOIC 18
Chillagoe Formation 18
Palaeontology and age 21
The origin of some of the sediment types 22
Depositional environment 23
Mount Garnet Formation 24
Hodgkinson Formation 26
Palaeontology and age 26
Depositional environment 27
Ringrose Formation (?) 28
Permo-Carboniferous igneous rocks 29
Boxwood Volcanics 30
Doolan Creek Rhyodacite 30
Nychum Volcanics 32
Porphyry at Redcap 32
Featherbed Volcanics 33
Dykes 34
Origin and deposition of the Permian Volcanics 35
Age and correlation 36
The Granites 36
Age and relationships between the granite varieties and the volcanics 42
MESOZOIC
Wrotham Park Sandstone 44
CAINOZOIC 45
STRUCTURE 45
GEOMORPHOLOGICAL EVOLUTION 46
GEOLOGICAL HISTORY 48

ECONOMIC GEOLOGY

INTRODUCTION
Mining history 53
Mineral exploration 55
Production 56
DISTRIBUTION AND CLASSIFICATION 57

DESCRIPTION OF MINES

	Page
COPPER, LEAD, SILVER, ZINC	
Mungana area	64
Redcap area	68
Ruddygore	71
Zillmanton	73
Calcifer area	75
Chillagoe group	76
Muldiva mines	79
Cardross area	80
Dargalong Group	84
Bamford area	84
Scattered mines	85
TUNGSTEN, MOLYBDENUM, BISMUTH	87
Wolfram Camp	90
Bamford Hill	93
Khartoum district	94
Koorboora area	95
Scardon's area	96
Emuford area	97
Sunnymount area	98
TIN	98
Koorboora area	99
Sunnymount area	101
Emuford area	102
Bamford area	103
GOLD	
Fluorspar area	105
Mount Wandoo	106
FLUORSPAR	108
Mungana	109
Dargalong area	111
Fluorspar group	112
Almaden	112
Emuford	113
IRON	113
LIME	115
MINOR MINERAL OCCURRENCES	
Antimony	116
Clay	116
Coal	116
Cobalt	117
Manganese	117
Mica	117
Quartz	118
Titanium	118
Uranium	119
CONCLUSIONS AND RECOMMENDATIONS	119
ACKNOWLEDGMENTS	121
REFERENCES	122
APPENDIX 1 : Index to mine locality map	127
APPENDIX 2 : Maps, plans, and sections of mines on the Almaden, Chillagoe, and Mungana 1-mile Sheets on file at Geological Survey of Queensland office.	131

TABLES

Table 1 :	Stratigraphical table	opp. p. 12
Table 2 :	Ore produced from the Chillagoe district	opp. p. 56
Table 3 :	Production of the principal copper and lead mines of the Chillagoe district	88

ILLUSTRATIONS

PLATES

Plate 1	—Stereo-photo pair of portion of Mungana 1-mile Sheet	between 16 and 17
Plate 2, Fig. 1	—Migmatite, Dargalong Metamorphics	
Fig. 2	—Augen-gneiss, Dargalong Metamorphics	
Plate 3, Fig. 1	—Limestone bluff at Chillagoe, showing karren erosion	
Fig. 2	—Stalactites in limestone cave, Chillagoe	
Plate 4, Fig. 1	—Photo-micrograph of quartz sandstone, base of Chillagoe Formation	
Fig. 2	—Photo-micrograph of spilite (?), Chillagoe Formation	
Plate 5, Fig. 1	—Photo-micrograph of conglomerate greywacke, Chillagoe Formation	
Fig. 2	—Ibidem	
Plate 6, Fig. 1	—Sericitic quartz sandstone, Boxwood Ring Complex	between 32 and 33
Fig. 2	—Photo-micrograph of porphyritic micro-adamellite	
Plate 7	—Stereo-photo pair of portion of the Featherbed Volcanics	
Plate 8, Fig. 1	—Spherulitic rhyolite dyke, Almaden	
Fig. 2	—Pyroxene-hornblende-biotite-quartz diorite, Petford (between crossed polarizers)	
Plate 9, Fig. 1	—Hypersthene-pyroxene-quartz diorite (between crossed polarizers)	
Fig. 2	—Granophyre, Boxwood Ring Complex	
Plate 10	—Mungana 1-mile Geological Series, Sheet No. 54, Zone 7	at back of Bulletin
Plate 11	—Chillagoe 1-mile Geological Series, Sheet No. 55, Zone 7	
Plate 12	—Almaden 1-mile Geological Series, Sheet No. 60, Zone 7	
Plate 13	—Distribution of mineralization and location of mines, workings, and prospects, Chillagoe district	
Plate 14	—Shannon-Zillmanton area, Chillagoe, Queensland, showing geology and axes of electromagnetic anomaly	

TEXT FIGURES

Fig. 1—The area mapped: 1, Mungana 1-mile Sheet; 2, Chillagoe 1-mile Sheet; 3, Almaden 1-mile Sheet	9
Fig. 2—Physiography of the Chillagoe-Mungana-Almaden 1-mile areas, North Queensland	8
Fig. 3—Conformity and non-conformity shown by a quartzo-feldspathic tongue in paragneiss, Wandoo Creek	13
Fig. 4—Probable eroded sub-volcanic stock with dyke swarms, Mungana Sheet, 30 miles west of Chillagoe	14
Fig. 5—The Doolan Ring Complex	31
Fig. 6—Observed relationships between Permian volcanics and granites	37
Fig. 7—Geomorphological development, Chillagoe district.	47
Fig. 8—Block diagram showing seven stages in the geological history of the Chillagoe district	49
Fig. 9—Tentative classification of the ore deposits in the Chillagoe district	58
Fig. 10—Copper and lead production, Chillagoe district	62
Fig. 11—Silver and gold production, Chillagoe district	63
Fig. 12—Wolframite and molybdenite production, Chillagoe district	89
Fig. 13—Tin production, Chillagoe district	98
Fig. 14—Fluorspar production, Chillagoe district	108

SUMMARY

This Bulletin presents the results of five months' fieldwork carried out by a joint geological party from the Bureau of Mineral Resources and the Geological Survey of Queensland in 1958, and incorporates subsequent scattered field observations in more recent years.

The area investigated is covered by the three One-Mile Sheets of Chillagoe, Mungana, and Almaden, and forms the north-western part of the Atherton 1:250,000 Sheet area, North Queensland. Metamorphosed and migmatized Precambrian schist, gneiss, and muscovite granite in the west are separated from folded Palaeozoic geosynclinal sediments by a large fault. The geosynclinal deposits are represented by Upper Silurian to Lower Devonian formations with mixed shelf facies, and, farther east, by the eugeosynclinal flysch sediments of the Middle to Upper Devonian Hodgkinson Formation. Remnants of unconformable lacustrine or estuarine sediments, probably Carboniferous, are also exposed.

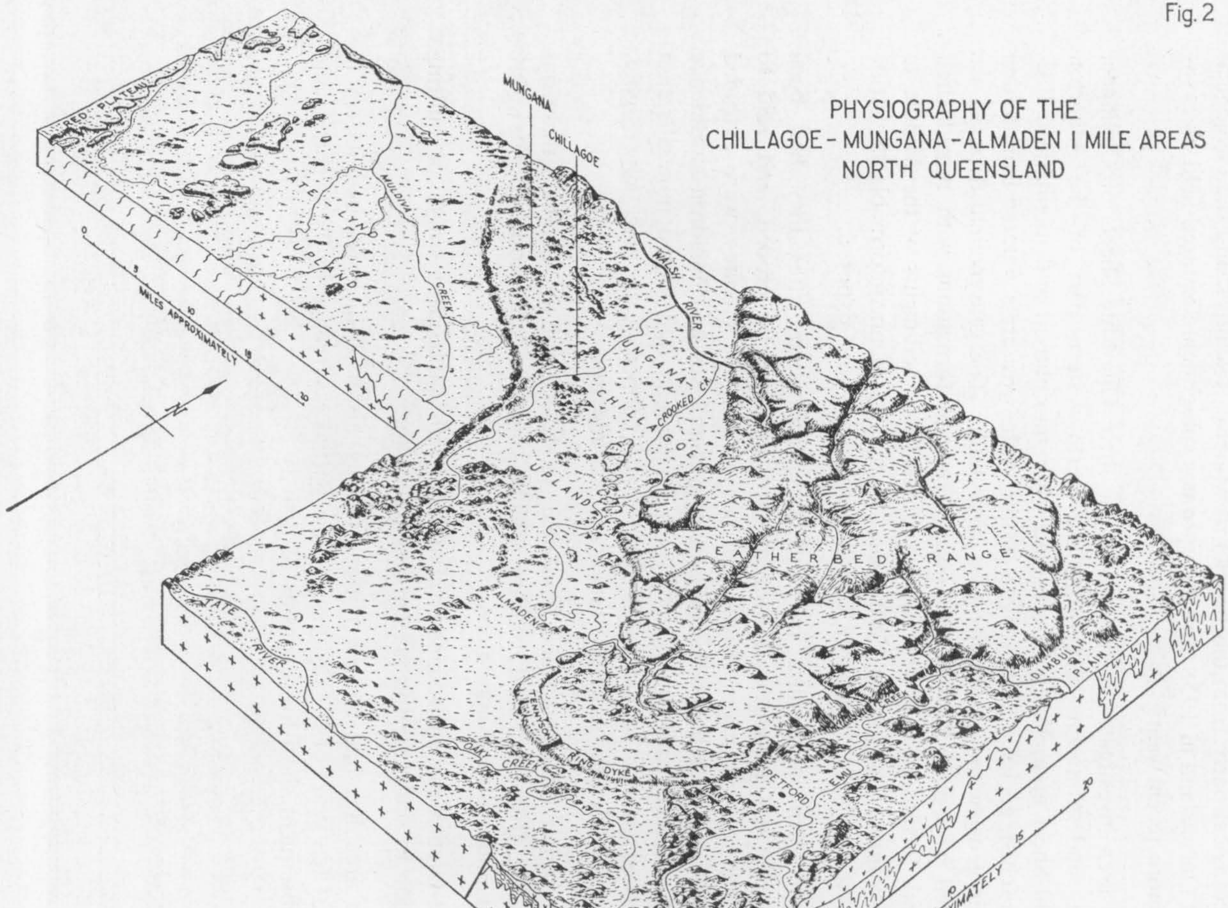
Upper Permian granites intruded these formations after they had been folded during a Carboniferous orogeny and subsequently eroded, and acid to intermediate volcanics, comagmatic and coeval with the granites, were extruded on a surface of low relief, commonly in ring complexes and cauldron subsidence areas. Associated with the granites is a widespread and varied mineralization which has given rise to numerous deposits of copper, lead, zinc, silver, gold, tungsten, molybdenum, bismuth, tin, fluorspar, and iron.

The region remained stable and near sea-level until the Lower Cretaceous transgression from the west, during which sandstone and conglomerate were deposited under littoral conditions.

Post-Cretaceous epeirogenesis combined with subsequent stages of faulting and erosion to sculpture the present-day landscape.

The area has had an intermittent mining history which reached its zenith in the first ten years of the century, with a partial resurgence in the twenties, and a few subsequent short-lived spasms of activity.

Fig. 2



PHYSIOGRAPHY OF THE
CHILLAGOE - MUNGANA - ALMADEN I MILE AREAS
NORTH QUEENSLAND

INTRODUCTION

Situation and Access

An area of about 1800 square miles is covered by the combined Mungana, Chillagoe, and Almaden 1-mile Sheets, and is contained within latitudes 17° and 17°30′ South and longitudes 144° and 145° East (Fig. 1). The settlements of Chillagoe, Almaden, and Petford, now virtually ghost towns of the old mining days, are connected with Cairns by rail and road. Chillagoe is 85 miles flying distance from Cairns, or 145 miles by road. A branch railway line to Mount Garnet (outside the area south of Petford) has been abandoned since 1961, and a weekly service to Mungana has also been discontinued since this settlement became deserted in 1961. Another line, branching off at Almaden, leads to Forsayth, outside the area mapped.

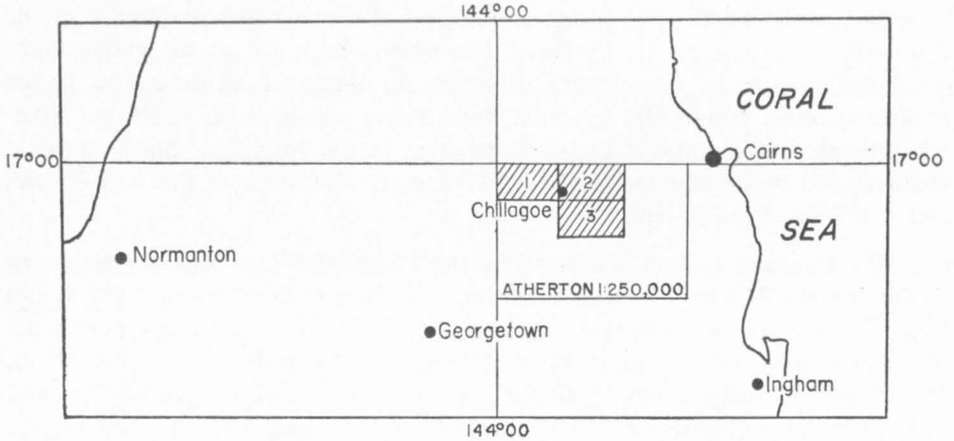


Fig. 1. The area mapped: 1. Mungana 1-mile Sheet; 2. Chillagoe 1-mile Sheet; 3. Almaden 1-mile Sheet.

Air-strips suitable for light aircraft are maintained at Chillagoe and at the Sunnymount battery.

Climate

The Chillagoe district lies within the semi-arid belt immediately west of the tropical coastal humid zone of North Queensland, and has a dry winter and wet summer. The average annual rainfall of 30 to 40 inches falls mostly in the summer months (January to March); the monthly average during the winter is less than an inch.

The mean daily temperature ranges from about 60° in the winter to 80° during the summer.

Geography (Fig. 2)

Both altitude and relief grade from moderate in the east to low in the west. Generally speaking, the area lies on the gentle slope from the Atherton Tableland in the east—outside the area—to the low sandy plains and alluvials around the Gulf of Carpentaria to the west. Within the boundaries of the area mapped this general tilt is apparent from the differences in altitude between Batcha siding in the south-east (1971 feet) and the Cardross area in the north-west (600 feet). The maximum elevations are found in the rugged Featherbed Range, where the highest summits are an estimated 2500 to 3000 feet above sea-level. The lowest points, at about 600 feet above sea-level, occur where the Walsh River leaves the area in the north-western part of the Mungana Sheet.

The landscape is controlled to a marked degree by lithology and by structure. Gently undulating country is characteristic of the Dargalong Metamorphics in the west (though the gneisses and granulites form some rough surfaces in the south-western parts). The deeply incised, rough, uninhabited, and stony massif or tableland of the Featherbed Range is built up of the massive porphyries of the Featherbed Volcanics. The Chillagoe Formation and much of the granite have developed moderately flat country in which the limestone crops out as jagged bluffs and ridges 100 to 300 feet high; chert ridges, on the other hand, are typically smooth and rounded. The western edge of the Mungana Sheet area is characterized by the horizontal beds of Cretaceous sandstone of the Red Plateau and its fringe of mesas and buttes.

The Chillagoe district is drained by the Walsh and Tate Rivers, which ultimately join the Mitchell River and flow into the Gulf of Carpentaria. The Walsh River is perennial most years; most of the other watercourses are dry during the winter or, at the most, maintain a chain of disconnected waterholes (e.g., Tate River, Emu Creek, Crooked Creek). In the Chillagoe limestone belt and at the base of the Cretaceous sandstone mesas springs can be found, some of which have enough discharge to maintain a permanent flow or trickle: the Chillagoe Creek is a good example.

Fieldwork

The survey was undertaken:

a. as part of the regional geological mapping of the Atherton 1:250,000 Sheet;

b. to locate and investigate the mineral deposits;

c. to map in detail the Chillagoe Formation.

The mapping was carried out between April and October, 1958, by a party comprising two geologists of the Bureau of Mineral Resources (F. de Keyser and M.B. Bayly) and a geologist of the Geological Survey of Queensland (K. W. Wolff). Air photographs taken by the R.A.A.F. at a scale of about 1:47,000 were used for navigation on the ground and as a base for the compilation of field data; air photographs at a scale of 1:12,000 were available for the detailed work in the environs of Mungana and Chillagoe. The results were plotted on planimetric maps (1:47,000) provided by the Division of National Mapping.

Various independent field observations made during more recent years by geologists of the Bureau of Mineral Resources have added to the clarification of outstanding problems.

Authorship.—The Summary, Introduction, and Regional Geology of this Bulletin have been written by F. de Keyser; the Economic Geology is based on an unpublished report by K. W. Wolff (1959), later revised by F. de Keyser. The Appendices are the work of K. W. Wolff, who also compiled Table 2.

Previous Investigations

Since 1887, when the first ore deposits became known, much has been published on the mineral occurrences in the area, but comparatively little attention was given to the regional geology.

Among the more important publications on various mining centres are those by Ball on Wolfram Camp (1919a, 1920), Bamford Hill (1914b), and Cardross (1917a); by Jensen on the mines in the Mungana-Almaden area (1920a,b,c; 1941); by Jack on many mines in the Chillagoe and Koorboora area (1891); by Morton & Ridgway on Wolfram Camp (1944b); and by Broadhurst on the Mungana and Chillagoe districts (1952, 1953). The role played by the various mining companies in the investigations of the area will be discussed in the chapter on Mining History (page 53).

The most comprehensive geological studies were made by Jensen (1923, 1941) and, in the more restricted area between Mungana and Chillagoe, by Broadhurst (1952). A good account of the Dargalong Metamorphics was given in a report by Ball (1917a).

REGIONAL GEOLOGY

STRATIGRAPHY

Broadly speaking, the Chillagoe district is situated along the western periphery of the Palaeozoic Tasman Geosyncline on the borders of the Precambrian basement, where shelf conditions once prevailed. After being folded, the Palaeozoic sediments were intruded by Upper Permian granites and covered by concomitant volcanics.

The following geological units are distinguished (see Table 1 for more detail):

1. Precambrian schist, gneiss, granulite, migmatite, and amphibolite of the Dargalong Metamorphics. These occupy most of the Mungana Sheet area.
2. Upper Silurian to Lower Devonian shelf sediments of the Chillagoe Formation (mixed facies) and the Mount Garnet Formation (clastic facies).
3. The Middle to Upper Devonian Hodgkinson Formation. This unit, with its thick pile of greywacke and siltstone, may be compared to a geosynclinal flysch facies, and crops out in the extreme north-eastern and south-eastern parts of the area mapped.

4. Remants of quartz sandstone and siltstone, probably Carboniferous, in the Koorboora and Boxwood areas, Almaden Sheet, may represent molasse-type deposits, and appear to overlie the older formations unconformably.
5. Acid to intermediate Upper Permian granites—the Herbert River and Elizabeth Creek Granites and their differentiates—intrude all previous formations, and occupy large tracts of the Chillagoe and Almaden Sheet areas.
6. Large volumes of concomitant volcanics — flows, pyroclastics, and welded tuffs — form the Boxwood, Nychum, and Featherbed Volcanics and the Doolan Creek Rhyodacite. They are widely distributed in the Chillagoe and Almaden Sheet areas.
7. Horizontal blankets of Lower Cretaceous sandstone — the Wrotham Park Sandstone — overlie the Dargalong Metamorphics with a strong angular unconformity, and form the Red Plateau, part of which occupies the western edge of the Mungana Sheet area.

Some of these units are represented on the photo stereo-pair of Plate I.

PRECAMBRIAN

The Dargalong Metamorphics

The Dargalong Metamorphics, first named by Skertchly (1899) and most comprehensively described by Ball (1917a), crop out over most of the area covered by the Mungana 1-mile Sheet. They are much folded and faulted, and are overlain by a blanket of Cretaceous sandstone in the west and by the Nychum Volcanics in the north. They are separated from the Chillagoe Formation in the east by a large fault—the Palmerville Fault. Upper Permian granite intrudes the metamorphics in places. The type area for the formation is the old mining centre of Dargalong, south-west of Chillagoe.

Quartz-mica schist, gneiss, augen gneiss, granulite, muscovite pegmatite, quartzite, amphibolite, migmatite, and muscovite granite are the types of rock normally exposed (Plate 2). With the exception of the amphibolites, they grade into one another.

The quartzite, mica schist, and gneiss are generally metamorphosed sediments, although some gneiss appears to be intrusive. The quartzite is generally a slabby, thoroughly recrystallized white to grey or—more rarely—dark rock, and has its greatest extent in the north-west. Rare examples of preserved ripple-marking have been found. The mica schist is silvery-grey and commonly crenulated and intricately folded, with amplitudes ranging from a few millimetres to several feet. Muscovite is generally more abundant than biotite, though biotite-rich rocks poor in muscovite are not uncommon.

With decreasing mica content and increasing grain size the marked schistosity is lost, and the rock grades into gneiss and granulite. Some gneiss contains conspicuous augen (Pl. 2, fig. 2) of untwinned potash feldspar, 1 to 3 inches across, set in a micaceous quartz-plagioclase matrix.

TABLE 1

STRATIGRAPHY OF THE CHILLAGOE, MUNGANA, AND ALMADEN 1-MILE SHEET AREAS, NORTH QUEENSLAND

	Unit and Symbol	Thickness	Lithology	Distribution	Structure and Topography	Age, Palaeontology and Correlation.	Relationships	Remarks
CAINOZOIC	Qa	?	Soil, alluvial, sand and silts.	Scattered patches along main rivers, and in Mungana, Chillagoe-Almaden area.	Level ground.	Recent, probably grading back into Pleistocene and perhaps Tertiary, in places.	Unconformable veneer over older formations.	Some alluvial tin in Koorboora area and along Spinifex and Halpin Creeks, Batcha.
	Czs	?	Residual sand cover.	Mainly along Tomato Creek (N.W. of Mungana Sheet) and over granite south of Oakey Creek, south of Tennyson Ring Dyke.	Level sandy ground	Possibly Tertiary to Recent.	Unconformable blanket over Cretaceous sandstone and Permian granite.	Derived from disintegrated Cretaceous sandstone and Permian granite.
MESOZOIC	Wrotham Park Sandstone Klw	330 ft. max.	Cross-bedded sandstone, pebbly sandstone, and conglomerate. Some shale.	Western edge of Mungana 1-mile Sheet area.	Forms mesas and eastern fringe of Red Plateau.	Neocomian or Aptian. Probably to be correlated with Gilbert Formation	Unconformably overlying Dargalong Metamorphics.	
	Undifferentiated Pzu	—	Coarse biotite granite, biotite-muscovite granite; grey biotite granite; fine-grained dark hornblende diorite.	In places within the Mungana 1-mile Sheet area, forming isolated stocks.	Usually hilly.	Probably Permian, and equivalent to the Herbert River, Almaden and Elizabeth Creek Granite.	Intrudes the Dargalong Metamorphics.	
	Elizabeth Creek Granite. Pgz	—	?a) Grey to pink hornblende-bearing biotite microgranite.	Granite massif south of Petford and Lappa Junction.	Jointed massif.	Probably Upper Permian.	Intrudes S-Dm and probably part of Pf. Is probably younger than Pgz^b, Pgz^c, Pgh, Pga.	Possibly represents contaminated Pgz. Usually contains allanite, as accessory.
	,,	—	b) Pink, leucocratic, biotite granite and adamellite; fine-grained and leuco-granite; coarse pink granite porphyry.	Mainly south of Tennyson Ring Dyke and along Tate River. Almaden 1-mile Sheet area. Smaller outcrops at Wolfram Camp and north of Almaden.	Varied topography: sand-covered low areas with scattered tors; and jointed hilly exposures.	Upper Permian; possibly grading into Lower Triassic.	Intrudes Pgh, S-Dm, part of Pf, and Cr.	All Pgz varieties have introduced tin, tungsten, molybdenum, bismuth, and fluorite mineralization.
	,,	—	c) Very coarse, pink-red, leucocratic alkali granite.	Along Halpin Creek south of Batcha, and along northern rim of Boxwood Ring Complex, Almaden 1-mile Sheet area.	Sand-covered tor and boulder areas.	Upper Permian.	Older than Pgz^a and probably Pgz^b; older than part of Pf (Tennyson Ring Dyke).	
PALAEOZOIC	Featherbed Volcanics Pf	At least 2000 ft. for the total of Pf, a,b,c.	a) Massive, dark-grey or green rhyolite to dacitic ignimbrites.	Largest portion of Chillagoe 1-mile Sheet area, and central-northern part of Almaden Sheet area.	Forms the high, rugged, deeply incised, jointed Featherbed Range.	Upper Permian.	Younger than Pf^b and possibly Pf^c Co-magmatic with Pgz^b?	Strongly porphyritic.
	,,		b) Pale-weathered, commonly flow-banded flows, pyeroclastics, felsites, some ignimbrites. Some localized flaggy sandstone with layers of coaly shale.	Generally forms the periphery of the Featherbed Range; forms the Tennyson Ring Dyke. Main outcrop area east of Koorboora.	Horizontal or low-dipping flows; thick dykes (e.g., Tennyson Ring Dyke).	Upper Permian.	Overlain by Pf^a younger than Pga, Pgz^c, S-Dm, and probably Pf^c. Intruded by coarse quartz-feldspar porphyry.	Spheroidal structures in some flows.
	,,		c) Dark-grey, green, or nearly black rhyolitic to dacitic ignimbrites, flows and pyroclastics.	Eastern portions of Chillagoe and Almaden 1-mile Sheet areas.	Near-horizontal expanses, massif structure, hilly topography.	Upper Permian. Possibly identical with Pf^a.	Overlying S-Dm, D-Ch. Intruded by Pgz-type granite, and by pink, rhyolitic dykes.	Strongly porphyritic Pf^a and Pf^c are possibly one and the same.
	Almaden Granite Pga	—	Biotite-bearing hornblende adamellite and granodiorite, grey.	Most of the granitoid rocks in the area between Almaden and the Walsh River.	Generally flat country, with scattered tors and outcrops.	Upper Permian.	Intrudes S-Dh, S-Dm, Pzur; is older than Pgz, possibly younger than ?Pga. Traversed by rhyolitic dykes. Overlain by Pf, but intruding Pun.	Possibly originated by assimilation of limestone by Herbert River Granite intruding Chillagoe Formation. Copper-lead-zinc-silver-gold mineralization.
	? Pga	—	Pyroxene-biotite-hornblende quartz diorite and gabbro, with hypersthene-bearing varieties.	Main exposures around Petford; south-west of Koorboora; and 12 miles south-west of Mungana.	Red-brown soil plain at Koorboora; elsewhere nondescript to hilly.	Upper Permian, possibly a more basic variety of Pga.	Older than Pf^b.	
	Herbert River Granite Pgh.	—	Grey to pale-pink hornblende-biotite adamellite, medium-grained.	Most of the granites south and south-west of Almaden; also represented in Almaden-Walsh River area.	Generally flat country; locally as jointed, hilly areas of exposure.	Upper Permian.	Intrudes Pgz^b near Khartoum. Transitional into Pga. Intrudes S-Dh, S-Dm, Ad.	
	Boxwood Volcanics Po.	Few hundred feet.	Grey to dark-green, porphyritic, rhyolitic and rhyodacite flows, pyroclasts, and ignimbrites.	Area west and south-west of Boxwood, south of Tennyson Ring Dyke, Almaden Sheet area.	Hilly country. Part of Boxwood Ring Complex.	Upper Permian.	Older than Pf^b, younger than Cr. Traversed by coarse quartz-feldspar porphyry.	
	Doolon Creek Rhyodacite Pd.	?	Grey or greenish, porphyritic rhyodacite.	Area along Walsh River at junction with Doolan Creek, Mungana Sheet.	Part of Doolan Creek Ring Complex. Low country.	Upper Permian? Possibly correlated with Pzur.	Older than Pf and Pgz^b, possibly also Pga.	
	Nychum Volcanics Pun.	Few hundred feet.	Grey ignimbrites and pyroclastics, basal agglomerate.	Outcrops along northern edge of Mungana Sheet area.	Low hilly country.	Upper Permian. Plant fossils in type area north of Walsh River.	Older than Pf; overlies Ad, S-Dh.	
	Undifferentiated. Pzur.	?	Grey, pink, or dark porphyritic micro-adamellite.	Localised area east of Redcap. Mungana Sheet area.	Hilly ranges up to 500 feet.	(Upper) Permian?	Intruded by Pga. Faulted boundary with S-Dh.	Either volcanic or sub-volcanic.
PALAEOZOIC	Ringrose Formation Cr?	Few hundred feet.	Sericitic quartz sandstone and quartz siltstone, conglomerate.	North-east of Koorboora; and within area of Boxwood Ring Complex.	Hilly ranges. Bedding obscure. Dips moderate.	Probably Carboniferous, possibly equivalent with Ringrose Formation.	Seems to overlie S-Dm unconformably. Is older than Pf and Po, and older than Pgz.	Molasse-type deposit? Some pneumatalytic alteration. Host rocks for tin, wolfram deposits.
	Hodgkinson Formation D-Ch.	At least 20,000-30,000 feet.	Greywackes and feldspathic sandstones, micaceous siltstone, shale; subordinate chert, conglomerate, and breccia.	North-east corner of Chillagoe Sheet area; south-east corner of Almaden Sheet area.	Hilly ranges with north-north western trend. Dendritic drainage folded.	Middle Devonian to Upper Devonian, possibly Lower Carboniferous. Poorly preserved plant fossils, common.	Unconformably overlain by ?Pf; intruded by Pgh and Pgz. Faulted boundary with S-Dm.	Sandy-flysch facies of Tasman Geosynclinal zone. Deposition commonly by turbidity currents.
	Mount Garnet Formation S-Dm.	?	Quartz greywacke and siltstone with some chert, conglomerate, sedimentary breccias.	Areas between Redcap and Walsh River; between Almaden and Featherbed Range; around Koorboora; and south-south-east of Petford.	Nondescript; low rubbly ridges and hills. Structure; steeply folded.	Pene-contemporaneous with part of Chillagoe Formation, and partly overlying the latter. Age probably Lower Devonian in Chillagoe District.	In Chillagoe district, overlying the Chillagoe Formn. Faulted boundary against Hodgkinson Formn. Intruded by all granites, overlain by all Permian volcanics.	Clastic shelf association of Chillagoe shelf area. Host rocks for some deposits of tin, wolfram, lead-silver.
	Chillagoe Formation S-Dh.	Est. at roughly 5,000-10,000 feet.	Fossiliferous, massive limestone, bedded chert; quartz greywacke and siltstone; lenses of conglomerate, sedimentary breccia, and basic lavas. Basal member of sericitic quartz sandstone and siltstone.	Zone, 6 miles wide, from near Almaden north-west to Walsh R. and beyond. Enclave at Ootann between Almaden and Tate River.	Characteristic rugged limestone bluffs; low ridges of chert, conglomerate, and arenites; broad plains over siltstone and part of the limestone. Steeply folded .	Pene-contemporaneous in part with Mt. Garnet Formation, but normally underlying the latter in the Chillagoe district. Fossils: corals (e.g. *Halysites, Favosites* spp., *Cyathophyllum* spp.) crinoids, brachiopods, gastropods, Upper Silurian-Lower Devonian.	Overlain by Mount Garnet Formation; separated from Dargalong Metamorphics by Palmerville Fault; intruded by Almaden Granite, Herbert R. Granite, and Elizabeth Ck. Granite. Overlain by the Permian Volcanics.	Mixed shelf association of the Chillagoe shelf area. Host rocks for most of the copper, silver, lead, zinc deposits.
PRECAMBRIAN	Dargalong Metamorphics Ad	?	Mica schist, quartz schist, gneiss, augen-gneiss, granulite, migmatite, muscovite granite, amphibolite, pegmatite.	Occupies the greater part of the Mungana 1-mile Sheet area.	Low, mature landscape, gradually roughening towards the south. Steeply folded for the most part.	Age probably Precambrian, possibly Archaean.	Unconformably overlain by Wrotham Park Sandstone and Nychum Volcanics; faulted against the Chillagoe Formn., intruded by all Permian granites and dykes.	Host rocks for some copper, gold, fluorspar deposits and mica prospects. Metamorphosed probably in the garnet-amphibolite facies.

'Granulite' is a term used here to imply a metamorphic rock built up predominantly of equidimensional mineral grains, whose texture is attributed to metamorphism, not to first consolidation. In other words, 'granulite', as used here, has no connexion with the granulite facies of metamorphism. Some of the granulites strongly resemble muscovite granite, and it is conceivable that the muscovite granite in the Dargalong Metamorphics is the ultimate product of granitization (metasomatism), and is not magmatic granite: its contacts are ill-defined and gradational. The largest outcrop area, with at least a fairly well defined photo-interpreted boundary, is at Dargalong. A thin section of a sample from this area consists of quartz, untwinned potash feldspar, oligoclase, muscovite, and partly chloritized biotite, in order of decreasing abundance. The feldspars are partly sericitized and kaolinized.

Where the metamorphics are conspicuously interveined and interlayered with quartzo-feldspathic material, either by injection (Fig. 3) or by metamorphic differentiation, the term 'migmatite' may be employed (Pl. 2, fig.1). Augen gneiss (Pl. 2, fig. 2) is commonly found in such migmatized areas. A 'basic front' rim of biotite forms a margin around some quartzo-feldspathic veins.

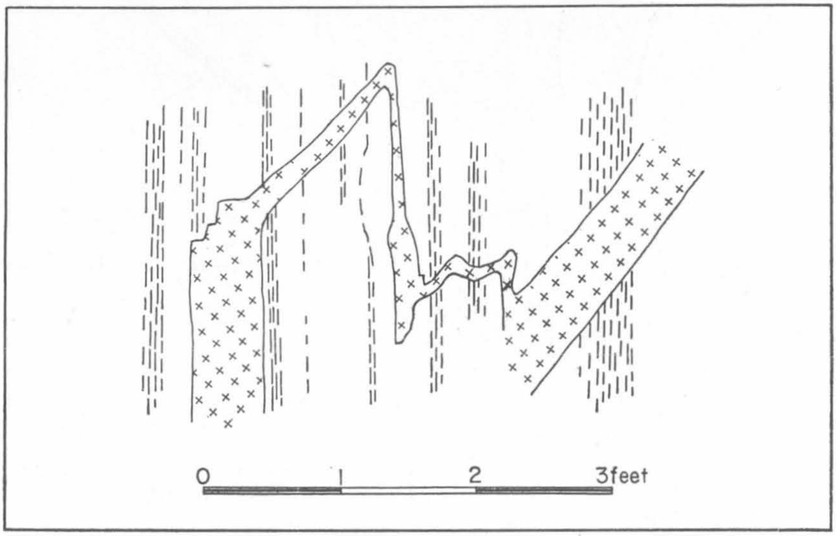


Fig. 3. Conformity and unconformity shown by a quartzo-feldspathic tongue in paragneiss, Wandoo Creek.

Quartz-feldspar-muscovite pegmatites are abundant in many areas, especially where granitic and granulitic rocks predominate. The veins are generally parallel to the foliation, but cross-cutting relationships are fairly common. The grain size is commonly of the order of several inches, and books of muscovite up to a foot across are known from the Mount Kitchin mica prospects (page 117).

The amphibolite is a dark green fine-grained to medium-grained rock composed of hornblende and plagioclase, together with some garnet, and is widespread in the eastern part of the outcrop area; it seems to be absent in the western part. The amphibolite forms uniform sheets intercalated with the schist and gneiss, and occurs also as irregular masses. The irregular shapes of some outcrops and the fact that the amphibolite nowhere grades into other rock types may point to an igneous origin.

The Dargalong Metamorphics were probably derived from aluminous and siliceous sediments, fairly rich in potassium, which were metamorphosed and granitized, presumably at medium to great depth.

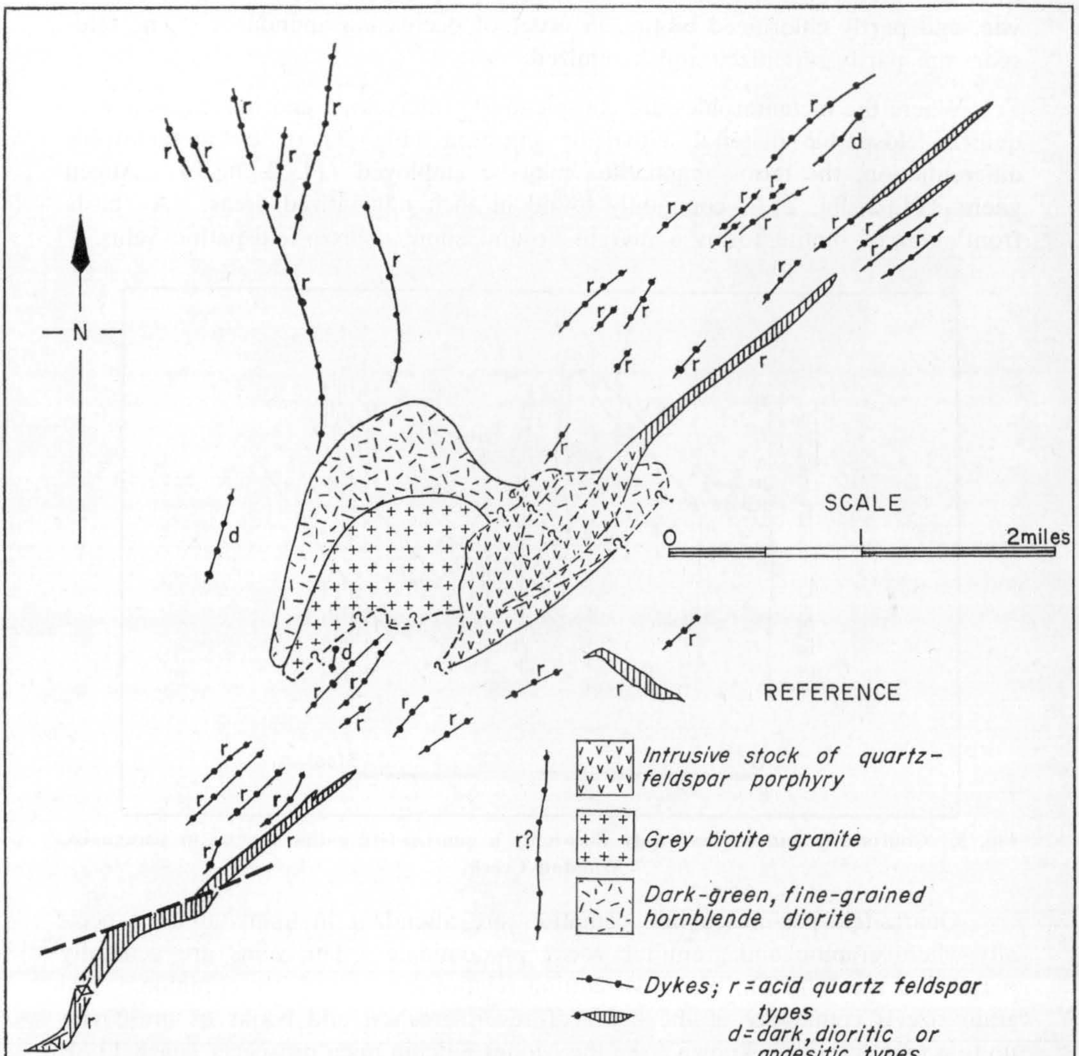


Fig. 4. Probable eroded sub-volcanic stock with dyke swarm. Mungana Sheet, 30 miles west of Chillagoe.

Metamorphism and Metasomatism

The grade of metamorphism cannot be determined with certainty, and more than one facies may be represented. Two thin sections of gneiss from outcrops on Muldiva Creek show the following, not very diagnostic, mineral composition: quartz, oligoclase, muscovite, and (chloritized) biotite. Specimens of amphibolite and gneiss from localities about 50 miles north of the Walsh River, outside the area mapped, contain andesine-labradorite feldspar, greenish brown hornblende, and garnet, and can be placed in the garnet amphibolite facies. Notwithstanding lack of compositional evidence in the Mungana Sheet area, the appearance in outcrop (Pl. 2), the coarse texture of some gneisses, and the presence of migmatite, all point to a high-grade metamorphism of the Dargalong Metamorphics in the Chillagoe district. Albite, reported by Jensen (1941), could not be found in the few thin sections examined.

Metasomatic processes have apparently played an active role during metamorphism. The potash feldspar augen in the augen gneiss are thought to be a result of potassium metasomatism: the potash feldspar (orthoclase or untwinned (?)microcline) contains ragged patches and shreds of muscovite, chloritized biotite, and quartz, which are thought to be remnants of the original mineral assemblage. Even the muscovite-biotite granite may be the ultimate result of metasomatism and granitization, as the granite does not appear to have sharp intrusive boundaries, seems to grade into granulite and gneiss, is composed of the same minerals—quartz, feldspar, muscovite, and chloritized biotite—as are the gneisses, and, under the microscope, shows plagioclase partly replaced by potash feldspar and quartz.

The Dargalong Metamorphics have all undergone retrograde metamorphism, which is expressed mainly in the universal chloritization of biotite and the alteration of feldspars. The rocks have also been subjected to post-metamorphic stresses: muscovite and biotite flakes are bent and warped, quartz is granulated and shows strain shadows and cataclastic effects. It is conceivable that these effects as well as the retrograde metamorphism were imposed on the schists and gneisses during the Carboniferous orogeny that folded the Palaeozoic geosynclinal sediments farther east.

Age

Until recently, no age more precise than pre-Silurian could be ascribed to the Dargalong Metamorphics. D. A. White (1961) considered them to be Precambrian, possibly Archaean, because of the apparent high grade of metamorphism. Certainly the inclusion of high-grade gneiss and amphibolite as pebbles in non-metamorphic Silurian conglomerate is conclusive evidence that a very long period of metamorphism, uplift, and erosion must have preceded the Upper Silurian sedimentation.

A granite sample taken from the vicinity of the Dargalong mines, on the Chillagoe-Bolwarra road, was dated at 1044 million years by the K/Ar method in the Geochronology Laboratory of the Australian National University (see page 43). This indicates that the Dargalong Metamorphics are at least not younger than the Middle Proterozoic.

Post-metamorphic Intrusions

The Dargalong Metamorphics are intruded by a variety of igneous rocks, both acid and basic, in the form of dykes and dyke swarms as well as plutonic stocks.

Most of the plutons are adamellites and granodiorites, which are undoubtedly part of the Permian Herbert River Granite and Almaden Granite. Other intrusives are grouped on the map as undifferentiated rocks, where correlation with these granites is uncertain. They include stocks of muscovite-biotite granite, grey biotite granite, coarse pink biotite granite, and dark green hornblende diorite. One complex body of diorite and granite with associated dyke swarm, some 10 miles south-south-west of Cardross, possibly represents a deeply eroded volcanic or sub-volcanic system (Fig. 4).

The Dargalong Metamorphics are traversed by innumerable dykes of quartz-feldspar porphyry, felsite, and andesite or dolerite. They are probably contemporaneous with the Upper Permian dykes and volcanics in the Chillagoe and Almaden Sheet areas, and may represent feeder channels for volcanic deposits now removed by erosion. On air photographs the acid dykes stand out as thin white lines and ribs, whereas the basic dykes are shown as dark lines and grooves. Networks and swarms of dykes are particularly well expressed on air photographs of the areas 10 miles south-south-west of Cardross and 14 miles south-south-east of Cardross.

Boundary with the Palaeozoic

The Chillagoe Formation, which bounds the Dargalong Metamorphics in the east, contains conglomerate lenses with pebbles of gneiss and amphibolite, and a long period of erosion undoubtedly separates the two formations. However, the character of the actual boundary has long been a problem. Jack (1891), for instance, found the boundary in the Chillagoe district transitional and intergrading, whereas Ball (1918) found it abrupt; Jensen (1941) regarded the boundary as a fault, whereas Broadhurst (1952) saw only a normal, unconformable relationship.

In 1960, during the regional mapping of the Mossman 1:250,000 Sheet area which adjoins the Chillagoe district in the north, enough evidence was found to prove that the boundary is a large fault of regional proportions (the Palmerville Fault), trending from the western coastline of Princess Charlotte Bay in the north of Almaden in the south; from there to the south-east the fault is obscured by the masses of igneous rocks, but it can be picked up again as a strong lineament from the Herbert River Gorge to the Pacific coast at Halifax

Part of Mungana 1-mile Sheet, between Rookwood Station and Walsh River. (Stereopair). Six formations and igneous units are represented. Note characteristic development of limestone bluffs, roughness of Featherbed Volcanics (Pf), renewed incision of the Walsh River and its branches.

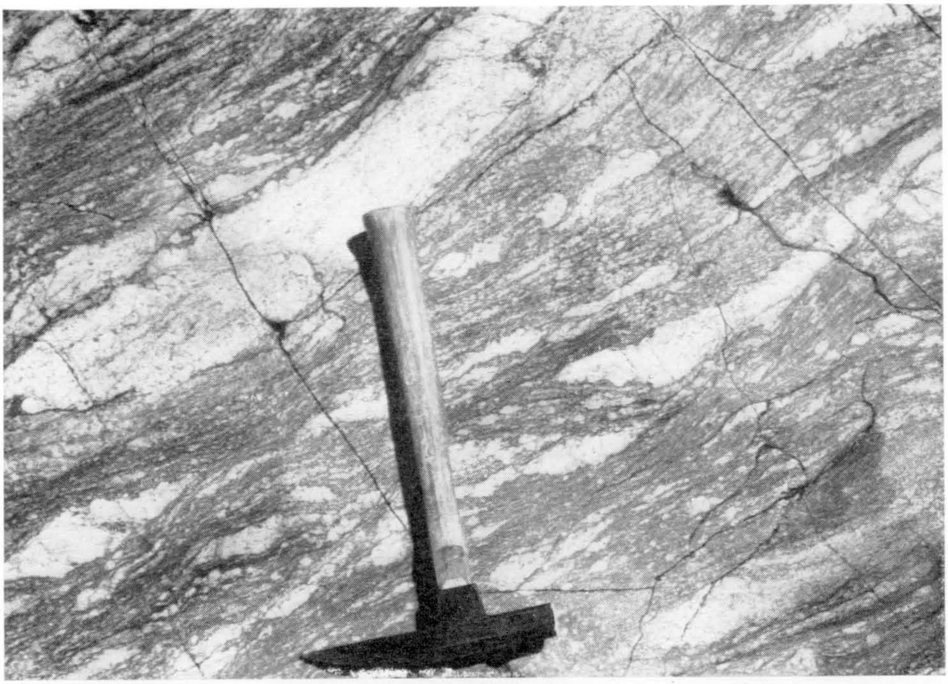


Fig. 1. Migmatite, Dargalong Metamorphics, Muldiva Creek.

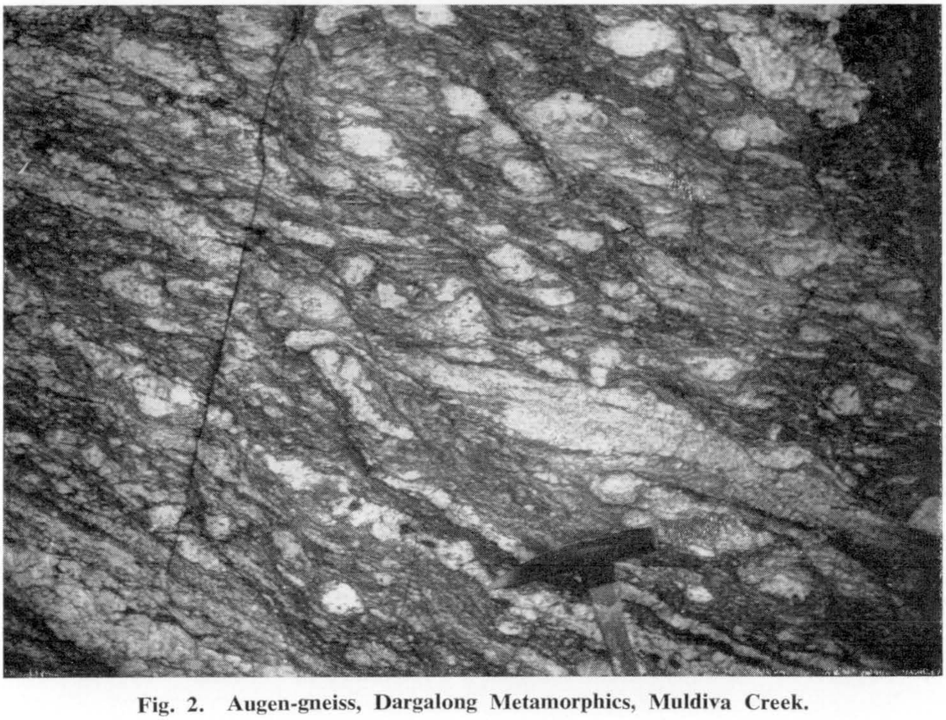


Fig. 2. Augen-gneiss, Dargalong Metamorphics, Muldiva Creek.

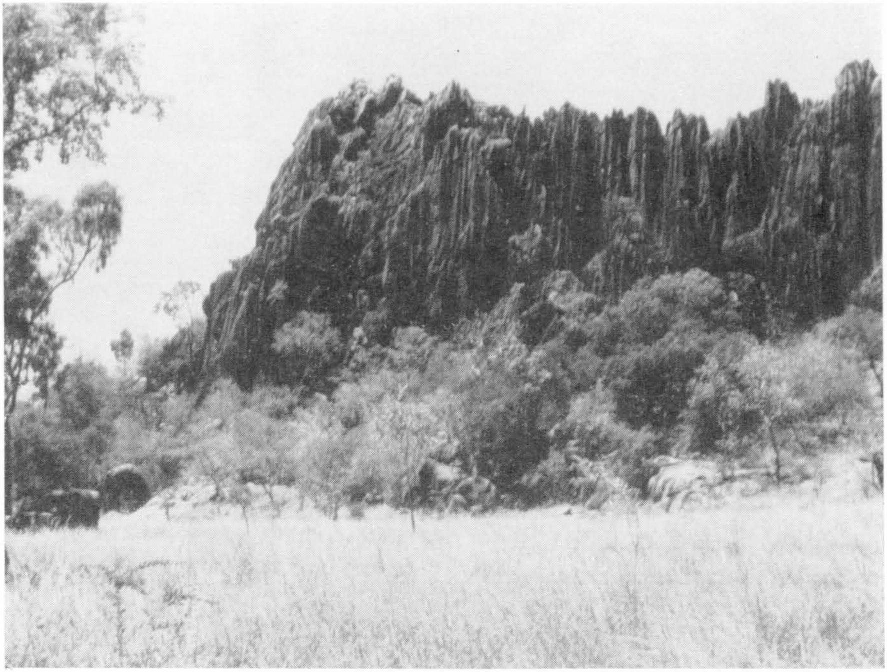


Fig. 1. Limestone bluff at Chillagoe, showing karren erosion.

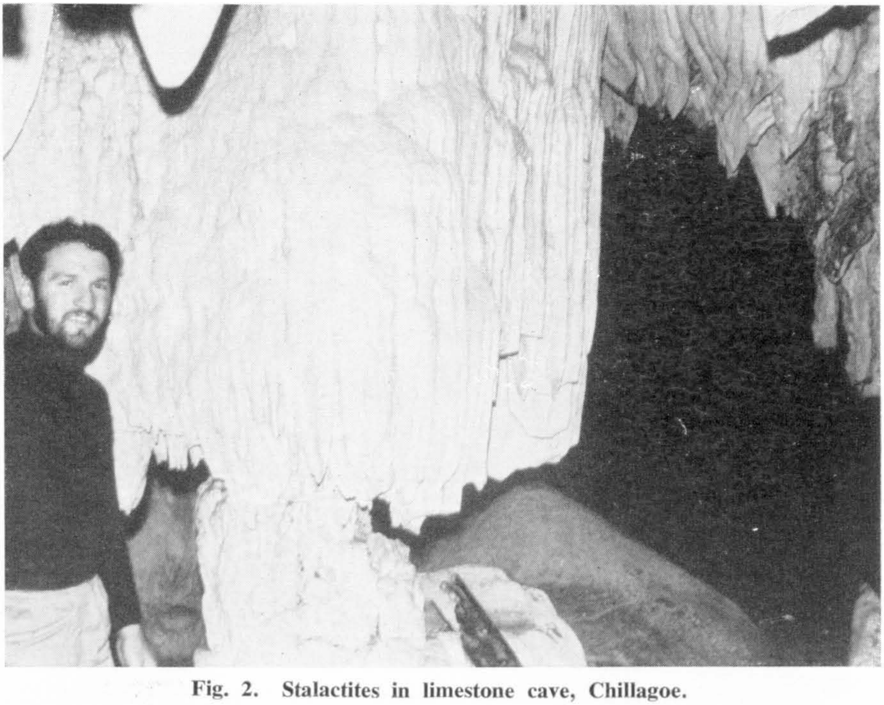


Fig. 2. Stalactites in limestone cave, Chillagoe.

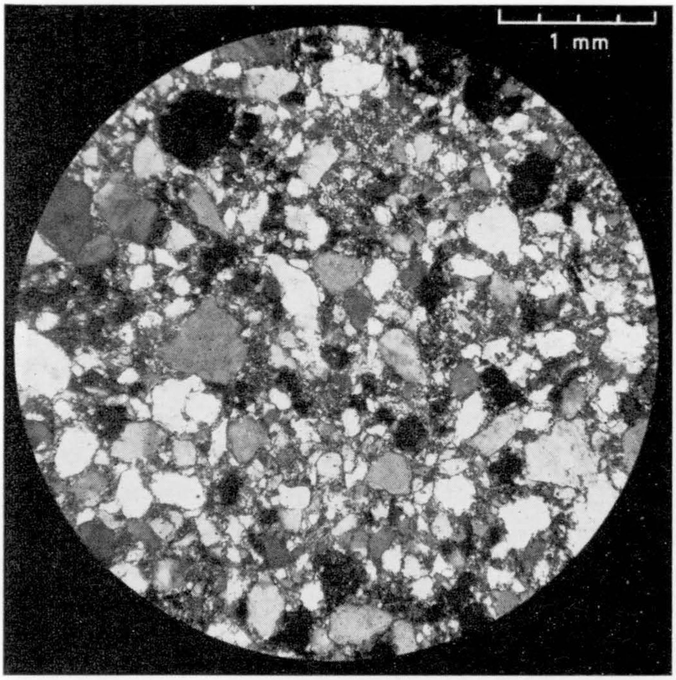


Fig. 1. Quartz sandstone, base of Chillagoe Formation. Mainly quartz, some chert, interstitial sericite.

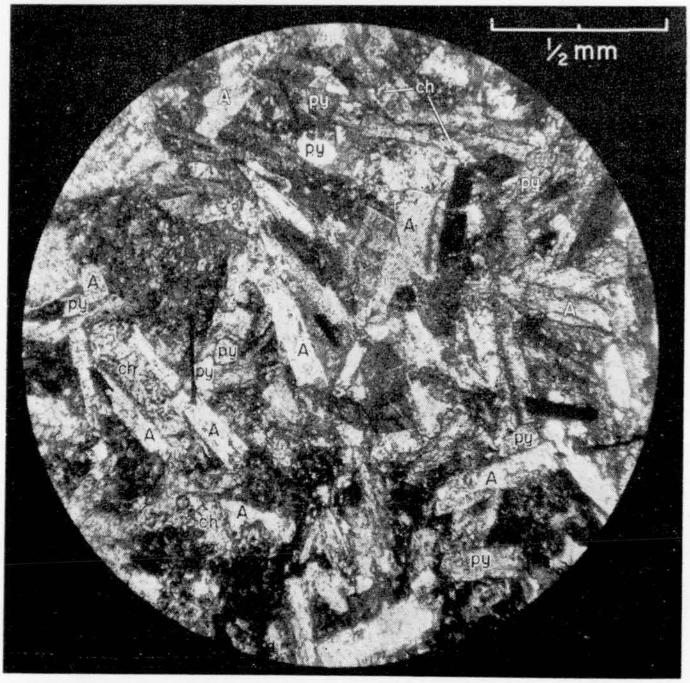


Fig. 2. Spilite (?), Chillagoe Formation. Near roadside, half-way between Chillagoe and Almaden. A = albite, py = pyroxene (augite), ch = chlorite.

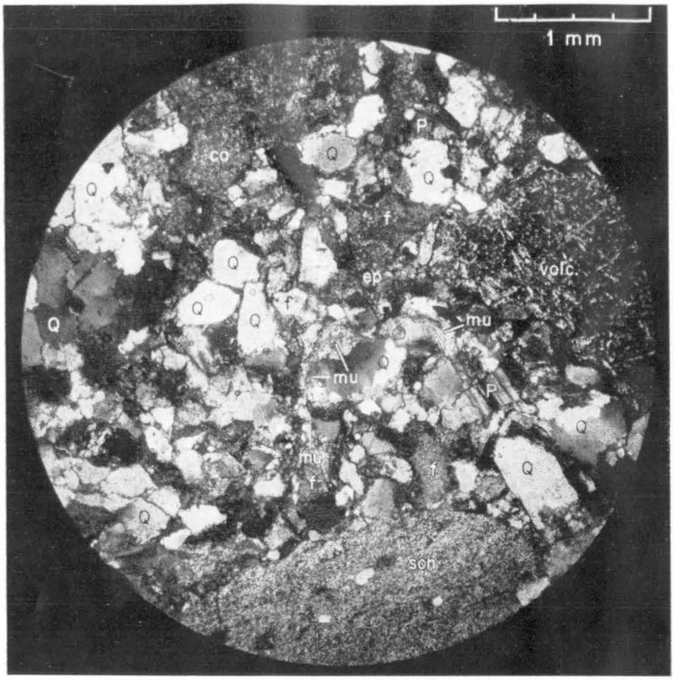


Fig. 1. Conglomeratic greywacke, Chillagoe Formation, Walsh River. Volc = volcanic, Q = quartz, P = plagioclase, sch = schist, f = altered feldspar, ca = calcite, mu = muscovite, ep = epidote.

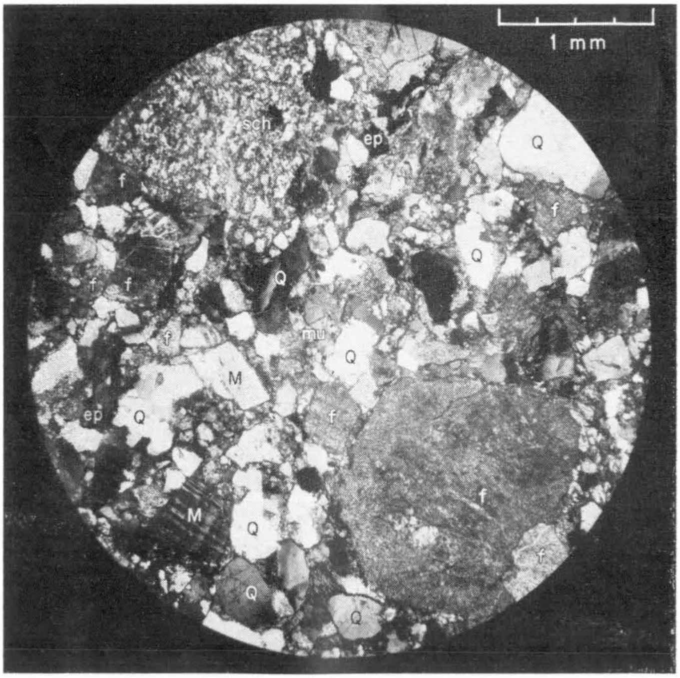


Fig. 2. Conglomeratic greywacke, Chillagoe Formation, Walsh River. Q = quartz, sch = quartz schist, M = microcline, mu = muscovite, O = orthoclase, A = albite.

Bay, south of Ingham. The coast-line along Halifax Bay to Townsville and beyond runs along the projected continuation of the fault, which must be considered to have been a major controlling factor in the formation of the coastal structure in this part of North Queensland (de Keyser, 1963).

The following evidence indicates the faulted nature of the boundary:

a. its absolute straightness and sharpness;
b. the absolute separation between the two formations—no outcrops of Dargalong Metamorphics exist east of the boundary, nor are sediments of the Palaeozoic formations found on the western side;
c. the movement or tilting of Cretaceous strata along the boundary;
d. a striking difference in topography on either side of the boundary, due to recent movements along the fault;
e. a graben formed as a wedge along the fault north of the Palmer River; in this graben down-faulted and crumpled Permian sediments have been preserved; the sides of the graben are part of the Palmerville Fault system;
f. physical effects on rocks of the Chillagoe Formation, which can be seen near Palmerville: along the boundary, sericitic schists occur that are probably the result of dynamo-metamorphism, and chert beds have been broken up;
g. the apparent control, in the area immediately north of the Walsh River, of the extent and distribution of the Permian Nychum Volcanics: outcrops of these volcanics are rare immediately east of the boundary, where they apparently have been removed by erosion;
h. the distinctive lithology of the base of the Chillagoe Formation: it is a distinctive fine-grained quartz sandstone and siltstone which is not repeated elsewhere in the formation, but is restricted to a zone adjacent to the fault, and probably genetically connected with it (see page 18).

The evidence proves conclusively the nature of the boundary; nevertheless, in the Chillagoe district it is not readily recognized. Here the fault-line is in many places marked by a peculiar massive green rock which under the microscope is seen to be composed of (?) dolomite with albite, calcite, chlorite, and quartz, in order of decreasing abundance. This rock is seen to alternate at one place with quartzite of the (?) Chillagoe Formation, and at another with mica schist. In places the green rock crops out in a zone hundreds of feet wide. As the rock is found nowhere else in either the Chillagoe Formation or the Dargalong Metamorphics, its origin must be sought in alteration processes connected with the faulting.

Where 'intergrading' seems to be present, the explanation must be sought in imbrication and the fading out of strong metamorphic contrasts owing to phyllonitization on the one hand, and retrograde metamorphism on the other.

PALAEOZOIC

Chillagoe Formation

The Chillagoe Formation occupies a north-westerly belt from the vicinity of Almaden to the Walsh River and beyond. An enclave is preserved in the granite near Ootann, south of Almaden. The western limit of the formation is the Palmerville Fault; in the east the sediments are overlain by the Mount Garnet Formation (the boundary of which is arbitrary only), or are truncated by granite, which also forms the boundary to the south. The maximum width of the formation exposed in the area mapped is about 6 miles.

The formation was first named by Jack (Jack & Etheridge, 1892), who used the term 'Chillagoe Beds.' Skertchly (1899) described the 'Chillagoe Limestone' as overlying the clastic sediments in the area. Dunstan (1916) used the 'Chillagoe Series' to include the limestone as well as associated cherts and clastic sediments. The type area is the Chillagoe-Mungana district.

The Chillagoe Formation consists predominantly of chert and fossiliferous limestone, with intercalated quartz greywacke and siltstone, and subordinate conglomerate, basic volcanics, sedimentary breccias, and possibly acid volcanics. The base of the formation is formed by a series of fine-grained sericitic quartz sandstones and siltstones with a total thickness of 500 to 1000 feet in the area mapped, and containing small lenses of quartz conglomerate, quartz greywacke, basic lava, shale, and limestone. The fine-grained sandstone (Pl. 4, fig. 1) is pinkish yellow to grey or greenish, and is distinguished from all other members of the Chillagoe Formation by its characteristic appearance. In places it grades into chert or quartz greywacke. The fact that the sandstone occurs exclusively along the Palmerville Fault, from near Chillagoe to beyond Palmerville, and is not repeated anywhere else away from the fault, suggests that its formation is linked with the history of the fault. B. J. Amos (Bureau of Mineral Resources) pointed out, in a personal communication, that the sandstone is most probably essentially a diachronous litho-stratigraphic unit, which accumulated over a long period as the basin sank, aided by periodically recurring vertical adjustments along the fault. Resulting rapid lensing-out away from the fault and interfingering with the normal Chillagoe sediments would then explain the absence of any repetition of the unit, notwithstanding the heavy folding.

The best-known lithological units of the Chillagoe Formation are its fossiliferous limestone and chert, which are interbedded in roughly equal quantities. The limestone is massive, generally dark grey where fresh, and usually compact. Around granite intrusions the limestone is mostly bleached to a coarse light grey or white marble. Some of the darker limestone has a strong fetid smell when broken with a hammer. A few outcrops of a sugary, friable white limestone ((?)carbonate sandstone) are known.

Outcrops are commonly in conspicuous jagged bluffs, about 100 to 300 feet high, showing karren erosion and containing many caves (Pl. 3). This habit is in strong contrast to the smooth, rubble-covered chert ridges, though low-lying smoothly worn limestone pavements are also exposed in several broad valleys.

On air photographs the bluffs are highly characteristic and unmistakeable (Pl. 1). Bedding is usually absent or hardly perceptible; thus it could happen that Skertchly (1899), in the belief that the limestone was essentially horizontal, arrived at the conclusion that it lay 'as a much denuded cake' unconformably over the cherts and clastic sediments of the Chillagoe Formation. However, careful examination during the 1958 season left no doubt that most of the limestone is nearly vertical, and is intercalated with the clastic sediments and cherts. Tight folding observable in rare thin-bedded limestone members also argues against the limestones' being remnants of a horizontal cover.

Some of the limestone contains chert lenses and tongues that swell laterally into branching layers of chert. Intensive interfingering of limestone and black chert is fairly common. Sandy limestone and calcirudite with arenitic matrix are also found in a few localities, mingled with lenses of limestone and chert.

Fossils are common, and are locally abundant in the limestone, but their preservation is not very good (list on page 21). A few fossils occur in chert. The fauna includes corals, which indicate a reef environment, but the outlines of the present-day bluffs do not necessarily coincide with original reef boundaries, and in some beds there is ample evidence for origin by mechanical deposition rather than by organic construction.

A striking feature of the limestone sequence is the occurrence of a rock here called 'breccia-conglomerate'. The fragments in it are either limestone or chert, and, rarely, reach diameters of several feet; fragments of other rock types, such as granite and gneiss of the Dargalong Metamorphics, were found in only a few places. Broadhurst (1952) regarded the breccia-conglomerates as volcanic breccias formed in diatremes; however, it is seen that the breccias form basal beds above local unconformities, and their long thin lateral extent in places, their occasionally sandy matrix, and the lack of recognizable volcanic rocks attest against the diatreme concept. The rocks are most probably sedimentary wave-platform breccias, locally contaminated with allochthonous pebbles and boulders.

The chert forms smooth, rounded rubble-covered ridges intercalated with the limestone and the clastic sediments. It generally shows regular rhombohedral joints, and its colour ranges from light grey to black, and from creamy through yellow to pink and red. The chert is commonly regularly bedded; the beds are from 1 to 3 inches thick and are separated from each other by shaly partings. Broadhurst (1952) distinguishes two classes—massive and bedded—but the distinction seems difficult to maintain because a unit which appears thinly-bedded in a creek exposure commonly seems massive where exposed on a ridge; the massive character of the lumps of rubble on the ridges is possibly attributable to their being derived from the thicker beds that are occasionally found in the thin-bedded cherts. Besides forming independent ridges, the chert also interfingers with the limestone, narrowing from massive bodies to nodular bands and branching tongues. In places it also includes limestone lenses, and commonly weathers in the same manner as limestone. Some of the chert, particularly the dark grey variety, contains silicified fossils, including *Heliolites* sp., and, in one place, remnants of a sponge with well-preserved inner structure. The origin of some of the brecciated chert members is discussed on page 23. Some 'cherts' appear to be fine-grained calc-silicate rocks and basalts. A greenish chert from the Cambourne lode, Redcap area, proved to be a fine-grained altered basalt, and Jensen (1923) described diopside 'chert' from the Muldiva open cut and scapolite-zoisite-diopside 'chert' from the Zillmanton road.

Shale and siltstone are readily eroded and therefore poorly preserved, so that outcrops are small and inconspicuous; but these rocks are thought to underlie a considerable proportion of the area covered by soil. Green and brown weathered varieties are common, and a black siliceous variety also occurs. Where fresh, most siltstones are grey or bluish-grey. Where they are more massive than shaly, the siltstone and mudstone may be conspicuously cross-bedded. Sequences of regularly alternating dark siltstone and fine-grained pepper-coloured sandstone usually show graded bedding, fine-scale cross-lamination, and scour-and-fill structures. It was noted that on the hillsides the siltstones tend to be more indurated than their counterparts in the creek beds.

The arenaceous members—quartz greywacke[1], pebbly quartz greywacke, feldspathic sandstone—vary in textural and mineralogical maturity. Some are coarse and poorly sorted, contain much feldspar and many rock fragments, and locally grade into fine conglomerate; a few are more even-grained. Under the microscope the quartz greywackes and pebbly arenites are seen to be composed of quartz, feldspar, muscovite, chert, and fragments of limestone, schist, basalt, porphyry, quartzite, and other rocks (Pl. 5, fig. 1).

The conglomerate members are coarse and polymict, and occur as bands and lenses, particularly in the lower (western) portion of the succession. Boulders and pebbles are well-rounded and include chert, amphibolite, muscovite granite, gneiss, and other rock types with diameters ranging from gravel size up to a general maximum of 10 inches, set in quartz greywacke or sandstone. Larger boulders are known—one measured two feet by one foot.

Finally, there are some basic and probably some acid volcanics in the succession. The acid types are porphyries closely resembling the Permian pohphyries, but they were steeply tilted in the outcrop investigated (along the road north of Rookwood station), and, if they are not in-faulted wedges of Per-

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1) Throughout this report the terms 'greywacke' and 'quartz greywacke' are used to imply sediments texturally and mineralogically immature, with moderate to poor sorting and rounding, large amounts of muscovite, feldspars, and rock fragments, and various amounts of a sericitic and quartzose, or, more rarely, a clayey matrix. Quartz greywackes contain a higher proportion of quartz and generally a more siliceous matrix; greywackes are richer in feldspars, mica, and rock fragments.

mian intrusives, must be intercalated in the Chillagoe Formation. Also, rhyolite has been found as fragments in a pebbly quartz greywacke. However, no outcrops of undoubtedly intercalated acid volcanics were found.

Basaltic (or andesitic) lavas are common, and indeed are one of the main components of the Chillagoe Formation some 60 miles north of the area mapped, in the region north of the Palmer River. Some of the outcrops may represent later dykes and sills, but the extrusive nature of other exposures is indicated by the presence of pebbles of this basic rock in a stratigraphically higher conglomerate. Some basaltic members are probably spilitic; a specimen of an outcrop about half-way between Almaden and Chillagoe is composed essentially of albite, augite, ilmenite, and chlorite, arranged in a pilotaxitic texture. However, the augite does not show the alteration characteristic of this mineral in spilites; it is, in fact, remarkably fresh (Pl. 4, fig. 2).

Palaeontology and Age

Fossils are almost entirely confined to the limestone, in which they are locally very abundant and commonly segregated in layers. Their preservation is usually not good; species determination is difficult because of silicification. Types identified or recorded are:

Corals: 1. Tabulata—*Favosites, Heliolites, Halysites, Cladopora, Propora.* (Identification by Prof. D. Hill and others.)

2. Rugosa — *Tryplasma, Kyphophyllum, ?Fasciphyllum* (identification by Prof. D. Hill);
Spongophyllum, e.g., S. cyathophylloides, Cyathophyllum, e.g., *C. dunstani, C. chillagoensis,* (Etheridge, 1911);
Cystiphyllum (Jensen, 1941);
Xystriphyllum, Pseudamplexus, Grypophyllum (Bryan & Jones, 1945).
The corals are the most abundant of all fossils in the area.

Crinoids: Very abundant, and in places forming crinoid limestone.

Brachiopods: Less common than crinoids, except in local concentrations. No specimens as yet determined. In places a big, stout-shelled variety 8cm. across occurs, probably *Stringocephalus* (identification Prof. D. Hill).

Gastropods: Rare. Species found were high-coned.

A few fossils were found to occur in chert. These include:

Radiolaria: reported by CSIRO (1950a).

Corals: *Heliolites* sp. (a few highly silicified fragments).

Sponges: A representative of the Demospongea, probably of the sub-order Eutaxicladina. This single example appears to be spheroidal, and is internally well preserved; elsewhere rare spicules are tentatively identified.

The fossil assemblage has Silurian affinities (*Halysites*), but the possibility that sedimentation has extended into Lower Devonian times is not excluded, as suggested by finds of doubtful *Stringocephalus* from two miles east of Rookwood (White & Hughes, 1957) associated with a pelecypod species also found in the Clarke River area (outside the area mapped), where a Middle Devonian age has been diagnosed.

The age of the Chillagoe Formation is here tentatively given as Upper Silurian, possibly extending into the Lower Devonian.

Origin of Some of the Types of Sediment

The origin of some of the sediments in the Chillagoe Formation is a matter of dispute. Jensen (1941) believes, for example, that the chert is silicified calcareous shale, whereas Broadhurst (1952) regards it as silicified tuff. The latter idea is based on the microscopic identification of partly or completely replaced feldspar crystals (CSIRO, 1950a); however, feldspar can also be an authigenic mineral, or may have been produced by metamorphism by the granite. One would also expect, in a tuff, other fragments such as quartz, possible hornblende, glass shards and the like. Another obstacle is the presence of fossils in the centre of the chert beds, so that the chert is not likely to represent a suddenly deposited tuff-layer suffocating the fossils 'just above coral reefs' (Broadhurst, op. cit.). The cherts are believed to be most probably either silicified calcareous oozes or primary precipitates or silica. If they are primary, the bifurcation and the rhythmic banding in the chert beds may, as Broadhurst has suggested, be attributed to diagenetic differentiation in accordance with Davis' theory.

A number of conglomerates and breccias, especially in the Redcap and Mungana areas, have been interpreted by Broadhurst as volcanic breccias; but a different origin is here proposed. The limestone breccia-conglomerate, for example, is here regarded as a wave-platform breccia overlying local unconformities and disconformities. An unconformable relationship could also be explained by the presence of diatremes, but several other factors make the volcanic hypothesis improbable; for example, the absence of any undoubted volcanic material, and the great lateral extent of some thin breccia-conglomerate sheets, and the fact that it is almost exclusively limestone that is brecciated in this fashion. For, whereas volcanic diatremes would be unlikely to be selective, limestone reefs would logically have been built up in some of the shallowest parts of the Chillagoe shelf and would therefore have been highly susceptible to destruction during even slight lowerings of sea-level.

The chert breccias of the Redcap and Girofla pipes both occur in limestone. Broadhurst (1952) has regarded the pipes as diatremes filled with silicified tuffs. This suggestion was based on the presence of partly or wholly replaced feldspar in the chert. However, as feldspars may have other modes of origin, and truly volcanic fragments have not been found (a pyroxenite from a drill core at Redcap may well be a calc-silicate rock rather than an igneous one), the evidence is scanty. Furthermore, as McKinstry (1955) points out, pipes are rather common in limestones, and this circumstance in itself is an argument against a general theory involving volcanic pipes. Finally, there can be seen at Redcap pairs of fragments whose matching profiles show only negligible movement since fracturing: this is more compatible with brecciation in situ than with volcanic activity. Jensen (1941) thought that the Redcap and Girofla breccias were chiefly due to faulting, but there is no sign of milling or preferred orientation. Nor is the breccia sedimentary, because there is no sign of bedding, rounding, sandy matrix, or sheet-like deposition.

Two processes that may have been responsible for the brecciation remain to be considered: a. brecciation brought about by the collapse of a rock into a cavity left by a solution of a limestone or oxidation of an ore; b. brecciation caused by hydrothermal-pneumatolytic corrosion. The hypothesis of a collapse breccia does not explain why the 'filling' of the pipe should in every place be chert, but hydrothermal brecciation seems to explain all observed facts in the least complicated way: the occurrences in limestone because of the weakness of limestones against chemical attack; the filling with chert, which may represent hydrothermally silicified limestone; the lack of rounding and—in places—displacement of the fragments; and the mineralization in the Redcap and Mungana Breccias.

Finally, some of the normal conglomerates, e.g., the conglomerate lens west of the Morrison mine in the Redcap area, were also regarded as volcanic breccias by Broadhurst (1952). The rounding of the pebbles and the occurrence of sandy lenses (occasionally with cross-bedding) or a sandy matrix are generally sufficient evidence for their sedimentary origin. Also, the conglomerate lens at the Morrisson mine and the chert breccia at Mount Redcap are within a mile of each other, and it seems unlikely that, if both rocks were volcanic, the rock should be exclusively chert in the one, and be composed mainly of Dargalong Metamorphics in the other.

Depositional Environment

All evidence suggests a near-shore, shallow-water, mixed clastic and reef environment with frequent oscillations of sea-level, a rapid shifting of facies, and entry of clastic material from the west. The evidence is:

a. the fauna of corals and sponges. Recent siliceous sponges rarely live at depths greater than 225 feet; colony-forming corals have an even shallower lower limit—about 150 feet.

b. the local unconformities and disconformities, wash-outs, scour-and-fill structures, and small-scale current-bedding.

c. the rapid interfingering and intergrading of chert and limestone, chert and siltstone, limestone and sandstone, sandstone and siltstone, etc.

d. the well-defined (but small) lenses and tongues of coarse, well-rounded conglomerate containing pebbles and boulders of Dargalong Metamorphics.

e. some sediment sequences, for example, the thin-bedded alternating siltstone/ pepper-sandstone sequence with its associated scour-and-fill, graded bedding, and other features, strongly resemble photographic illustrations of recent littoral sediments such as are deposited in tidal channels (Straaten, van, 1959).

The general absence of a markedly coarse basal sequence might suggest that the clastic sediments were derived from a low-lying, morphologically mature or old continent.

Mount Garnet Formation

Sediments in three separate areas — Redcap, Koorboora, and Petford to Emuford — were, after the 1958 field season, included in the 'Herberton Beds' (Skertchly, 1899) by de Keyser, Bayly, & Wolff (1959), but should probably be correlated with the Mount Garnet Formation (Best, 1962); use of the term 'Herberton Beds' is no longer warranted, as the mapping of the Atherton 1:250,000 Sheet area has shown (Best, op. cit.).

The boundary between the Chillagoe and Mount Garnet Formations is ill-defined and arbitrary, and is drawn where the limestones have largely disappeared (and the cherts are becoming scarcer). As discussed later (page 25), the Mount Garnet Formation is probably partly penecontemporaneous with, and partly younger than, the Chillagoe Formation. The top of the Mount Garnet Formation is not represented in the Chillagoe district because it is hidden by the overlying Featherbed Volcanics, or is a faulted boundary like that in the area south of Petford.

The Mount Garnet Formation consists of quartz greywacke, greywacke, quartzite, sericitic siltstone, and shale, with subordinate intercalations of chert, conglomerate, and sedimentary breccia, and an occasional lens of limestone.

In the Koorboora and Petford-Emuford areas, chloritic siltstone and shale are also common, and the ratio of greywacke to quartz greywacke seems higher. A thick and extensive conglomerate member is found six to nine miles south-south-east of Petford; it contains well-rounded pebbles of quartz, quartzite, and other sediments, including rocks probably belonging to the Dargalong Metamorphics. Between Koorboora and Torpey's Crooked Creek mine, dark grey soft graphitic schists are intercalated.

In general, the composition and texture of the sediments are much the same as those of the clastic members of the Chillagoe Formation, with which no sharp boundary exists. Bedding characteristics vary; the most well-bedded members are those composed of alternating layers of dark siltstone and pepper-coloured sandstone, commonly showing cross-lamination, slump-structures, and graded bedding. The thickness of these layers is generally between half an inch and two inches. Of the coarser arenites, some are massive and structureless, and show no sign of bedding, whereas in other exposures regular thin beds are prevalent.

Throughout the succession, massive and well-bedded members alternate, and quartz greywacke also occurs as lenses in siltstone.

The massive quartz greywacke is composed of quartz, feldspar, muscovite, chert, and fragments of several other rocks (Pl. 5, fig. 2). Some of the greywacke has a calcareous matrix. Quartz greywacke grades—without sharp boundaries—into fine uneven-grained conglomerate in which pebbles are of quartz, chert, siltstone, etc. The conglomerate also has many cavities, in a few of which relics of dissolved limestone fragments can be found. Besides the conglomeratic and pebbly greywacke varieties, the greywacke also includes lenses of fairly pure quartz sandstone.

Weathering of the greywacke commonly leads to spheroidal structures, and the rocks may then superficially resemble igneous rocks: Jensen (1941), for instance, confessed that he had trouble distinguishing them from 'syenite'.

The chloritic shales, which are especially abundant in the Koorboora area and south of Petford, were considered by Skertchly (1897) to be altered basic dykes, but this suggestion cannot be upheld. They are commonly associated with tin lodes and may be shale and siltstone that were chloritized by widespread hydrothermal processes.

The few chert lenses present are identical with the chert of the Chillagoe Formation.

Broadly speaking, the Mount Garnet Formation may be defined as a Chillagoe Formation without chert and limestone, and it is probably partly penecontemporaneous with, partly younger than, the Chillagoe Formation. Within the Chillagoe district the Mount Garnet Formation is undoubtedly younger, but beyond the boundaries of the area mapped, near Mount Garnet, the Chillagoe Formation as such has largely disappeared and has been replaced by the Mount Garnet facies. Near the Mitchell River, north of the area mapped, on the other hand, the Mount Garnet Formation is absent, and the Chillagoe facies, which is there well-developed, is in direct contact with the Hodgkinson Formation.

It is conceivable that the Chillagoe Formation represents a mixed-type shelf facies as described by Kuendig (1959); the Mount Garnet Formation may be designated as its clastic-type shelf counterpart, possibly deposited in a deltaic-lagoonal environment. It is not necessary to consider the Mount Garnet Formation as an off-shore, deeper-water equivalent of the Chillagoe shelf association; the lithology of the clastic Chillagoe members is virtually identical with that of the Mount Garnet sediments. It is probably more a question of hinterland relief: where there was strong erosion in the source area supply of clastic material was plentiful, and coral reefs were not likely to flourish: a Mount Garnet facies resulted. Where, on the other hand, the hinterland was flat and mature, supply of clastics became scarcer and more localized and coral reefs more abundant: a Chillagoe facies was deposited. This reasoning seems in line with the assumption of tectonic land in the south, as White has proposed (1961).

Though no fossils were found, the age of the Mount Garnet Formation probably ranges from Upper Silurian to Lower Devonian by analogy with the Chillagoe Formation.

Hodgkinson Formation

The north-eastern corner of the Chillagoe Sheet area and the south-eastern edge of the Almaden Sheet area are occupied by sediments of the Hodgkinson Formation ('Hodgkinson Beds' of Jack, 1884). They are, like the older Palaeozoic formations, steeply folded and tilted, and consist of micaceous greywacke, siltstone, and shale, interbedded in a broadly uniform and monotonous series containing sporadic intercalations of chert and conglomerate. Small lenses of limestone and flows of basic volcanics are known from areas just beyond the boundaries of the Chillagoe Sheet.

The lower boundary of the Hodgkinson Formation is concealed in the Chillagoe district by the overlying Permian volcanics. About seven miles south-southeast of Petford, sediments of the Hodgkinson Formation are separated from probable members of the Mount Garnet Formation by an inferred system of faults. The upper boundary is unknown, but the formation is unconformably overlain by essentially horizontal (?)Permian volcanics in places north-west of Wolfram Camp.

The greywacke ranges from coarse to fine-grained, and grades into siltstone. It has typical immature mineralogical composition and texture, the particles poorly sorted and subangular; the amount of matrix (averaging an estimated 10 percent) is commonly below the usual percentage implied by the term 'greywacke'. The structure is generally massive, although the finer members are commonly well-bedded at about 1-foot intervals. Graded bedding, slumping, and some cross-lamination in places allow the determination of top and bottom relationships and show that overturning is fairly common.

With slight variations in matrix content and relative abundance of mineral species, the greywacke grades into quartz greywacke and feldspathic sandstone.

Where fresh, the greywacke is dark bluish or greenish-grey, but it becomes yellow brown, olive green, or purplish-grey on weathering. Pebbly and gritty lenses and tongues are present throughout the exposed sequence. The shale is soft, smooth, and fissile, and is generally grey or greenish-grey and probably chloritic, though black shale also occurs. In volume the shale is subordinate to the greywacke and siltstone, and forms only thin intercalations.

Palaeontology and Age

Remains of plant fossils are widespread, but in the Chillagoe district consist only of poorly preserved stem fragments. From the type area in the Hodgkinson Gold Field, north-east of the Chillagoe district, Jack (1884) reported the occurrence of *Lepidodendron* (?) *australe,* and of *Retzia* sp. and *Cyathophyllum* *helianthoides* from a penecontemporaneous limestone conglomerate. Jack & Etheridge (1892) described *Pachypora* sp. and *Cyathophyllum* sp. from the limestone. *Favosites* sp., *Grypophyllum* sp., and other corals were identified by Prof. D. Hill (personal communications). Mary E. White (1960, 1961) described the occurrence of *Leptophloeum australe* (McCoy) and possible Psilophyte stems.

The evidence thus indicates a Devonian age. During the 1961 field season Bureau of Mineral Resources geologists in the Cooktown area collected corals from a limestone lens in the Hodgkinson Formation; they were examined by Prof. Hill, who ascribed to them a 'probable late Lower Middle Devonian or an early Middle Middle Devonian age' (pers. comm.). Concrete evidence for an age extending into the Lower Carboniferous, which is commonly assumed, has not been found thus far.

Deposition of the Hodgkinson Formation must have started at latest in the Middle Devonian and in all likelihood continued into the Upper Devonian, and possibly—though this is without proof—into the Lower Carboniferous.

Depositional Environment

De Keyser et al. (1959) thought that the greywacke and siltstone of the Hodgkinson Formation were deposited in a 'basin-type' delta environment (Dapples, 1947). The idea is, perhaps, justifiable for the small part of the formation exposed in the Chillagoe district, but work outside this area, in particular by K. G. Lucas (Bureau of Mineral Resources), has shown that in general the Hodgkinson Formation is a geosynclinal trough deposit with a flysch facies, partly laid down by turbidity currents (de Keyser, 1961). Typical of such a flysch facies are, according to Termier (in Oulianoff, 1960), the following features: essentially detrital character; more or less regular alternation of arenites and micaceous shales, with occasional intercalations of conglomerate and lenses of limestone; a thickness of many thousands of feet of rather monotonous, undifferentiated lithologies in which fossils are few and sub-division virtually impossible. In the Swiss Alps (Trumpy, 1960), the flysch sandstones are micaceous and feldspathic, show poor sorting and rounding, and have a silty cement, whereas 'typical' greywacke (in the original sense) is rather uncommon. The shales are silty and sandy and generally micaceous.

All the above-mentioned features are characteristic of the Hodgkinson Formation. Even negative features are recognisable: Trumpy's (op. cit., p. 891) description: 'Flysch cordilleras have a disconcerting tendency to vanish into thin air, thus the . . . granite which furnished great boulders to the Wildflysch is not known in outcrop'; is exactly analogous to the situation in the Hodgkinson Basin in general.

The depth of deposition of flysch sediments is rather variable, and there is, according to the latest research, a repeated and irregular shifting of axes of subsidence and uplift.

In the area north of Wolfram Camp, massive arenites are predominant, turbidity features are not common, and rare limestone lenses are associated with sedimentary limestone breccias in which a corallogene fauna points to shallow-water conditions; this part of the Hodgkinson Basin was probably not far removed from its source land, whose coastline probably ran in a general north-westerly direction somewhere through the Chillagoe district.

Ringrose Formation (?)

On the southern side of the Tennyson Ring Dyke, within the Boxwood ring complex structure, and in an area one to two miles north of Koorboora, there occurs a series of sericitic quartz siltstone and fine-grained quartz sandstone which may have a Carboniferous age.

Their lithology is quite distinct from that of the Mount Garnet Formation, in which they seem to occur. Their colour is white or pale grey or greenish, commonly spotted with purple or red iron stains; in thin section all are seen to be quartz-sericite rocks with interstitial sericite, chlorite, and accessory biotite, tourmaline, apatite, sphene, zircon, and (?)rutile (Pl. 6, fig. 1); there is some evidence of pneumatolytic alteration in the form of sericitization (quartz corroded by sericite) and the growth of rare tourmaline clusters. Some thin sections carry both euhedral and corroded quartz grains and shadowy relics of large feldspar crystals, and it seems very likely that part of the quartz 'siltstone', at least, may be pneumatolytically altered tuff or other volcanics. The sediments are rather structureless, and attitudes are not easily recognizable, but, where observed, dips were only moderately steep.

De Keyser et al. (1959) originally included these rocks in the Mount Garnet Formation ('Herberton Beds'), although they noticed the difference in lithology. K. G. Lucas, more familiar with the stratigraphy of the Herberton district, suggested after a short visit to the outcrops north of Koorboora that the beds might be Carboniferous (personal communication). In 1961 de Keyser visited both the Herberton and the Chillagoe districts and found further evidence for a possible Carboniferous age: the beds commonly dip less steeply than the Mount Garnet sediments, and they crop out only within the Boxwood ring complex and the Featherbed cauldron structure. In other words, the quartz siltstones may unconformably overlie the Mount Garnet Formation; and their restriction to the specific areas mentioned above means that only in these down-faulted blocks were they protected against complete removal by erosion, thus implying that they were in a higher stratigraphical position than the Mount Garnet sediments.

As the sediments show some affinity with the (?)Carboniferous Ringrose Formation near Herberton, they are here tentatively correlated with that unit.

The relationship with the Boxwood Volcanics is not beyond doubt. M. B. Bayly, one of the geologists of the 1958 survey, thought that they were interbedded with the volcanics, but this seems improbable: in places the contact between the volcanics and the (?)Ringrose Formation closely follows the hill contours, although the quartz siltstone is moderately steeply tilted. The impression is gained that the volcanics formed sub-horizontal flows or sheets around the base of a hill which was the eroded remnant of a (?)Carboniferous land surface. In one locality there is a little peak composed of porphyry on top of a sandstone hill higher than the surrounding volcanics; this may be the eroded remnant of a volcanic neck protruding through the sandstone, in which case the volcanics are definitely younger than the Carboniferous sediments.

Permo-Carboniferous Igneous Rocks

The Palaeozoic geosynclinal sediments were folded and uplifted, probably during the Carboniferous, and were subsequently denuded to a region of low relief. Tectonic stresses were, after the uplift and erosion, relieved by tensional strain, leading to fissuring and cauldron subsidence with accompanying extrusion of large volumes of lava flows and ignimbrites, and the intrusions of granitic batholiths.

These Permo-Carboniferous igneous rocks are widely distributed over the areas covered by the Chillagoe and Almaden Sheets; outcrops in the Mungana Sheet area are less extensive. Some of the outstanding topographic features—the Featherbed Range in particular—are composed of Permian volcanics. The relationships between the various types of granite*, between the volcanic sequences, and between the granites and volcanics, have always been a problem to investigators, though the difficulties arise mainly from trying to fit all units into a single episode. The problem will be discussed in the relevant section on the volcanics and the granites.

The Permian volcanic deposits are only slightly folded and undulating, and they dip at angles generally less than 15 to 20 degrees. They overlie the older Palaeozoic formations with strong angular unconformity, and are partly intruded by some of the granites. They may be subdivided into five or more units on both geographical and stratigraphical grounds, some of these units are probably of approximately the same age, but geographical separation and the impossibility so far of accurately dating them makes attempts at correlation unwarranted. Some of the units (1, 2, and 5 below) are associated with ring complexes and cauldron subsidence blocks.

The five units are:

1. Boxwood Volcanics;
2. Doolan Creek Rhyodacite;
3. Nychum Volcanics;
4. The porphyries at Redcap;
5. Featherbed Volcanics (divisible into two or three sub-units).

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*) In this publication the term 'granite', where used without qualification, denotes a variety of granitoid rocks, including granite, adamellite, granodiorite, granophyre, alaskite, leucogranite, monzonite, etc.

Boxwood Volcanics

The Boxwood Volcanics are associated with the Boxwood ring complex, which occurs in the Almaden Sheet area along Oaky Creek, west of Boxwood, and occupy about 45 square miles on the south side of the Tennyson Ring Dyke. The Boxwood Volcanics were made a separate unit by geologists of the Bureau of Mineral Resources after fieldwork during the years 1960 and 1961, and consist mainly of rhyodacite, which is generally grey and massive and strongly porphyritic.

The most common rock types contain abundant phenocrysts of plagioclase and quartz, 0.25 to 4 mm. across, in a dark grey aphanitic matrix. The plagioclase is twinned and zoned and has a composition ranging from oligoclase to andesine; albite is common in some members. Potash feldspar is less common as phenocrysts, occurs more generally in the matrix, and amounts to less than two-thirds of the total feldspar content. Biotite is the normal mafic constituent, and is usually bleached, partly chloritized, or altered to magnetite and epidote. Vestiges of altered hornblende remain in some thin sections. Accessories include sphene, apatite, magnetite, and allanite. The groundmass shows signs of being devitrified. Cracks and veinlets in the rock are filled with secondary alteration products such as epidote and chlorite. Inclusions of foreign rock types are fairly common, and include fragments of quartzite and chert, fine-grained pink leucocratic granite or aplite, and basaltic or andesitic rocks.

Most members are massive, structureless, and strongly porphyritic, but fine-grained felsitic varieties, fragmental (?) tuffaceous rocks, and flow-layered rocks were also noted. The angularity of mineral fragments, in some specimens, set in a devitrified groundmass, suggests that these members could be welded tuffs.

The Boxwood Volcanics form the higher parts at the northern, eastern, and southern rim of the Boxwood ring complex, and are most probably younger than the suspected Carboniferous sediments. The inclusions of granite or aplite indicate that they are also younger than at least part of the granites. A minimum thickness of 200 or 300 feet may be estimated.

Doolan Creek Rhyodacite

At the junction of Doolan Creek and the Walsh River, 10 miles north-north-west of Chillagoe, a second ring complex was found in 1961 (Fig. 5). Rhyodacite—for which the name Doolan Creek Rhyodacite has been proposed—forms the outer ring of the complex. The rhyodacite is massive, porphyritic, and generally green-grey where fresh, but turns red-brown on weathering. Phenocrysts of quartz and oligoclase, several millimetres across, are set in microcrystalline, xenomorphic, equigranular, and clear quartz-feldspar matrix which shows signs of having been recrystallized, an effect probably due to intrusion by granite. Mafic minerals—mainly biotite—have been largely altered to chlorite, epidote, and calcite. Some of the biotite forms clusters of fine scales, possibly in pseudo-

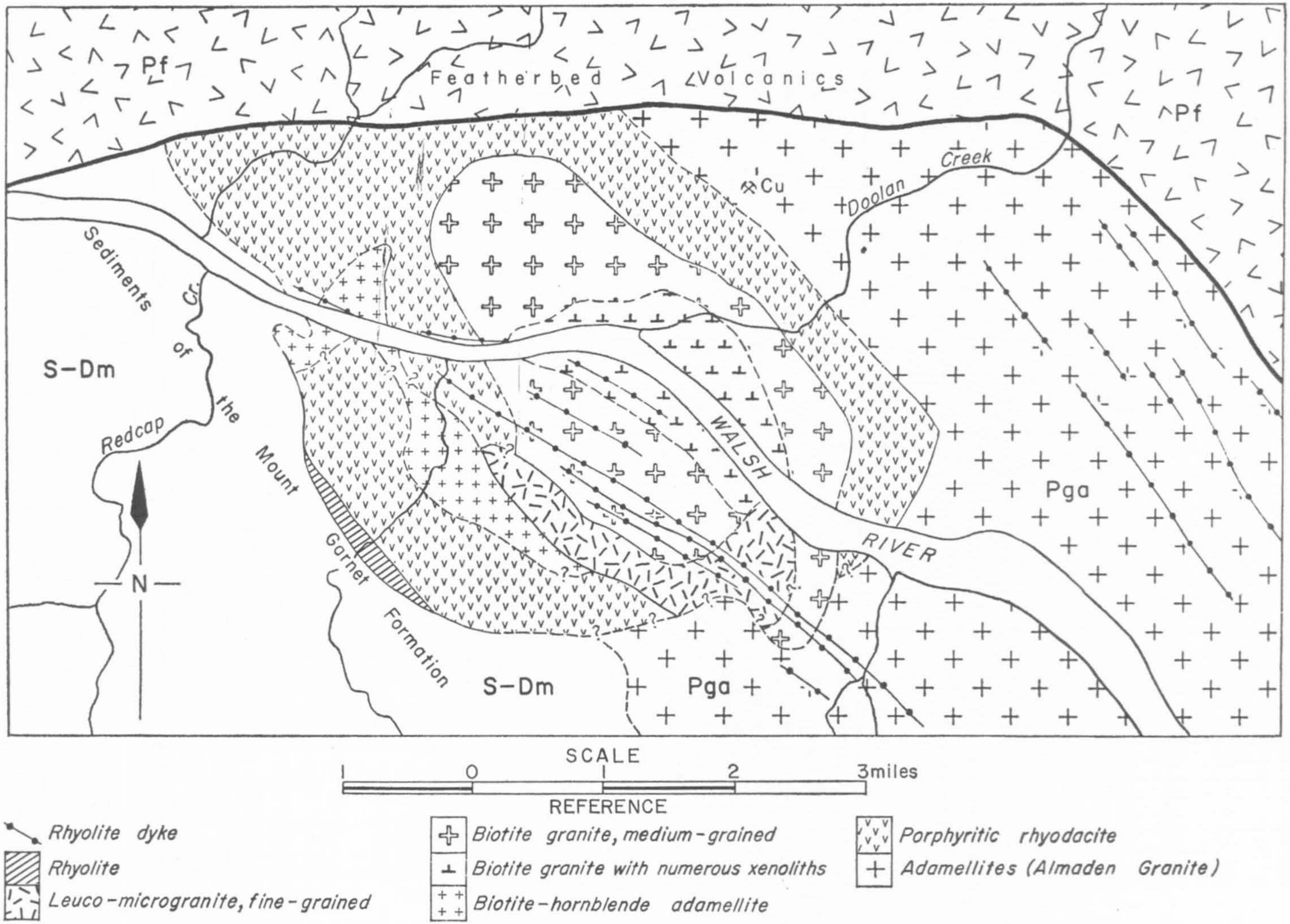


Fig. 5. The Doolan ring complex.

morphs after hornblende, and may be further evidence for recrystallization due to heat. Apatite and magnetite are accessory. Although potash feldspar was not seen as phenocrysts, it is virtually the only feldspar in the matrix (unless some of the clear feldspar is untwinned albite); thus the name 'rhyodacite' seems warranted.

The Doolan Creek Rhyodacite is probably effusive-volcanic, but definite evidence has not been found so far, and in view of its occurrence as part of a ring complex the unit may equally well be intrusive sub-volcanic. The thickness cannot be estimated, as the relief is extremely low and the base is not exposed.

On its northern side the complex is abruptly terminated against the Featherbed Volcanics by a large fault representing the rim of the cauldron subsidence area in which the Featherbed Volcanics were deposited.

Nychum Volcanics

The Nychum Volcanics were recognized as a separate unit during the 1960 field season in the Mossman 1:250,000 Sheet area north of the Walsh River (de Keyser, 1961), and were fully described by Morgan (1961). An outlier is exposed in the northern part of the Mungana Sheet area, along the Walsh River north-west of Rookwood Homestead, and consists here of massive, porphyritic rhyodacite and hornblende andesite with volcanic breccias and pyroclasts near the base. Their effusive character is recognizable north of the Walsh River, where several old vents or eroded volcanic necks have been found. In the type area a maximum thickness of 500 feet has been measured, and lateral variations in the flows and sheets are so common that no two fold sections are alike (Morgan, 1961). The Nychum Volcanics are terminated against the Featherbed Volcanics by a large fault, and are obviously older. Plant fossils from associated sediments in the type area suggest an Upper Permian (or perhaps even Lower Triassic) age, according to Mary E. White (1961), while the pollen and spore content has an Upper Permian affinity (B. E. Balme, pers. comm.).

Porphyry at Redcap

Near Redcap Mountain, massive porphyry covers an area of seven and a quarter square miles, three to five miles north-east of Mungana, forming hilly country rising several hundred feet above the surrounding area. The rock is a porphyritic micro-adamellite with a microscopic texture strongly resembling that of the Doolan Creek Rhyodacite. Phenocrysts, 0.5 to 3mm. across, of quartz and plagioclase are set in a grey, pink, or less commonly dark, aphanitic to microcrystalline groundmass with an average grain-size of less than 0.1 mm. This groundmass consists of an equigranular, xenomorphic mosaic of clear quartz and untwinned potash feldspar (and possibly untwinned albite), and shows signs of recrystallization under thermal conditions (Pl. 6, fig. 2) undoubtedly during the intrusion of the nearby Almaden Granite. Biotite, partly chloritized, is the main mafic mineral; iron oxide, epidote, and muscovite are accessory.

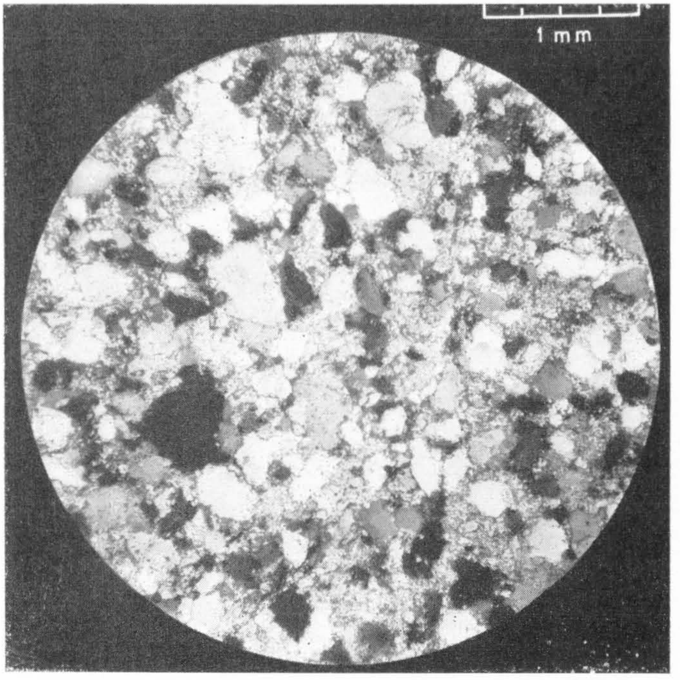


Fig. 1. Sericitic quartz sandstone, Boxwood Ring Complex. Quartz, with interstitial sericite; some pneumatolytic corrosion.

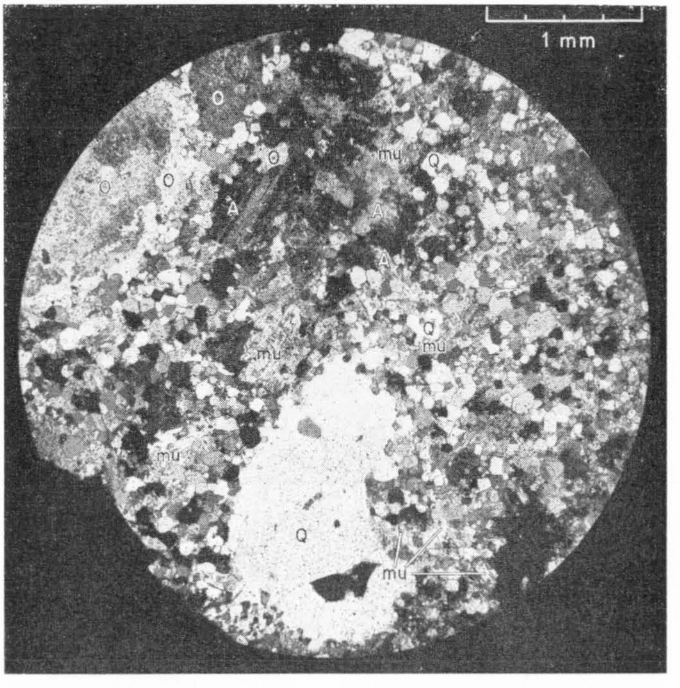
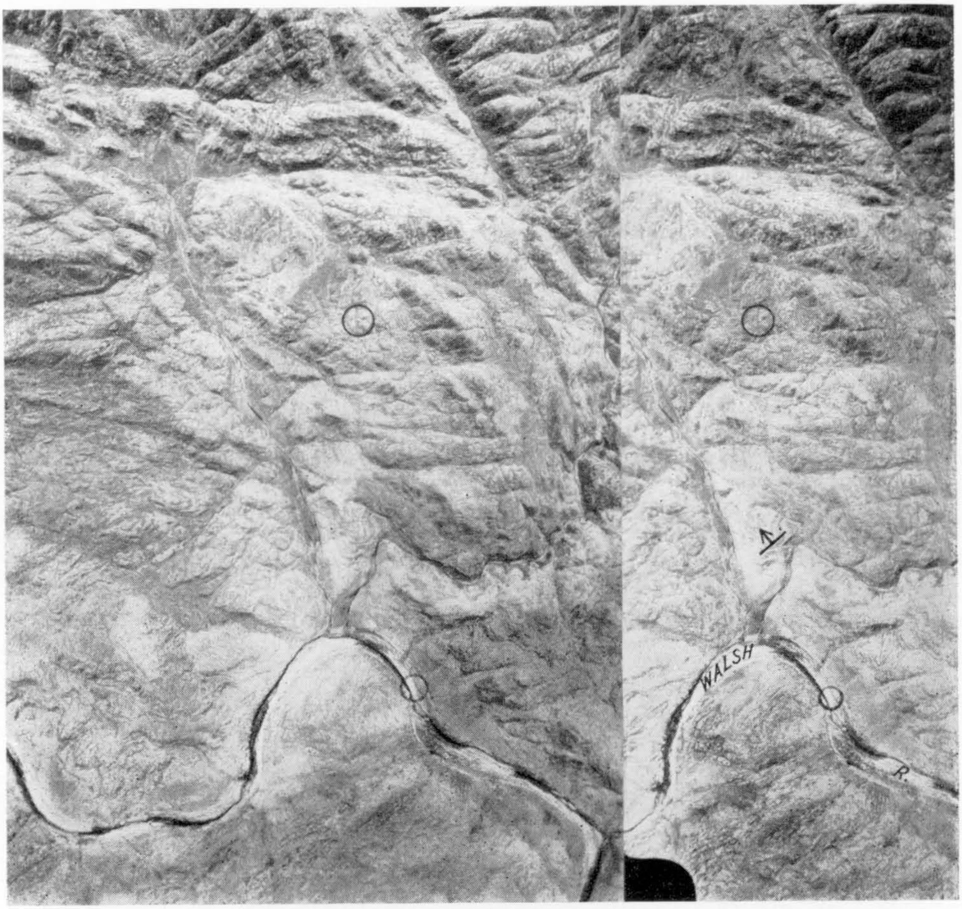


Fig. 2. Porphyrite-micro-adamellite, Redcap. Q = quartz, mu = muscovite, O = orthoclase, A = albite.



Part of the Featherbed Volcanics along the Walsh River, Chillagoe 1-mile Sheet (Stereopair). Note rough topography, scarcity of vegetation, intense jointing controlling drainage pattern, and obscure bedding.

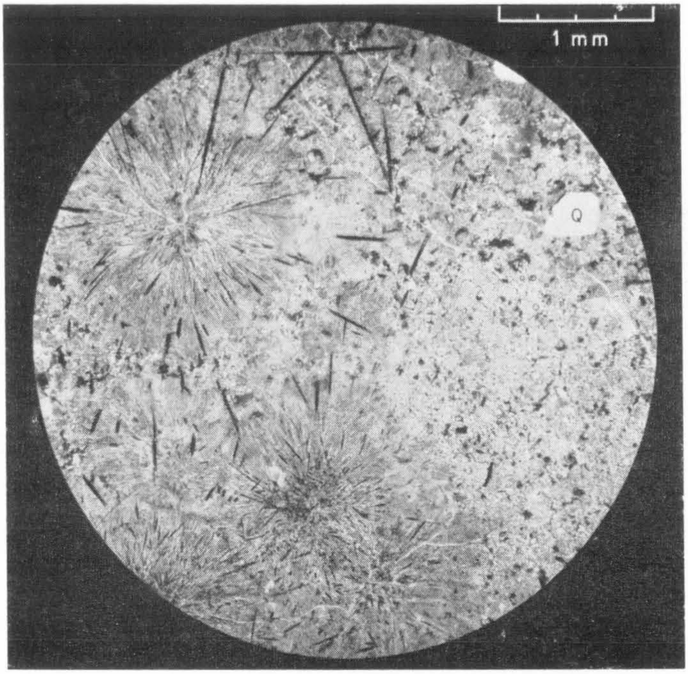


Fig. 1. Spherulitic rhyolite dyke, south-east of Almaden. Q = quartz

Fig. 2. Pyroxene-hornblende-biotite-quartz diorite, Petford. (Between crossed polarizers). P = plagioclase, Q = quartz, bi = biotite, ho = hornblende, py = pyroxene.

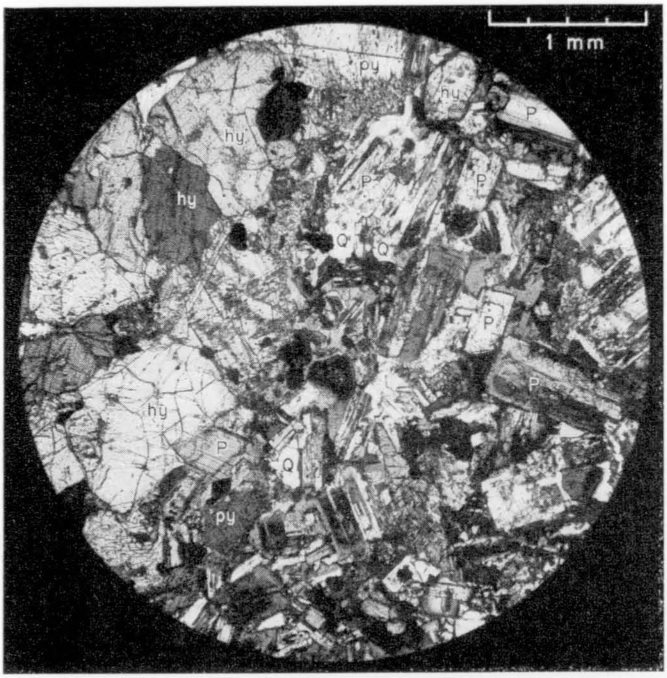


Fig. 1. Hypersthene-pyroxene-quartz diorite, 19 miles west-south-west of Chillagoe. (Between crossed polarizers). P = andesine, hy = hypersthene, py = pyroxene, Q = quartz.

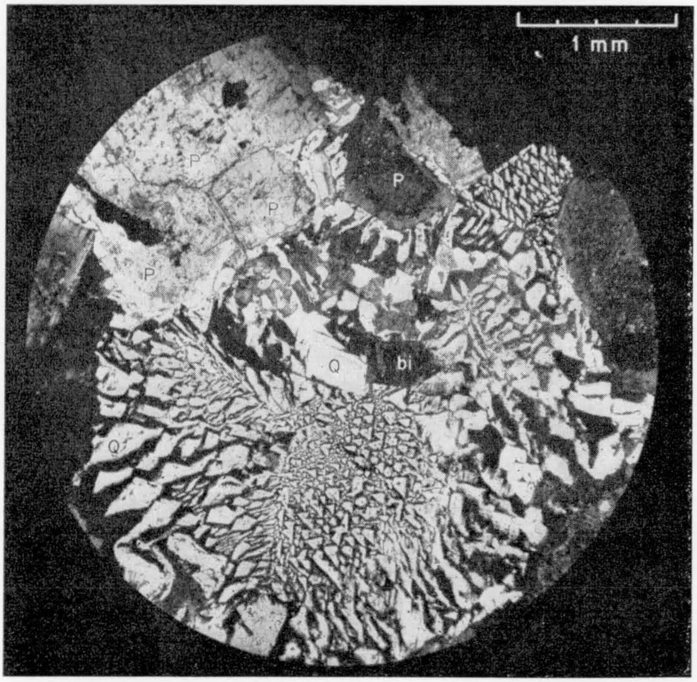


Fig. 2. Granophyre, Boxwood Ring Complex. P = plagioclase, Q = quartz, bi = biotite. Black: orthoclase in extinction position.

Broadhurst (1952) noticed associated scoria and tuffs, and consequently assumed an extrusive origin. Air photographs show a distinct rectilinear west-north-west zoning, characterized by different tonal values, and indicate a steep dip to the south. The widths of individual zones range from a quarter of a mile to three-quarters of a mile. This type of zoning is not characteristic of rocks that originated by flow over a land-surface, and the presence of muscovite and the relative coarseness of the groundmass in the thin sections examined would normally suggest that they were, in fact, not effusive rocks, if it were not for the possible explanation of these features provided by the presence of granite and the pneumatolytic alteration and thermal recrystallization that no doubt accompanied its intrusion. Perhaps the steep zoning represents originally horizontal bedding that became steeply tilted during faulting, and the porphyries would thus represent a thick wedge between the fault planes.

The porphyry at Redcap resembles the Doolan Creek Rhyodacite texturally, and may possibly be correlated with it.

Featherbed Volcanics

The Featherbed Volcanics, by far the most voluminous of the Permian volcanics discussed in this Bulletin and occupying most of the Chillagoe Sheet area and a large portion of the Almaden Sheet area, have built up the rugged Featherbed Range and form extrusive sheets over other parts of the district, east and north of Petford. They cover about 440 square miles in the Featherbed Range, within the boundaries of the mapped area, and a further 350 square miles in the adjoining Mossman 1:250,000 Sheet area, north of the Chillagoe district. The photo stereo-pair (Pl. 7) shows the typical photographical expression of the rock unit; although at first glance the massive rocks seem quite structureless, closer inspection reveals low bedding dips in places.

The total thickness of the Featherbed Volcanics, which consist of rhyolitic to rhyodacite flows and ignimbrites, must be at least 2000 feet, as the Walsh River has incised itself that much below the level of the higher summits without exposing any of the older formations.

After the 1958 survey, de Keyser et al. (1959) subdivided the Featherbed Volcanics into three superposed units (Fig. 6), for reasons to be discussed later (page 36). C. D. Branch (pers. comm.) is of the opinion that there are only two of these units, the top and 'bottom' ones being the same. The top and bottom units are certainly much alike; both comprise massive, generally dark grey, green-grey to black, acid to intermediate porphyry with a devitrified aphantic groundmass. The phenocrysts—quartz and feldspar—are closely spaced and commonly about 2mm. across. The rocks are structureless, and weather to boulders retaining their dark colours or turning to a deep red-brown. Viewed under the microscope they commonly appear to be ignimbrites.

The middle unit, on the other hand, is distinct from the other two: its members are usually weathered white, cream, pink, yellow, pale green, or pale brown, though they may be black or grey when entirely fresh. Flow-banding and vesicular, amygdaloidal, or spheroidal structures are quite common. Weathering generally produces rocky rubble-masses instead of rounded boulders. Phenocrysts are less abundant, and may be wholly lacking in some varieties; the proportions of quartz and feldspars also vary widely. The groundmass is aphanitic and very dense. Agglomerates and volcanic breccias are widespread, particularly in basal sections, where they generally contain fragments of sediments and are likely to be bottom-flow breccias.

The spheroidal beds have a structure for which no easy explanation can be evoked. In the Tennyson Ring Dyke, spheroids range from ½ in. to 2 in. diameter, and are clustered like bubbles in contact; elsewhere, especially on the sides of the Walsh River gorge, spheroids are from 1in. to 3in. across and closely packed, but apparently not with impinging forms. Some spheroids have a porous core or irregular central cavity; in some, such a space is filled with opal, in others the whole spheroid is dense and flinty. A parallel to radial structure may be seen under the microscope. At the Walsh River locality, spheroids occur near the top of a certain flow.

Although most of the Featherbed Volcanics are massive and structureless, there is sufficient evidence to indicate that they are effusive rocks: low bedding dips can be recognized on air photographs; the attitude of columnar jointing, the occurrence of a thin horizontal chert-like rhyolitic layer sandwiched between massive members, and the presence of a fossil volcanic vent five miles north-east of Petford, all indicate their effusive origin.

Sedimentary intercalations in the Featherbed Volcanics are very rare and of limited extent. One locality is about three miles north-east of Koorboora and shows grey to cream, well-bedded flaggy sandstone (probably tuffaceous), and thin-bedded water-lain or reworked ashstone and tuff with graded bedding and alternating with fragmental rhyolite beds. It is here that impure coal is exposed (Q.G.M.J., 1910), which is interlaminated with tuff and ash. These sediments are at or near the base of the volcanic pile and dip at angles of about 5 degrees.

Dykes

In addition to the units described above, numerous acid and some basic dykes traverse the country. They normally contain small (1-3 mm.) phenocrysts, but there is also a very coarse variety of quartz-feldspar porphyry with phenocrysts of feldspar up to 2 cm. long.

The typical acid dyke weathers pink, brown-red, yellow, buff, grey-green, or white; fresh rock is generally grey. Phenocrysts of quartz and feldspar are embedded in a flinty, felsitic, or microcrystalline matrix. Occasionally the matrix carries spherulites consisting probably of albite (and (?)silica) (Pl. 8, fig. 1), presumably as a devitrification product. Kelyphytic rims on phenocrysts are also developed in some places. Flow-banding is common, and shows the effects of drag along the walls; it also proves that the dykes are intrusive in the granite and do not represent undigested rafts of porphyry.

In the coarse variety of quartz-feldspar porphyry the groundmass is similar to that of the normal type, but the phenocrysts are much larger. The feldspar is white or pink, euhedral, zoned, and commonly altered at the core; the quartz is water-clear and may be euhedral, and the grains are mostly between 5 and 10 mm. across. In a few places the coarse dyke rock can be traced laterally into a dyke rock of normal appearance.

In places the dykes are grouped in swarms, e.g., south of Cardross (Fig. 4), and on both the west side and the east side of the Featherbed Range. They are probably the deeply eroded roots of volcanic feeder channels.

Basic dykes are known, but they are far less common than the acid dykes. They are also less common on the Chillagoe and Almaden Sheet area than they are on the Mungana Sheet area. Near Lappa Junction they intrude the granite.

Origin and Deposition of the Permian Volcanics

The Permian volcanics were deposited in ring structures and areas of cauldron subsidence as well as in normal surface flows. Associated sediments—flaggy sandstone, re-worked or water-laid tuff, impure coal—are strictly localized, and indicate by their fossil content and bedding structures (de Keyser, 1961) that the Permian landscape was one of low relief, with isolated shallow lakes scattered over its surface.

The Permian vulcanism was a result of the tensional strain that followed the Carboniferous orogeny. Fissures and normal faults were formed while granite was making its way upwards, and some of the fissures acted as feeder channels for the comagmatic and coeval volcanic products. Faulting, formation of ring structures, and finally cauldron subsidence accompanied these processes. The Tennyson Ring Dyke is a fine example of a composite ring dyke that has been only superficially eroded: spilled-over flows are still preserved west of Lappa Junction. This area is probably a shallow portion of the Featherbed cauldron subsidence area, and the Tennyson Ring Dyke may continue, unrecognized, around most of the edge of the Featherbed Range and form part of it.

Volcanic necks and vents are still preserved in places, e.g., five miles north-east of Petford and possibly at two or three localities in the Boxwood ring complex; many are probably still unrecognised. Some exposures seem to represent deeply eroded sub-volcanic roots and stocks: examples are the complex 30 miles west of Chillagoe, and possibly some of the granite porphyries on the eastern periphery of the Featherbed Range.

Although there are normal lava flows, tuffs, and pyroclasts among the volcanic products, most were undoubtedly deposited as ignimbrites or welded tuffs—they occur in very thick units (sections of several hundred feet are commonplace) of non-bedded, structureless material, with great lateral extent and low angles of dip: the 'phenocrysts' are usually angular, and quartz phenocrysts are, in places, deeply embayed and corroded; the matrix is devitrified, and signs of welding are occasionally visible.

Age and Correlation

Because the volcanics are generally associated with, and localized at, fault-lined structures, the various units are difficult to correlate. Only for the Nychum Volcanics has an age been determined—from plant fossils and microflora (de Keyser, 1961); they are Upper Permian. In view of the great similarity of lithology and structural setting, all the volcanic units described above are included in the Upper Permian in this Bulletin. The Featherbed Volcanics are probably the youngest member, as their outer boundary fault cuts off any surrounding volcanics and structures that happen to be in contact with them.

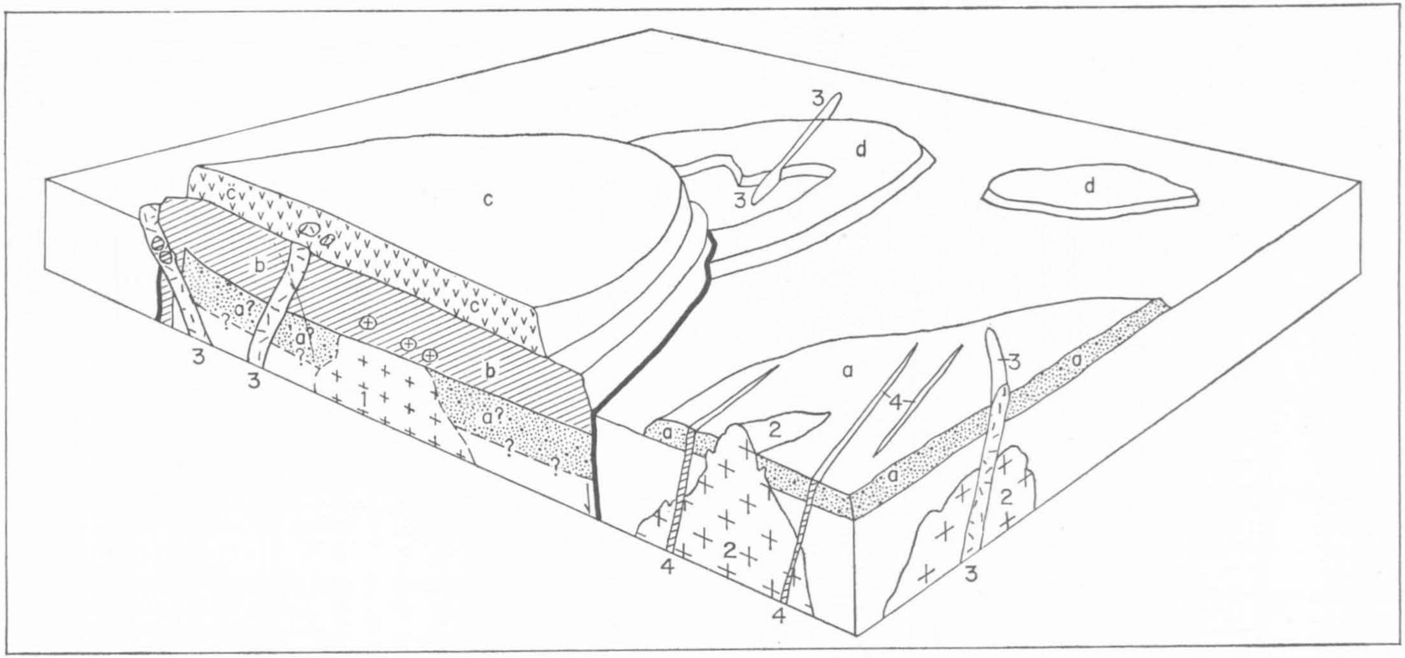
In Figure 6 the observed relationships between some of the volcanics and granites are brought together. A few deductions are shown in broken lines.

De Keyser et al. (1959) divided the Featherbed Volcanics into three subunits: a lower 'dark' prophyry ('a' in Fig. 6) indicated on the Chillagoe and Almaden Sheets as Pf? (Plates 11 and 12); a middle 'pale' porphyry (b), indicated on the maps as Pf; and an upper 'dark' porphyry (c) indicated also as Pf, but with a different pattern. The reasons for this subdivision may be seen on the diagram: porphyry (a) is intruded by granite, has undergone some mineralization (Dover Castle tin mine and lead prospects) and is traversed by dykes that are very probably a degenerated northern continuation of the Tennyson Ring Dyke (which belongs to the 'pale' porphyries (b)); porphyry (b) is overlain by the upper 'dark' porphyry (c), contains inclusions of granite, and is intruded by coarse quartz-feldspar porphyry dykes that do not intrude (c); which, however, contains inclusions of the dyke material.

C. D. Branch, on the other hand, thinks that the two 'dark' porphyries represent one and the same unit (personal communication), and ascribes differing relationships with the granite to the fact that granite intrusions have taken place at more than one time.

The Granites

Granitic rocks occupy most of the southern and western parts of the Almaden Sheet area and the western part of the Chillagoe Sheet area, and are also exposed east of the Featherbed Range and west of the Palmerville Fault. They form rather flat, sand-covered surfaces for the most part, with scattered boulder hills and tors cropping out in places; in some areas they have higher relief, and their massive joint-controlled lithology is then easily recognizable on the air photographs.



REFERENCE

Featherbed Volcanics
- c — Upper "dark" porphyry : massive grey–green ignimbrites
- b — Middle "pale" porphyry : pale–coloured, flow–banded flows, pyroclastics, ignimbrites
- a — Lower "dark" porphyry : massive grey and dark ignimbrites, flows, pyroclastics

Other Volcanic Units
- d — Ignimbrites, rhyodacite, etc. Boxwood, Doolan Creek, and Nychum Volcanics
- 4 — Acid porphyry dykes, possibly coeval with b
- 3 — Coarse quartz–feldspar porphyry
- 2 — Biotite granite, greisen (Elizabeth Creek type ?)
- 1 — Coarse, leucocratic granite (Elizabeth Creek type, coarse variety ?)

Fig. 6. Observed relationships between Permian volcanics and granite.

The granites intrude all pre-Permian formations and igneous rocks, and part of the Permian volcanics. Boundaries are sharp and well-defined, thermal metamorphism slight (except in the limestone areas), and the granites are clearly high-level intrusions. Branch (1961) has inferred that their depth of intrusion was about 1000 feet.

Marginal effects of the intrusions include auto-greisenization, induration, and generally slight metamorphism of the surrounding rocks. Although effects of a slight auto-pneumatolytic alteration—degeneration of biotite, sericitization of feldspars—are fairly widespread, strong greisenization is restricted to areas in the roof-zone of certain cupolas, as at Wolfram Camp, Bamford Hill, in the Emuford area, and probably also in the granite 14 miles west-south-west of Chillagoe. The granite here has been locally transformed into quartz-muscovite rocks with specific accessory minerals such as topaz, fluorite, tourmaline, etc. These greisen areas are of economic importance, as they are the loci for certain ore deposits—tungsten, molybdenum, bismuth, tin, and possibly rare metals.

Metamorphism of surrounding rocks is slight where the intruded sediments are siltstone and greywacke, and in such places takes the form of induration and silicification. In the limestone areas of the Chillagoe Formation, on the other hand, strong mineralogical changes were induced, leading to complete recrystallization of limestone, or to the formation of skarn rocks composed of garnet (grossularite-andradite), wollastonite, tremolite, actinolite, epidote-zoisite, diopside, scapolite, albite, and magnetite. Some of the most important copper-silver-lead ores of the Chillagoe district are associated with these contact rocks.

A minor economic product of limestone metamorphism may be the silica quarry at Chillagoe (page 118), which possibly represents an extreme case of silicification of limestone by granite.

The tough, dense, calc-silicate hornfelses that have been developed in layers of impure limestone resemble bands of chert in limestone, but can easily be distinguished from them under the microscope. Other dense calc-silicate rocks are hardly distinguishable, in outcrop, from fine-grained andesite or basalt; an example is the garnet-scapolite-calcite-hornblende-chlorite rock from near the road side about seven miles north-west of Almaden.

Metamorphism in the volcanics is less easy to see. Nevertheless, microstudy shows that near granite contacts some of the porphyries have phenocrysts with crenulated margins whose depth is related to the coarseness of the matrix, which is recrystallized to a clear, uniform quartz-potash feldspar mosaic with equidimensional grains (Redcap and Emuford areas) (Pl. 6, fig. 2). Moreover, feldspar phenocrysts are generally sericitized and clouded near a granite contact (Ball, 1919).

The granites, *sensu lato,* include a great variety of rock types, extending over granite, adamellite, granodiorite, alaskite, quartz diorite, and monzonite, and including such rocks as granophyre, microgranite, granite porphyry, and others distinguished by differences in texture and grain-size. Biotite and hornblende, the chief mafic constituents, are present in various proportions, and some of the more basic rock varieties contain monoclinic pyroxene and hypersthene as well. The various granites grade into one another; sharp boundaries are rare.

De Keyser et al. (1959), after their field work in 1958, grouped all varieties together as belonging to one batholith with numerous modifications. However, Branch (1961), from his field work in areas outside the Chillagoe district, recognised two separate epochs of granite intrusion—an older one, giving rise to the Herbert River Granite, and a younger period during which the Elizabeth Creek granite was emplaced.*

The Herbert River Granite is normally a grey or very pale pink hornblende-biotite adamellite. The *Elizabeth Creek Granite* is characteristically a pink-red, leucocratic biotite granite or adamellite poor in mafics, and intrudes the Herbert River Granite.

The granites in the Chillagoe district were subsequently revisited in 1960 and 1961 with this two-fold subdivision in mind, but it appears now that the situation is more complicated here. As a result of the field observations the granitoid rocks in the Chillagoe district have now been subdivided into six or more groups, generally with gradational, or at least obscure, boundaries:

1. Even-grained, medium crystalline, dark-grey or green-grey quartz dioritic to quartz gabbroic rocks (Pl. 8, fig. 2) with a colour index exceeding 25. The plagioclase is generally a labradorite or basic andesine, and constitutes 45 to 50 percent of the rocks, orthoclase makes up 5 to 15 percent, as does quartz, and the mafic minerals about 25 percent. The plagioclase is strongly zoned, as in virtually all the granitic rocks in the Chillagoe district. Biotite and hornblende are the principal mafic minerals; augite, in small grains, is subordinate, and is commonly mantled by hornblende. In some specimens hypersthene and monoclinic pyroxene are present (Pl. 9, fig. 1). Main areas of outcrop are south-west of Koorboora; around Petford; and on the western extension of the intrusion 15 miles west-south-west of Chillagoe.
2. Medium-grained, grey, hornblende-biotite adamellite and granodiorite, porphyritic in places. Plagioclase (andesine to oligoclase) generally predominates over the potash-feldspar, some of which is microperthite. Biotite and hornblende are present in about equal proportions, and rare grains of augite have been noted. This—the *Almaden Granite*— is a common rock type in the area between Almaden and the Walsh River, where, in places, it grades into the Herbert River Granite (which is not shown in this area on Plates 10. 11, and 12 because of the ill-defined and gradational nature of the boundaries between the two granites). Most of the copper-lead-silver and gold ores are associated with the Almaden Granite.

* Branch (pers. comm., 1963) now considers the granites to be more or less contemporaneous, but of different origin. He is preparing a Bulletin for the Bureau of Mineral Resources which treats of the ring-complexes and associated igneous activity.

3. Fine, medium, or coarse-grained biotite adamellite with various amounts of hornblende: the *Herbert River Granite*. This forms the bulk of the outcrops south and south-west of Almaden. The plagioclase, with An20 to An25, is generally white, the potash-feldspar often delicately pale pink. Potash feldspar generally predominates slightly over oligoclase. Quartz constitutes from 25 to 40 percent of the rock, mafic minerals about 15 percent or less.

4. Leucocratic, pink-red, coarse alkali granite, poor in mafics. In the one thin section made, from a sample taken south of Batcha siding, the feldspar is mainly (kaolinized) microcline, microcline-perthite, and albite Albite also forms a thin clear rim around the other feldspars, particularly in strongly protoclastic zones, and may be the result of late-stage unmixing of feldspar. Biotite, the only mafic mineral, occurs in minute shreds and is very subordinate. Alteration products are chlorite, epidote, sericite, and magnetite.

   This rock type (the 'pegmatitic' granite of de Keyser et al., 1959) is distributed south of Batcha siding and along the northern rim of the Boxwood ring complex. Its boundaries appear to be comparatively sharp. Branch considers this a coarse phase of his *Elizabeth Creek Granite,* but field relationships suggest that it is slightly older than the normal Elizabeth Creek type (see page 30).

5. Fine, uneven-grained, commonly porphyritic or glomeroporphyritic, pink, leucocratic biotite granite poor in mafics. This is the typical *Elizabeth Creek Granite,* which constitutes most of the granite south of the Tennyson Ring Dyke. Associated with it are a number of varieties — porphyritic micro-leucogranite, alaskite, biotite granite, biotite micro-adamellite, and others. The maps include most of the 'aplites' and greisenized granites (as at Wolfram Camp and in the area south-south-east of Petford) under this heading also. The Elizabeth Creek Granite is intermixed with probable Herbert River Granite in the area south of the Tate River. The Elizabeth Creek Granite is of economic importance because it is the type of granite with which most of the tin, tungsten, molybdenum, and fluorspar deposits are associated.

   The feldspars consist of potash-feldspar (orthoclase, microperthite, and, in places, also microcline), generally in excess of plagioclase. Albite is an important constituent in some of the rock types, such as the alaskite. Biotite is not prominent, and hornblende is rarely present. In one or two thin sections fluorite was found among the accessory minerals. On the whole the texture is more xenomorphic than in the other groups. Fine myrmekitic textures between plagioclase and potash-feldspar, and graphic intergrowths between quartz and potash-feldspar, are fairly common. Graphic intergrowths have also been noted in some granites of the other groups.

6. The pink or grey, fine-grained, hornblende-bearing biotite microgranites forming the granite massif south of Petford and Lappa Junction are distinctive enough to be separated as an individual group. Potash feldspar (including microcline in some specimens) predominates over plagioclase (oligoclase-andesine), often sufficiently to allow the use of the term 'granite' instead of

'adamellite'. Mafic minerals are rather scarce (about 5 percent of the total mineral content), and biotite predominates strongly over hornblende. Characteristic of this group is accessory allanite, in scant amounts but persistently present.

Apart from these six groups there are odd varieties of granitic rocks of too small extent and with too vague boundaries to be shown individually on the maps. Within the Boxwood ring complex, in particular, the granites are rather diversified, and contain, amongst others, micro-pegmatitic or granophyric modifications (Pl. 9, fig. 2).

The granites in the Chillagoe district still present many controversies and problems. Furthermore, the distinction between Herbert River Granite, Almaden Granite, and Elizabeth Creek Granite cannot everywhere be made with certainty, as there appear to be intermediate types. Therefore, the boundaries between the various modifications as represented on the three maps (Plates 10, 11, 12) are tentative only, and are open to a good deal of future amendment.

Branch (pers. comm.) was at first inclined to ascribe the various modifications to assimilation and contamination: thus the grandiorite of the Almaden Granite was, in his opinion, the result of assimilation of Chillagoe limestone by Herbert River Granite. Assimilation of limestone by granite was seen in situ near the Hobson mine by W. B. Dallwitz, who recorded (pers. comm.) a gradation from wollastonite-grossularite-plagioclase-diopside hornfels (metamorphosed Chillagoe Formation) through porphyritic wollastonite-diopside microgranodiorite to porphyritic hornblende microgranodiorite. However, quartz diorites and granodiorites are not restricted to the limestone belts, but are also found in areas lying at great distance from existing or inferred pre-existing limestone formations, and assimilation as observed near the Hobson mine is therefore considered to be a strictly local phenomenon. Branch later revised his original idea of wholesale assimilation, though on different grounds (Branch, 1962), and he put forward the view that acid Herbert River magma had mixed with basalt magma to form hybrid granites such as the Almaden Granite.

Another granite modification in the district—our group 6—is regarded by Branch (pers. comm.) as contaminated Elizabeth Creek Granite, whereas we prefer to see it as a differentiate; there is as yet no concrete evidence for either opinion.

Magmatic differentiation may well have played at least as great a part in the formation of the various granite types as have assimilation and contamination by mixing. Wheeler (1955) describes varieties of granites in Labrador that form part of one adamellite batholith and that, he thinks, have resulted from differentiation without any important introduction of material. He subdivided the adamellite into hypersthene, hornblende, and biotite types similar to our groups 1, 2 and 3, and 4 and 5 (a fourth type—fayalite—is not represented in the Chillagoe area). The more leucocratic rocks of the biotite type are younger than those of the other types. These features, and several others, apply to the Chillagoe granites also. From triangular composition diagrams Wheeler concluded that 'all the features fit a theory of magmatic differentiation'. The principle of differentiation, if applied to the granites of the Chillagoe district, would explain why the more basic granodiorites and quartz diorites are not restricted to limestone belts, and also why the leucocratic biotite modifications are younger than the others. And, although no diagrams have been made, it can be said that the relative proportions of quartz, potash-feldspar, and plagioclase in the various modifications of the Chillagoe granites seem to follow a trend similar to that of the Labrador adamellite varieties.

The Chillagoe granites and volcanics are expected to be treated against a wider and more regional background in a forthcoming Bulletin on the geology of the Hodgkinson Basin, by F. de Keyser and K. G. Lucas (in preparation).

Age and Relationships between Granites and Volcanics

The relations between the Permian igneous rocks have long been a problem to investigators, though the difficulties mainly arise from trying to fit all the granites and volcanics into single episodes. This mistake was avoided by Ball (1915), who distinguished a 'pre-granite' and a 'post-granite' porphyry, and by Jensen (1941), who, although claiming most of the porphyry as pre-granite, dated some, including the Tennyson Ring Dyke, as post-granitic.

Evidence showing granite younger than the adjacent porphyry includes: apophyses of aplite in porphyry (Wolfram Camp: Ball, 1919); porphyry matrix recrystallized (at Redcap and in the Emuford area), and adjacent granite finer-grained, probably chilled (Fluorspar area: Jensen, 1941; Wolfram Camp: de Keyser, 1959). Evidence showing porphyry younger than granite includes: inclusions of granite fragments in many of the porphyries, e.g., in the Tennyson Ring Dyke and the Boxwood Volcanics.

As mentioned before, de Keyser et al. (1959) subdivided the Featherbed Volcanics into three superposed groups, and considered all the granites as the differentiates of the one magma, and successively intruded during a long time interval. Branch (1961) assumed the existence of two volcanic and two intrusive periods in the Cairns hinterland area; however, in the Chillagoe district, the granitic relationships seem to be more complicated.

Subsequent fieldwork in 1961 has led to the distinction of the six groups mentioned in the previous pages. Some of them may be correlated with the Herbert River and Elizabeth Creek Granites; others may be products of contamination and assimilation—as favoured by Branch—or may be normal differentiates, like the example given by Wheeler (1955). Branch considers group 4 and 5 as coarse and normal varieties, respectively, of the Elizabeth Creek Granite. However, it was seen that the coarse variety occurs as inclusions in rocks of group 6 (= contaminated group 5?), and also in volcanics of the Tennyson Ring Dyke, which are supposed to be intruded by Elizabeth Creek Granite. Thus we may have Elizabeth Creek Granites of two different ages, although the older phase (coarse) was possibly still hot when intruded by the younger phase.

The quartz diorites of group 1 are older than the Tennyson Ring Dyke, which cuts through them; dykes of quartz diorite adjacent to the Ring Dyke, when examined microscopically, appear to consist of strongly crushed rock.

Group 5 ('normal' Elizabeth Creek Granite) can be seen to intrude group 3 (Herbert River Granite) in the Khartoum district, north of the Tate River.

It seems that the various groups may have succeeded one another in the order 1, 3 and 2, 4, 5 and 6. Group 1 is regarded as the oldest member here because a general trend from more basic to more acid and leucocratic can then be recognised, and because Wheeler (op. cit.) has found the same conditions in Labrador.

The granites in the Cairns Hinterland have been systematically sampled in order to have their absolute age determined by means of the potassium-argon method. These determinations have been carried out in the Geochronology Laboratory of the Australian National University, Department of Geophysics, by Dr J. R. Richards and A. Cooper, and by A. Webb, of the Bureau of Mineral Resources. Results of their work have yet to be published at the time of writing, but the ages determined for the Herbert River Granite and the Elizabeth Creek Granite show spreads between 315 million years and 267 million years, that is, from Middle Carboniferous to Lower Permian. Samples selected from within the Chillagoe district gave the following results:

Almaden Granite, 1 mile west of Almaden—292 million years;
Elizabeth Creek Granite (or assimilated Herbert River Granite ? according to Branch, 1962), 4 miles south-west of Almaden—284 million years;
Elizabeth Creek Granite, Wolfram Camp—275 million years;
Herbert River Granite, 12 miles south-west of Chillagoe—285 million years;
(Dargalong Metamorphics, 7 miles south-west of Chillagoe—1044 million years, cf. page 15).

When plotting all ages determined from Herbert River and Elizabeth Creek types in the Cairns Hinterland, one notices that both types show a very considerable overlap in time, and also that all granites, regardless of type, become younger from south (Einasleigh 1:250,000 Sheet area) to north (Cooktown 1:250,000 Sheet area). Evernden & Richards (1962) had already described similar tendencies in the granites of the southern part of the Tasman Geosyncline, and it is advisable therefore to regard the granite modifications in the Chillagoe district as lithological types only, without attaching too rigidly defined age limits to them.

The results of these age determinations became available only after the maps and references had been drawn; hence the discrepancy between the text of this Bulletin and the Reference on the maps. The granites had been considered to be Upper Permian because the Almaden Granite seemed to intrude the Nychum Volcanics, which have been dated as Upper Permian on palaeontological evidence (de Keyser, 1961, and Morgan, 1961). However, it now seems quite possible that the field evidence had been incorrectly interpreted; inclusions of rhyolitic fragments in the granite which crops out alongside Nychum Volcanics in the Mossman 1:250,000 Sheet area (Morgan, 1961) need not be derived from these volcanics, and furthermore, the Almaden Granite here may theoretically be of a younger age than its representatives farther south. And at Wolfram Camp, the volcanics that are [illegible] granite are positioned outside the cauldron area occupied by the Featherbed Volcanics, and hence may not belong to the period of Featherbed vulcanism but may represent an older, Carboniferous, phase.

Mesozoic

Lower Cretaceous sediments of the *Wrotham Park Sandstone* make their appearance in the western part of the Mungana Sheet area, where they transgress over the Dargalong Metamorphics and the Nychum Volcanics, and have been preserved as a fringe of mesas along the scarp of the Red Plateau. The thickness of the formation is variable, owing to differences of relief on the pre-Mesozoic land surface; a maximum of 250 to 300 feet can be estimated for the exposure within the Mungana 1-mile Sheet area.

The name 'Wrotham Park Sandstone' was introduced by Laing & Power (1959) for the Mesozoic sandstone sequence along the Chillagoe/Wrotham Park road, immediately north of the Walsh River; fossils found by W. R. Morgan (Bureau of Mineral Resources) on top of a small mesa in that area, in 1960, were identified by J. T. Woods (1961) as *Maccoyella barklyi*. The age of the formation was stated as lower Aptian by Laing & Power, as Neocomian by Woods (1961).

The formation consists mainly of cross-bedded, white or red, thick-bedded, feldspathic quartz sandstone; pebbly members and intercalations and lenses of conglomerate are very common, and layers of shale are also present.

The sandstone is texturally and mineralogically mature, well rounded and sorted, with grain-sizes ranging, with few exception, from 0.5 to 1.0mm. Mud cracks occur locally, and cross-bedding is well developed in many places and generally indicates that the direction of transport was from the east. In the north-west corner of the Mungana Sheet area the sandstone has disintegrated and now forms a thick blanket of loose white quartz sand. Locally in this part a kind of dense grey billy quartzite can be found; it is composed of sand-sized quartz fragments in a dense pale grey or cream siliceous matrix. Pebbles in the conglomerate reach a maximum size of about five inches, and are composed of quartzite, vein quartz, porphyry, chert, schist, and gneiss. The shale is light grey, weathering to rust red. It contains sandy laminae with worm tracks.

Where the unconformity at the base is exposed, it is seen to be overlain by a breccia bed three or four feet thick, and composed of fragments of the directly underlying Dargalong Metamorphics.

The eastern depositional limit of the Wrotham Park Sandstone is ill-determined, but it appears to have reached at least as far as Rookwood and Mungana. Jensen (1923) noted the close resemblance of friable quartz sandstone, occurring in pockets near Mungana, to the Mesozoic lithology of the western areas. Similar patches of sandstone were found near Rookwood Homestead during the 1958 survey. Their preservation in low-lying localities may be due to their being valley-fill deposits in the pre-Mesozoic topographic surface.

Cainozoic

Cainozoic deposits are scarce and unimportant. They comprise areas of residual sand, sheet-flood sediments, and isolated patches of stream alluvium.

Residual sands overlie parts of the granitic areas along the Tate River and Oaky Creek, and south of Wolfram Camp. A thick blanket of white quartz sand derived from disintegrated sandstone mesas is spread out along Tomato Creek in the north-western corner of the Mungana Sheet area, and contains outcrops of dense billy-quartzite.

Stream alluvium and residual soils are found in the belt occupied by the Chillagoe Formation, where soluble limestone and incompetent shale have permitted their formation and deposition in easily eroded valleys and plains.

Sheet-flood or piedmont alluvial deposits cover the area between Chillagoe and the Featherbed Range, and carry much volcanic rubble in sands overlying the granitic surface. They have been incised by Recent creeks.

True river alluvium is confined almost entirely to stretches along the Walsh River on either side of the Featherbed Range. Natural levees composed of sand and silt were built up along the river in the area occupied by the Dargalong Metamorphics, probably in pre-Recent times, as they appear to be incised.

STRUCTURE

The area has known at least two main periods of orogenesis—one in pre-Silurian time, a second during the Carboniferous. The first formed the Precambrian basement, which subsequently acted as a buttress at the time of the Carboniferous orogeny, when the Palaeozoic geosynclinal formations were tightly folded. This phase of folding was followed by isostatic readjustment, the mobile belt became more rigid, and fracturing reached a maximum during the Permian with the formation of ring complexes and cauldron subsidence blocks. Folding activity died out — the Permian formations show only broad, gentle folds. Vertical movements have continued up to Recent times, and many old faults were repeatedly rejuvenated. The best example of this is the great Palmerville Fault, which probably originated during the Upper Silurian with the down-faulting of an eastern block. Recurrent movements took place during Carboniferous, post-Permian, and post-Cretaceous times (de Keyser, 1963), causing the eastern block alternately to rise and fall relative to the western block.

The Dargalong Metamorphics are strongly foliated; the foliation planes commonly dip steeply, although in some areas the dips are low to moderate. The foliation is generally parallel to the original bedding, but exceptions are found. Minor folding and crenulation, boudinage, and plastic folding are observable, but have not been systematically investigated. The general strike of foliation swings from north-east (in the western part of the Mungana Sheet area) to south-east (in the eastern part). The only effect the Carboniferous orogeny had on the Dargalong Metamorphics consisted of some internal strain and cataclasis, accompanied by retrograde metamorphism and faulting.

The geosynclinal Chillagoe, Mount Garnet, and Hodgkinson Formations are steeply tilted along north-west trends. Although very few actual fold axes can be recognised in outcrops or on air photographs, strong folding and overturning can be inferred from top and bottom relationships in the beds.

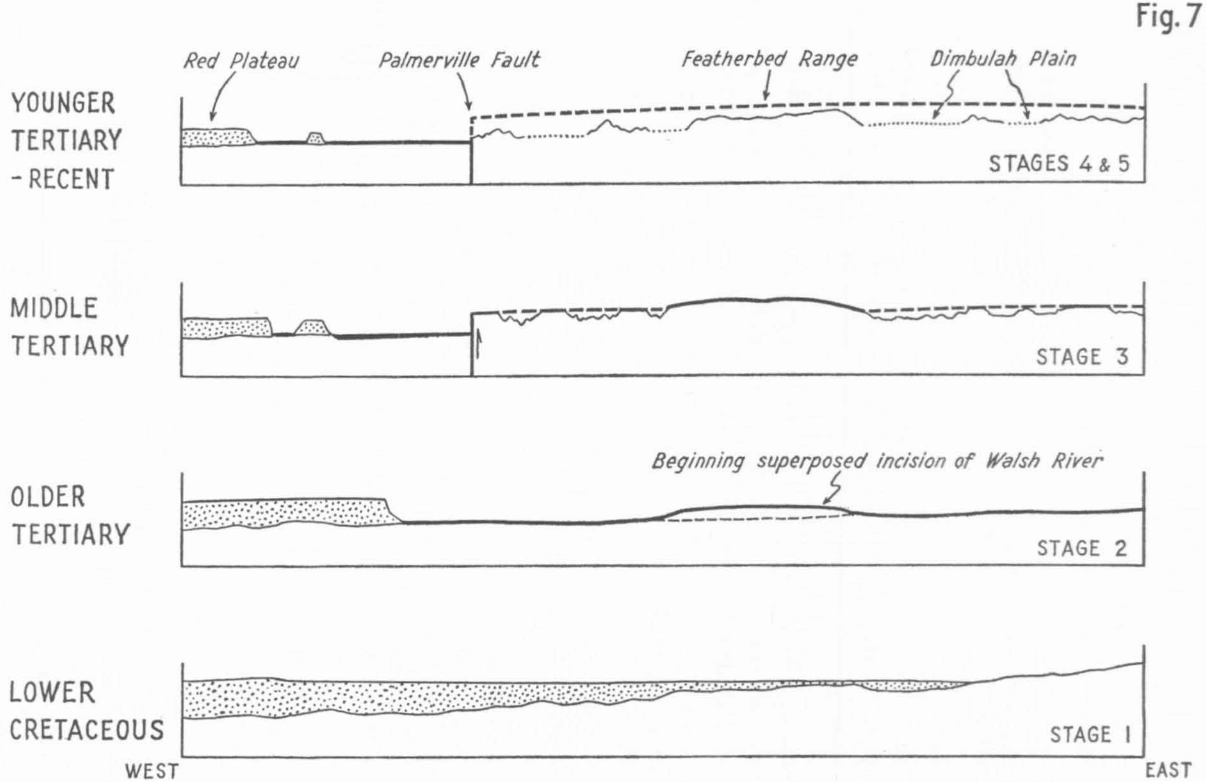
Amos (1961, 1962) has concluded from studies in the Mossman 1:250,000 Sheet area that folding of the geosynclinal formation took place in at least three or four stages under somewhat different stress systems. A first, tightly isoclinal folding phase resulting from horizontal compression was followed by a second stage of broader folding due to mainly lateral movement of material (probably because vertical movements at this stage were restricted by the load of the already folded sedimentary pile). The resulting steep plunges were determined by the intersection of the second-generation axial planes with the steeply dipping limbs of the first generation of folds. A third phase of deformation produced megascopic folds with intense axial-plane slaty cleavage.

It is not known what relative intensity these various phases of deformation had in the Chillagoe area. Probably they are not all represented here owing to the dampening effect of the shallow Chillagoe shelf, over which the total thickness of accumulated sediments was probably far less than in the axial regions of the geosyncline farther to the north-east (outside the area), where thick deposits of flysch sediments (Hodgkinson Formation) were laid down.

Faulting during all these stages of deformation was intense, as has been recognised in the adjoining Mossman and Cooktown 1:250,000 Sheet areas. The faulting and fissuring assumed an unusual character during the Permian, when ring complexes and cauldron subsidence blocks were formed.

GEOMORPHOLOGICAL EVOLUTION

The area covered by three one-mile sheets is too small to be comprehensively analysed, and most physical features — relief and drainage — have been described in the Introduction. However, field work in the surrounding areas during the last few years has yielded much information, and the development of the present landscape, as sketched in the series of profiles (Fig. 7) and described below, is mainly based on such outside evidence.



GEOMORPHOLOGICAL DEVELOPMENT, CHILLAGOE DISTRICT

Stage 1: Cretaceous transgression from the west over a low-relief, pre-Cretaceous surface of denudation. Deposition of Lower Cretaceous sandstone and conglomerate with a littoral facies at the base.

Stage 2: Uplift and erosion. Formation of one or two older Tertiary erosion surfaces. After the thin Cretaceous cover had been stripped, the Walsh River began its superposed incision into the Featherbed Range, which became carved out in relief because of its uniform toughness and the massive structure of its volcanics.

Stage 3: Renewed major movements along the Palmerville Fault caused uplift and warping of the eastern block. The older Tertiary surface became incised, and the beginning of a 'gipfelfluhr' was formed.

Stage 4: Younger broad valleys and plains — e.g., the Mareeba - Dimbulah Plain — were formed, possibly during the Pliocene. The superposed incision of the Walsh River continued. Possibly the climate at that time was wetter (see below).

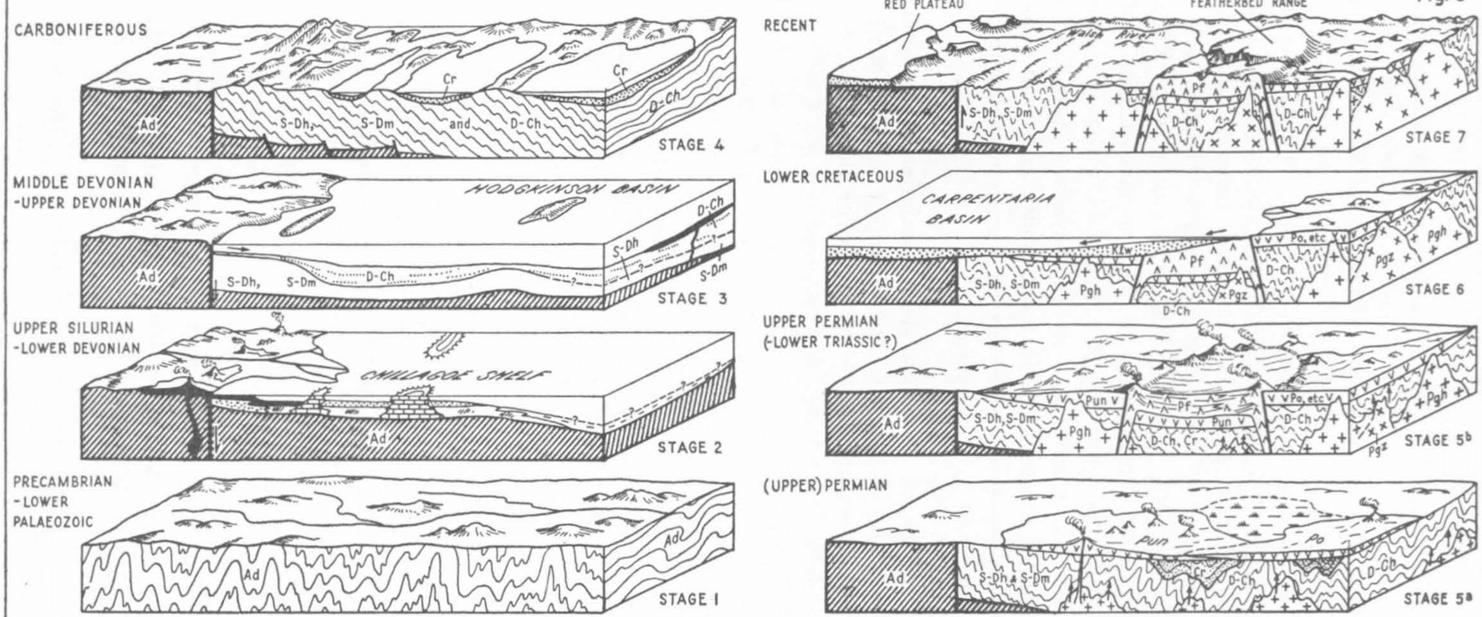
Stage 5: (not represented in the diagrams). In Pleistocene to Recent times earth movements continued to a greater or lesser degree. Faulting and fissuring is in evidence in the Mossman and Atherton areas, and may be assumed to exist in the Chillagoe district as well, thus explaining the sudden changes of relief in some granite areas such as the one south of Petford. The incision of large alluvial plains, e.g., west of the Featherbed Range, may be due in part to renewed uplift or else to a change in climate. Change of climate is here also held responsible for the formation of the so-called 'Metal Hills' granite outcrops north-west of Chillagoe: it is thought that, after the dwindling of the rich vegetation from the previous wetter period, the soil and weathering mantle was easily stripped off from the most prominent (but not necessarily the most elevated) parts of the granite topography, so that the core-mantle became exposed, and degenerated to a naked boulder mantle on which no soil can form owing to the stripping action of heavy rain during the wet season, and the arid conditions in the other half-year.

GEOLOGICAL HISTORY

Figure 8 shows, in a series of diagrams, the most likely sequence of the main geological events. The post-Mesozoic history has been treated in the foregoing chapter on geomorphological evolution.

Stage 1: A Precambrian sequence (Ad) of arenites and pelites with interbedded basic volcanics was folded, metamorphosed, and partly granitized. After isostatic uplift a long period of denudation led to the formation of a mature to old landscape.

Fig. 8



GEOLOGICAL HISTORY, CHILLAGOE DISTRICT

Stage 2: A shallow sea transgressed this land in the east, during the Upper Silurian, possibly as the result of the appearance of the Palmerville Fault, along which an eastern block was gently down-faulted. It was the beginning of the Tasman Geosynclinal subsidence in this part of North Queensland. Sediments of the Upper Silurian Chillagoe Formation (S-Dh) were deposited in a shelf area, and represent a mixed shelf association of reef limestone, with arenites and siltstone laid down in deltaic sectors, and chert probably in quiet and isolated lagoons. The Chillagoe shelf area can be termed a miogeosyncline, if a miogeosyncline may be defined as the more stable marginal part of a geosyncline, forming the transition into the craton (see Kuendig, 1959). Basic extrusives are present in this miogeosyncline, and this is an exception to the generally accepted 'rule' that miogeosynclines do not experience igneous activity. They may have accompanied the generation of the Palmerville Fault, subsidiary fissures of which may have served as feeder channels to the basic volcanics: basic dykes parallel the fault in many places.

Within the area mapped, the mixed shelf association of the Chillagoe Formation was followed by the clastic shelf association of the Mount Garnet Formation. In other regions outside the Chillagoe district the Mount Garnet Formation (S-Dm) as a facies type seems to have replaced the Chillagoe Formation; the two formations are probably partly penecontemporaneous. It is conceivable that the clastic shelf assemblage of the Mount Garnet Formation was deposited when—or in places where—erosion in the bordering continent was more active.

Chillagoe and Mount Garnet sediments have not been found in areas towards the centre of the Tasman Geosyncline, to the east of the area mapped. It is assumed that towards these deeper parts the sediments deposited during the Upper Silurian were much finer, forming uncharacteristic slate and siltstone sequences which may be actually exposed, but not recognized, in parts of areas mapped as Hodgkinson Formation and so-called 'Barron River Metamorphics', between Cairns and the Chillagoe district. Such sediments, though time-equivalents of the Upper Silurian Chillagoe and Mount Garnet deposits, would not be distinguishable from the fine-grained members of the Devonian Hodgkinson Formation, because they were deposited under essentially the same conditions.

Stage 3: From about the Middle Devonian, subsidence of the geosynclinal trough accelerated, and depth of deposition increased. The area of shelf facies probably shrank considerably, while greywacke and siltstone were deposited on a large scale, partly by turbidity currents and submarine sliding. Interbedded shale and chert probably represent the 'normal' facies of continuous deposition. Basic and acid volcanics—spilite, andesite, quartz keratophyre (though not represented in the Chillagoe district)—were extruded. This succession of sediments and volcanics forms the Hodgkinson Formation (D-Ch). The sediments may be regarded as representing a flysch facies (see page 27), although some authors distinguish between a flysch facies and a greywacke facies.

Some workers, for instance Jones (1943), think that there was a folding phase between the deposition of the Chillagoe (Mount Garnet) Formation and the Hodgkinson Formation, during the (?) Lower Devonian; Jones nevertheless confessed that there was no valid evidence for such an orogenic phase. White (1961) presented evidence for an unconformity in the region south of the Chillagoe district, but such an unconformity could not be proved in the Chillagoe area. Nevertheless, White's concept of a tectonic land to the south would not be incompatible with the lack of an unconformity in the north: the rise of land in the south would first supply abundant detritus (thick Mount Garnet deposits near Mount Garnet), diminishing to the north (thinning of the Mount Garnet Formation, and its final disappearance north of the Mitchell River). With continuing rise during Devonian times the formation of a definite unconformity between the Mount Garnet and Hodgkinson Formations was possible in the south, grading northwards into a disconformity and finally into an uninterrupted sequence. In the Chillagoe district, however, the contact between the Mount Garnet and Hodgkinson Formations is not exposed, so that conclusions cannot be drawn from this area.

Stage 4: Beginning of the Carboniferous orogeny. The Silurian and Devonian formations were folded and partly elevated above sea-level, and in the isolated or narrowed marine and continental basins quartzose sandstone and siltstone and some conglomerate were laid down with angular unconformity. They are possibly comparable to 'molasse' deposits. Remnants of such Carboniferous formations are probably represented, within the Chillagoe district, in the areas of Boxwood and Koorboora (?Ringrose Formation, Cr). Continued compressional forces folded these Carboniferous deposits, too.

Stage 5: Compressional stresses ceased, and during the following isostatic re-adjustment the region was elevated above sea-level; a long period of denudation set in, transforming the area to a mature old plain of low relief.

Granites, which had possibly been generated during the Carboniferous orogeny by differential melting and fusion of the deeper parts of the sedimentary pile, at depths of about 5 miles, were probably subjected to over-heating, which enabled them to work their way upwards for considerable distances without (immediately) solidifying, and finally crystallized as high-level plutons — the Herbert River (Pgh) and Elizabeth Creek (Pgz) Granites. Meanwhile, tensional faulting and fracturing provided supply channels for coeval and co-magmatic volcanic extrusions; ring complexes were formed, and the final stage was the formation of a large cauldron subsidence block in which large volumes of welded tuffs and lavas were poured out (Stage 5b).

Stage 6: Erosion and denudation, which had started to plane down the landscape after the Carboniferous orogenic uplift, continued during the Mesozoic. During the Lower Cretaceous transgression, which encroached from the west, sandstone and conglomerate of the Wrotham Park Sandstone (Klw) were deposited in the littoral environment of a shallow sea. This sandstone facies was succeeded by the marine shale facies of the Blackdown Formation (Klb).

Stage 7: Epeirogenic movements and faulting elevated the area once again above sea-level, and post-Cretaceous vertical movements combined with erosion to form the present-day landscape. This phase has been described in more detail on page 48.

ECONOMIC GEOLOGY

INTRODUCTION

The area covered by the one-mile Sheets of Chillagoe, Almaden, and Mungana ('the Chillagoe district') contains most of the old mining centres within the Chillagoe Gold and Mineral Field, and includes small corners of the Herberton Gold and Mineral Field and the Mareeba Gold and Mineral Field. During its life it has produced copper, silver, lead, gold, tungsten, molybdenum, bismuth, tin, cobalt, zinc, and iron minerals, fluorspar, and lime; minor uneconomical occurrences of mica, silica, clay, coal, antimony, cobalt, manganese, and titanium minerals are also known. The workings are almost all inaccessible—collapsed or filled with water—and the information compiled in the following pages has been collected from many various sources.

Mining History

The first official record of the presence of mineral deposits in the Chillagoe district appears in the Annual Report of the Department of Mines (Queensland) for the year 1888: it states that one of the managers of Messrs Moffat and Company, while searching for a dray road from the 'copper mines in the Chillagoe district' to the east, had found tin at Koorboora. It appears that the existence of these copper and silver lodes had first been mentioned to John Moffat, one of the mining pioneers on the Herberton tin field, by Mr Atherton, an early settler of Chillagoe. By the end of 1888 Moffat employed more than 70 men on testing and development work on deposits around Chillagoe, Redcap, and Mungana.

Jack (1891), Skertchly (1897, 1899), and Dunstan (1900) were the first geologists to describe these deposits. Although they were unanimously of the opinion that the district had very great potential, activities at first remained restricted to further prospecting and non-productive development, largely because of the lack of a good transport link through the rough country to the east. The only production during this time came from tin placers around Koorboora.

To remedy the situation several small smelters were erected to treat the ores locally: examples were the smelter at Muldiva, built in 1891, for the silver-lead ores, and the copper smelter at Calcifer, built in 1894 by the Irvinebank Tin Mining Company. However, only the rich ores could be treated effectively, and soon the need was felt for a central plant able to treat the lower grade ores, and for a good transport link to the east to export the matte. As a consequence the Chillagoe Railways and Mines Co. Ltd. was formed and, in 1897, began the construction of a railway line from Mareeba to Chillagoe and Mungana. In 1901 the last stretch was completed, and in the same year a large smelting plant was opened by the company at Chillagoe.

The Chillagoe district now entered its most prosperous period, which lasted until about 1914 for the base metals, and until 1920 for tin, tungsten, and molybdenum. The base-metal deposits were almost all mined by the Chillagoe Railways and Mines Co. Ltd (known as the Chillagoe Co. Ltd from 1905 to 1913, and as Chillagoe Ltd from 1913 to 1915) and by its subsidiary, the Mungana (Chillagoe) Mining Company. Wolfram Camp and Bamford Hill became the most important wolfram producers in Australia. The overall peak of production was reached in 1908. After that year a gradual decline set in, brought about by strikes, lower metal prices, mining difficulties, fires in one of the largest producers (the Lady Jane), and other factors. Several mines, including important ones like Zillmanton, Ruddygore, and Lady Jane, closed down. Much of the capital backing the companies was German and was frozen when war broke out in 1914. The smelters stopped operating, entailing a severe setback for the surviving base-metal mines: the only important copper producer left during the war years was Cardross. However, the wartime demand for tungsten and molybdenum kept the Wolfram Camp and Bamford Hill mining centres going.

In 1918, the Queensland Government, wishing to prevent the total decline and eventual abandonment of the area, took over the assets of the company, re-opened the smelters in 1920, and continued mining. A second but shorter and less intense boom followed; in 1923 silver-lead again reached a high peak, but copper production remained rather low. Fluorspar entered the list of minerals found, and its production culminated in 1925.

However, the average grade or the ores had dropped considerably, and the Chillagoe smelters, not equipped to deal with the low-grade material, were forced to bring in large quantities of rich ore from such outside areas as Etheridge and Herberton, and from as far as the Cloncurry district. Mining in the Chillagoe area itself languished and grew stagnant. When circumstances forced the smelters to close down temporarily in 1927, the mines had to follow suit, but they lacked the vitality to revive when the smelters re-opened in 1929. The bulk of the ore henceforth was imported from outside districts. In 1943 the smelters were closed for the last time and were finally sold for removal in 1950.

Minerals other than the base-metal ores caused a slight recurrence of activity after 1930, when gold was found near Fluorspar, and interest in the Mount Wandoo gold mines reawakened. Gold, fluorspar, and wolfram became the dominant minerals won. However, production gradually declined, and at the time of our survey in 1958 mining had come to a virtual standstill: only insignificant quantities of cassiterite, fluorspar, and molybdenite were being won.

In 1961 a good tin lode was being successfully reworked at the Dover Castle tin mine, but all other minerals had completely dropped out of the picture. At present Mungana is deserted, part of the railway has been abandoned, and the remaining services have been reduced.

Mineral Exploration

No systematic exploration was made during the early days: the numerous ferruginous-siliceous and skarn outcrops were obvious enough. In later years the various deposits were visited and described by a succession of Queensland State Government geologists. At the beginning of World War II Jensen (1941) mapped in detail part of the Chillagoe district, and gave a full and comprehensive description of its many workings. Broadhurst (1953), a consulting geologist, did much detailed work in a more restricted area between Mungana and Chillagoe. In 1958 a combined geological party of the Bureau of Mineral Resources and the Geological Survey of Queensland undertook the systematic mapping of the area as a whole, and located and described its many workings.

After the end of World War II several mining companies took renewed interest in the district, and Authorities to Prospect were issued, among others, to Broken Hill South Ltd for the Mungana-Redcap areas and Ruddygore (1947-1951); to Clutha Development Ltd for the western part of the area (1956-1958); to New Consolidated Gold Fields Ltd for the eastern part (1957-1958); to Metals Exploration N.L. (1956) for the Redcap area; to the Chillagoe Prospecting Syndicate for the Mungana area (about 1955-1956); to Enterprise Exploration Pty Ltd (1961) for the Chillagoe-Almaden area; and to Broken Hill Pty Co. Ltd (1960-1961) for the Sunnymount and Koorboora areas. During their exploration activities churn and diamond drilling was put to use at Ruddygore, on Moffat's Hill, and on the Griffith Lease in the Mungana district, and in the Redcap and Cambourne (Redcap) areas. The latest drilling tests were carried out by Mount Isa Mines Ltd at Ruddygore (1960), and by Broken Hill South Ltd at Cardross in 1962-1963.

Geophysical methods were first put into practice in 1930 in the Redcap and Mungana areas by the Imperial Geophysical Experimental Survey (Broughton Edge & Laby, 1931), but the results were inconclusive, and the survey was criticized by Ball (1931), who observed that only a hurried reconnaissance had been made, that only an unchecked equipotential method had been used, without the assistance of a geologist familiar with local conditions, and that '. . . on the work done, they should not have been expected to select sites for boring'.

In 1949 the Commonwealth carried out electromagnetic surveys in the Redcap, Mungana, and Zillmanton areas (Langron, 1957). An airborne scintillometer was used in 1954 by the Bureau of Mineral Resources over a large area, including the Chillagoe Field (Parkinson & Mulder, 1956). This was followed up by a more closely spaced combined magnetometer and scintillograph aerial survey of the Chillagoe area in 1958. The following year geophysical work was done at Ruddygore and Wolfram Camp (Horvath, 1959; Daly, 1959). In 1961 Mineral Deposits Ltd (Southport) carried out a magnetometer survey around the iron deposits of Mount Lucy, west of Almaden.

Geochemical prospecting methods were tried out by the Bureau of Mineral Resources in 1961 around Redcap, Ruddygore, and the old Khartoum district, and in the area south-west and south-east of Almaden. A more detailed sampling system was tested by Enterprise Exploration Pty Ltd in the same year. The results indicate that the geochemical technique is workable in these areas.

Production

Table 2 gives the annual production figures for the various minerals won in the Chillagoe district—the area covered by the three one-mile Sheets of Chillagoe, Almaden, and Mungana. Figures 10 - 14 show graphically the production of the most important minerals won. The total production has been valued at more than £2,500,000.

In the early years output was not accurately recorded, but from 1891 the production figures appeared in the Annual Reports of the Queensland Department of Mines, and were included in the records of output of the Herberton Mining District (Walsh and Tinaroo Mineral Field). In 1909 the area was included in the newly designated Chillagoe Gold and Mineral Field. Wolfram Camp was detached from this field in 1949, and incorporated in the newly designated Mareeba Gold and Mineral Field.

Considered objectively, the Chillagoe district has been over-rated as a base-metal mineral field. The area contains hundreds of mines and prospects, yet, during its entire life span, its total output of lead has been only about 20 percent of the 1960 production of Broken Hill, or 85 percent of that of Mount Isa, and is only five times that of the 1960 production of Captains Flat. Its total copper yield has been 33 percent of that of Mount Isa for the year 1960, and only twice that of the 1960 Mount Lyell copper production.

Wolfram has been relatively much more important. Wolfram Camp, with a total production (to end of 1960) of 5400 tons—about a third of the total production to the end of 1960 of Australia's main tungsten producer, King Island —was once the major wolfram centre of Queensland.

Before 1920, when the world's consumption of molybdenum was very much smaller than it is now, Australia was the leading producer of this metal, and the Chillagoe Field was the main centre. However, in modern perspective, this is an unimpressive fact—the Chillagoe Field's total molybdenum output during its entire productive period amounts to less than 4 percent of the 1961 production of the Climax mine in the United States.

As a goldfield, the Chillagoe district attracted considerable attention during the thirties, and there was a continual small production of gold as a by-product from the base-metal mines, but the recorded total is insignificant; it amounts to about 8 percent of the 1961 production of the Lake View and Star gold mine in Western Australia.

TABLE 2

PRODUCTION TABLE OF ORE PRODUCED FROM THE AREA EMBRACED BY ALMADEN, CHILLAGOE AND MUNGANA ONE-MILE SHEETS

Year	Silver (oz.)	Gold (fine oz.)	Gold (Bullion)	Copper (tons)	Lead (tons)	Silver-Lead (Bullion) (tons)	Zinc (tons)	Tin Oxide (tons)	Wolfram (tons)	Scheelite (tons)
1891	1,856			27						
1892				20				10		
1893	187,571							56		
1894				212				3	65	
1895	9,000			275		59			21	
1896	3,810			328		30				
1897	31,992			147	250	401			13	
1898									68	
1899								37	270	
1900								105	188	
1901	15,721	75		367				168	72	
1902	23,792			402				116	55	
1903	351,263			2,119	3,636			150	188	
1904	357,197	31		1,446	1,661			112	652	
1905	238,326	121		1.005	1,585			144	815	
1906	347,513	77		1,665	1,715			265	488	
1907	488,152	367		2,026	4,370			352	433	
1908	638,100	94		2,170	6,356			251	229	
1909	541,746	114		1,998	4,568			572	354	
1910	340,261	23		1,623	981			589	496	2
1911	128,826	85		741	920			320	216	5
1912	175,765	133		327	1,859			385	116	
1913	197,636	557		630	2,273			347	76	
1914	27,032	171		176	260			133	64	
1915	32,922	769		593	17			166	144	
1916	4,726	50		94	6			117	84	
1917	17,096	6		204	16			75	122	
1918	3,015	92		61				90	105	
1919	122	.1		1				66	87	1.5
1920	72,385	2.7		217	1,070			19	50	
1921	95,292	.3		101	881			23	4	
1922	190,267	3.4		63	2,338			1	1	
1923	375,158	98		651	4,871			18		
1924	247,264	1.4		472	3,494		130	55	1	
1925	184,928	.3		184	3,116			46	5	
1926	104,484			89	1,839		200	49	.5	
1927	23,706	8.7		8	401			58		
1928	556			4				76	27	
1929	14,168			16	224			45	8	
1930	12.008	140		40	57			27	6	.3
1931	1,107	967	298	51	.5			25		
1932	5,669	925	880	27	.2			23	6	1
1933	4,790	2,233	540	16	.8			29	13	
1934	4,461	1,767	605	21				38	29	
1935	7,135	1,719	400	149				15	22	.1
1936	5,386	1,157	95	104	1			36	19	
1937	4,699	519	19	40	1			77	24	
1938	936	161		21	.8			20	54	
1939	147	115	12	.2				13	42	.1
1940	1,228	327	77	40				78	62	
1941	988	118		32				35	38	
1942	186	124		4				35	58	.7
1943	13	14						34	73	
1944		7						20	122	
1945		11						22	87	
1946								9	31	
1947	3							11	35	
1948								6	38	
1949								20	26	
1950	137	.3		.5				18	16	
1951	467				14			5	23	
1952								20	53	.4
1953				1.4				22	51	
1954				1				64	21	
1955		65		7.3				17	41	
1956								22	27	
1957								14	7	
1958								4.7	.2	
1959								76.7		
1960								63.7		
TOTAL	5,521,258	13,250	2,926	21,067.4	48,701.3	490	330	5,941.1	6,541.7	10.1

Year	Molybdenite (tons)	Bismuth (tons)	Bismuth Wolfram (tons)	Wolfram Molybdenite Mixed Concentrate (tons)	Fluorspar (tons)	Antimony (tons)	Mica (tons)	Rutile (tons)	Clay (tons)	Quartz Crystal (tons)	Silica (tons)	Limestone (tons)	Ironstone (tons)
1891													
1892													
1893													
1894													
1895													
1896													
1897													
1898		1											
1899													
1900	11	5											
1901	9	6	17										
1902	38	1	3										
1903	10	.2	13									3,698	8,721
1904	21	2.1	3									4,017	4,424
1905	64	7	20									4,434	2,627
1906	92	5	22									5,971	3,364
1907	63	6	11									9,685	5,708
1908	112	12	147									13,396	2,960
1909	91	4	64									14,550	1,036
1910	104	7	14									15,557	3,403
1911	99	4	98									11,870	2,280
1912	101	3	147	23								12,929	2,965
1913	64	2	174	146								9,100	2,797
1914	76	.7	180									1,224	523
1915	92	1.2	224									2,500	
1916	75	2	126									805	
1917	106	3	121									973	
1918	90.5	1	111									738	
1919	74	.7	133									2,355	
1920	23	.6	48		603							3,879	
1921	9				536							10,991	181
1922		1										2,565	
1923	9	.2										8,580	200
1924	3	.2			1,864							4,987	
1925	2	.5			4,227						168	6,782	345
1926					2,311						389	6,484	4,412
1927	1		6		1,033							1,282	506
1928		.8			1,125							1,548	
1929					592							3,342	1,236
1930	2		1.5		751						223	8,873	1,149
1931	.3				521							9,767	798
1932	1				1,220						83	13,429	578
1933	4				737						118	11,413	1,434
1934	1				1,307				51		24	9,138	887
1935	10	.1			182				50		50	2,761	946
1936	17	.1			479				158			4,604	2,236
1937	13	.1			920				176			6,367	4,290
1938	7	.2	1		2,435				159			6,276	5,125
1939	7	.5	.7		20				217			9,740	3,940
1940	3	.3	.1		874				177		106	7,860	2,841
1941	6	.8	.1		144				134		137	6,245	2,312
1942	9	.8	1		306		.1		90		74	6,230	3,469
1943	9	.7	1		535				33	.7	67	3,959	960
1944	1	.9	1.5		512							3,390	
1945		.8	.1		788							5,009	
1946	8	.5			593							4,724	
1947	1	1			741	.5						3,448	
1948	2	1			288							4,896	
1949	5	.2			377							4,864	
1950	3.5				595							3,862	
1951	.2				277							3,204	
1952	.1				85							3,087	
1953	2				206							3,300	
1954	.7				240							2,930	
1955	3							1.7				2,380	
1956												2,298	
1957	3											2,001	
1958	4.5											3,360	
1959												2,555	
1960												3,610	
TOTAL	1,564.8	85.5	1,689.0	169	27.424	0.5	0.1	1.7	1,245	0.7	1,439	329,822	78,673

Silver quantities compare a little more favourably; Chillagoe's total silver production was more than a third of the highest total annual silver production yet recorded in Australia.

The main interest of the Chillagoe district lies in the diversity of its mineral deposits, and in its latent potential for rare metals that may occur in some of the greisens and pegmatites in the area.

DISTRIBUTION AND CLASSIFICATION

Mineralization is widespread and varied in the Chillagoe district; nevertheless, several generalized groups can be recognized, each characterized by its own specific mineralization and geological conditions (Pl. 13). The majority of the lodes lie in the sedimentary formations; a few—most of the tungsten and molybdenum deposits—are found in granite. The Featherbed Volcanics are almost devoid of mineral deposits, with the exception of the Lappa Lappa lead and tin mines north-west of Petford and Bamford Hill.

In Figure 9 an attempt is made to fit most of the mines or groups of mines into a classification that is based on both the character of mineralization and the structure of the deposits. High-temperature pneumatolytic to hypothermal conditions appear to have prevailed. No epithermal lodes have been recognised. All deposits in the area can probably be linked with the intrusion of the Permian granites and granodiorites, with the single exception of the Mount Kitchin mica pegmatites.

Most of the ore was won from the oxidation zone or from zones of secondary enrichment; with greater depth conditions usually became unfavourable, either because of a change in mineral composition (increase in sphalerite in the lead ores, for instance) or because of the uneconomic grade of the primary ores. In many places technical difficulties also increased, owing to such natural troubles as copious influx of mine water or the softness of clayey wall rocks.

The depth of the groundwater level in the Chillagoe belt generally ranges between about 50 and 100 feet, but the zone of oxidation in places extends well below the water level, probably owing to a free and fast groundwater circulation through the cavernous limestone masses.

Smirnov (1959) has noted that in Russia the axial parts of a geosynclinal area are usually the sites of tin, tungsten, and molybdenum mineralization, whereas the peripheral parts are commonly characterized by contact-metasomatic and hydrothermal sulphide deposits. The same seems to apply to the ore distribution in the Chillagoe district and the adjoining Mossman Sheet area: the tin, tungsten, and molybdenum mines are found towards the axial parts of the Tasman Geosyncline, whereas the copper, lead, zinc, and silver lodes are concentrated along its western margin.

Fig. 9

TENTATIVE CLASSIFICATION OF THE ORE DEPOSITS IN THE CHILLAGOE DISTRICT

	PEGMATITES	CONTACT DEPOSITS	FISSURES, SHEARS, PIPES	DISSEMINATIONS
MESOTHERMAL			*Dargalong* Pb — Ag *Fluorspar* Au, F *Fluorite veins?* *Mount Wandoo*	*Ruddygore*
HYPOTHERMAL		*Zillmanton* *Mungana* *Redcap*	*Cardross* *Dover Castle* *Koorboora & Sunnymount* *Khartoum* *Bamford Hill* *Wolfram Camp*	
PNEUMATOLYTIC		*Muldiva* *Christmas Gift* *Boomerang, Hobson* *Ti-tree, Mount Lucy* *Chillagoe Consols* *Harper*		
PEGMATITIC	*Mount Kitchin mica*			

All important copper-lead-zinc-silver deposits in the Chillagoe district occur within a belt 30 miles long and roughly six miles wide, stretching from near Almaden to the Mungana and Redcap areas. They are generally associated with the limestones of the Chillagoe Formation, which are intruded by the Permo-Carboniferous granites and granodiorites and have been locally transformed by contact-metamorphism and metasomatism to marble, calc-silicate and skarn rocks, and magnetite and hematite-quartz lodes. Jensen (1940) thought that, in general, the more basic differentiates of the granodiorites produced wider and more ferruginous belts of contact alteration than did the acid varieties, and that copper was mostly concentrated within the garnetiferous belts, whereas the lead lodes were generally not associated with garnet rock. He also suggested that the lead lodes have a narrower, but well-defined, compact, and jasperized 'ironstone' cap. However, one has only to examine the abundant garnet rock deposits at the Muldiva lead mines to come to the conclusion that at least some important exceptions do occur.

The usual order of formation in contact deposits is: calc-silicates-magnetite-sulphides, and the Chillagoe lodes generally appear to follow the rule. Noteworthy is the opinion expressed by Dunstan (1906) and by Denmead (1934d) that the magnetite-hematite mixtures at Mount Lucy are probably the result of surface concentration due to weathering and alteration of garnet, and its replacement by magnetite. This conclusion was based on the observation that in that and other localities the iron oxides gave way to garnet rocks at small depth whenever shafts were sunk.

Typical contact deposits are generally known to be irregular and unpredictable, though knick-points in the contact surface and embayments of limestone in granite seem to be favourable loci for ore concentration. The Chillagoe contact lodes are no exception, and as the easy-to-find surface deposits have all been found and have for the most part been worked out, a search for deeper deposits of ore will eventually have to be made by drilling and geophysical means, should increased demand for base metals warrant further prospecting. At present such a proposition is quite unattractive: besides being difficult to find and to assess, individual deposits are generally small and not of very high grade.

Other deposits, probably also of high-temperature origin, but more regular in configuration, are those occupying fault or fissure zones, such as the Chillagoe Consols and the lodes at Zillmanton, Redcap, and Mungana. Geophysical exploration has outlined a considerable length of possible ore-bearing structure at Zillmanton, but this work has not been followed up by test-drilling (Langron, 1950; Branch, 1960).

The pipes of the Girofla and Lady Jane mines (pages 65, 66) and the breccia of Mount Redcap are much-discussed and controversial subjects. The Redcap breccia was considered by Jack (1891) as well as by Broadhurst (1952) to be a volcanic breccia, and by Jensen (1941) to be a fault breccia, but these explanations are here rejected (see page 23). Broadhurst also considered the

Girofla and Lady Jane pipes to be volcanic diatremes. However, we envisage a hydrothermal-pneumatolytic origin by which the corrosive action of fluids and vapours transformed the limestone in their pathways into chert, and consider that brecciation was brought about by cracking due to changes in volume and pressure (see also page 23). The pipes may be aligned on faults or shear zones, as at Redcap and possibly at Mungana.

The Ruddygore copper mine (page 71) is different from the other mines; it is a disseminated deposit of the 'porphyry copper' type, probably formed under mesothermal conditions. Metasomatism of the granodiorite, and mineralization, were attributed by both Broadhurst (1949) and Branch (1960) to the most acid differentiates of the granite, called 'aplites' by Broadhurst, 'leucocratic micro-granodiorites' by Branch. The cracking and brecciation of the orebody may have been due to mineralization stoping, as advocated by Broadhurst, or to upward pushing of the acid differentiate, as favoured by Branch, or to a combination of these processes.

There seems to be a suggestion that the purer silver-lead ores, poor in copper, are the farthest removed from the granite contacts, and that copper is predominant where granite outcrops are very near, or where granite is suspected to be present at shallow depth.

Ovchinnikov (1959) found (partly by experiment) that, when a granite melt becomes contaminated with lime-rich rocks, it is likely to produce iron and copper ores at the granite-limestone contact by means of a kind of natural flotation process. Gas escape is localized in segments controlled by faults and fissures; the gas may even force its way upwards 'under its own steam', thus forming 'gas breccias'. Orebodies may be formed in contact-metasomatic skarns and hydrothermal deposits. The Chillagoe district, with its cupriferous iron contact deposits commonly controlled by faults and fractures, and with its breccia pipes, might serve as an ideal illustration to the ideas expressed by Ovchinnikov.

The copper lodes scattered around Cardross in the Dargalong Metamorphics have a more hydrothermal character, though the presence of such minerals as magnetite, tourmaline, topaz, fluorspar, and wolframite, and the kind of wallrock alteration, point to deposition under still high temperatures. They differ from the copper lodes in the Almaden-Mungana belt also in the absence of appreciable amounts of lead and zinc, and in their comparatively high gold values.

The belt of fluorite veins south-west of Chillagoe and Almaden runs approximately parallel with the Palmerville Fault; the numerous veins may, perhaps, have been emplaced in secondary fissures formed during one of the stages of movement along the Palmerville Fault.

The gold deposits at Mount Wandoo and Fluorspar are probably mesothermal metasomatic and vein deposits. Arsenopyrite is their most common noncommercial metallic gangue mineral.

The tin lodes of the Koorboora and Sunnymount areas may be the result of two phases of mineralization—one with a more pneumatolytic, the other with a more hydrothermal character. The high-temperature phase would be represented by the tin-wolfram association, and by the pneumatolytic alteration of wall-rocks (formation of mica and tourmaline); the hydrothermal phase is probably characterized by the sulphide paragenesis and perhaps by the chloritization of wall-rocks. This two-phase emplacement may explain the apparent reversed order of mineral zoning in the lodes: according to several reports the tin ores tend to give way to sulphides in depth. Within the high-temperature sequence the mineral zoning is 'normal': the upper parts of the cassiterite lodes commonly contained appreciable amounts of wolframite. The tin lodes are all associated with the ring complexes of Boxwood and the Featherbed Ranges. A possible two-phase mineralization could perhaps be explained in the terms of this environment: a first phase of normal hydrothermal activity, followed by a phase of high-temperature mineralization due to the foundering and sinking of large blocks to a depth of several thousand feet below their original level. On the other hand, Blanchard (1947), in his discussion of the Tennyson tin pipes, states that the sulphides, which are intimately intergrown with the cassiterite, do not show any preference for any part of the lodes, and he considered that the sulphides and the cassiterite were precipitated simultaneously.

The tungsten-molybdenum-bismuth deposits of Wolfram Camp and Bamford Hill are situated in greisenized granite cupolas which have only recently been uncovered by erosion, as is evidenced by remnants of the original sedimentary and volcanic cover on some of the granite tops at both Wolfram Camp and Bamford Hill. The irregular pipe-like bodies have been puzzling features since their first discovery. Cameron (1904) thought that the pipes were formed where joints intersected. Ball (1920) envisaged magmatic stoping along joint intersections, followed by introduction of colloidal silica and, later, of ore metals precipitated from fluids and vapours. He illustrated with a diagram how the tortuous pipes might have been developed along such joint intersections. Jones (1943) favoured igneous injection governed by the joint systems, followed by replacement. MacKinstry (1955) concluded from the description of the pipes by Blanchard (1947) that '. . . it is difficult to explain these pipes as other than the results of corrosion followed by filling and replacement accomplished by fluids (whether liquid or gaseous) originating from the granite and making their way upwards'. Whatever the process, the pipes are unique orebodies in the combination of shape, increase of sulphides with depth, and the clearly evidenced precipitation of wolfram later than molybdenite. In the diagram (Fig. 9) the pipes are tentatively placed in the hypothermal group because of the presence of tourmaline, bismuthinite, topaz, fluorspar, and pyrrhotite, and the greisenous wall-rock alteration.

The deposits south-east of Petford appear to be a mixed collection of hydrothermal tin, wolfram, fluorspar, silver-lead, and copper lodes. They are possibly associated with important north-south fault systems, the existence of which has been inferred from photo-interpretation and stratigraphical considerations.

Among the remaining groups scattered over the area are the Khartoum molybdenum-quartz veins; the Fluorspar gold and fluorite veins; and the Lappa Lappa silver-lead and tin veins north-west of Bamford Hill.

The mica-pegmatite deposits at Mount Kitchin are the only examples of deposits that are not associated with the Permo-Carboniferous granite intrusions. They are an extreme result of the pre-Silurian metamorphic-metasomatic processes and associated pegmatite intrusions in parts of the Dargalong Metamorphics.

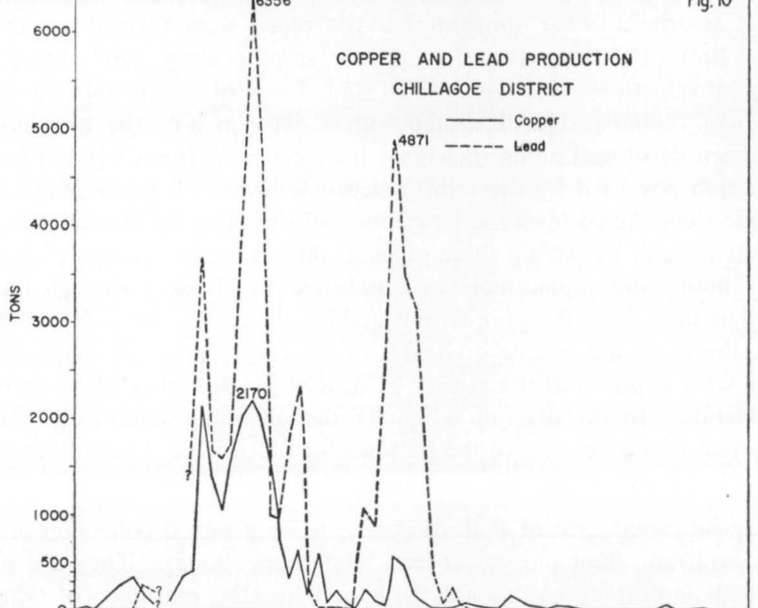
DESCRIPTION OF MINES

In the following pages, bracketed numbers after the names of mines refer to the Mine Locality Index (Appendix 1) and to the Mine Locality Map (Plate 13). All mines located during our field work in 1958 are briefly described, and references are given for further detail. The great majority of the workings have collapsed or are water-filled, and are now inaccessible.

Copper, Lead, Silver, Zinc

The copper and silver-lead deposits in the Chillagoe district have generally been given the most attention throughout the years, though quantitatively their aggregate yield is small compared with that of other mining centres in Australia.

Many of the lodes contained a mixture of lead (silver) and copper minerals in varying proportion, from almost lead-free ore (Ruddygore) to copper-free

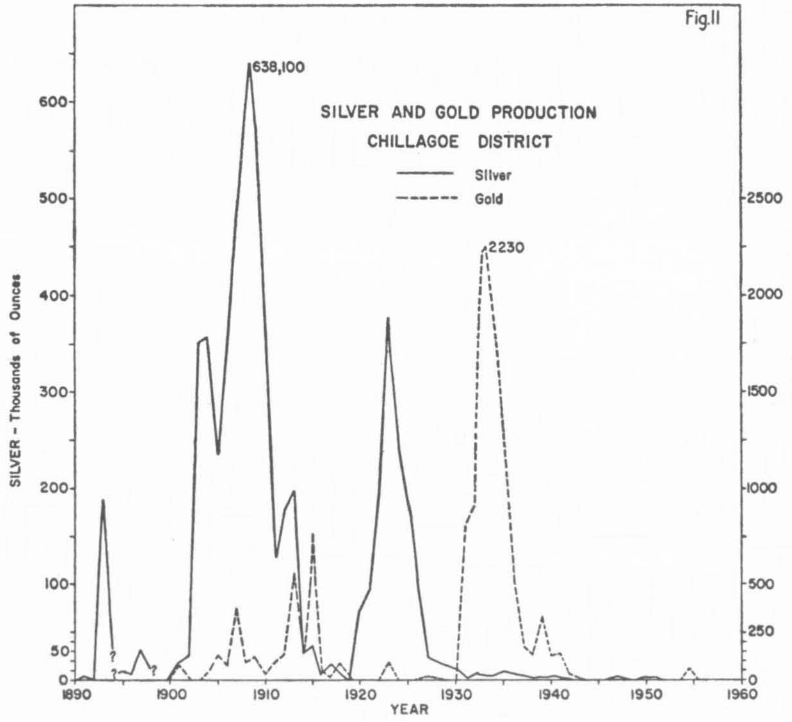


silver-lead ore (Torpey's Crooked Creek). Most of the lead ores carried increasing quantities of sphalerite in depth, and the copper lodes generally contained some bismuth as an impurity. As the smelters could not separate the zinc, large quantities were wasted during treatment.

Initially the grades of ore were high: in 1896, for example, ore from the Harper and from the Lady Jane contained 25 percent copper, from Ruddygore 20 percent copper, and from the Christmas Gift shaft as much as 40 percent copper.

The hundreds of shows and workings in the area are concentrated mainly in the region between Almaden and Mungana-Redcap, and around Cardross. Most of the workings were small, disconnected, and shallow. Greatest production has come from the Mungana lodes, which were responsible for about one-third of the total production of copper, and for two-thirds of the total of lead and silver.

Most of the mines have been fully described by Jensen (1941), after detailed geological mapping of the area by the Aerial, Geological, and Geophysical Survey of North Australia. Individual reports by geologists of the Geological Survey of Queensland have appeared from time to time in official publications. Several private companies, and E. Broadhurst, consulting geologist, investigated most of the important deposits after the war, in particular those in the Redcap and Mungana areas and at Ruddygore. A list of plans and sections of the various workings, kept in the offices of the Geological Survey of Queensland, is given in Appendix 2.



Mungana Area

(Jack, 1891, 1898; Poole, 1922; Jensen, 1920b, 1941; Broadhurst, 1952, 1953)

The Mungana mines are aligned along a zone extending for about 1½ miles from Mungana to the south-east, parallel to the general strike of the sediments, and include the Girofla, Lady Jane, Dorothy, Griffith, Magazine Face, and a number of smaller workings.

Total production has been 31,831 tons of lead, 7907 tons of copper, and 3,228,600 ounces of silver from 333,591 tons of ore (Broadhurst, 1953). The average recovery grades can thus be taken as being 9.6 percent lead, 2.35 percent copper, and 9.7 ounces of silver per ton. The Girofla and the Lady Jane were the outstanding producers.

The lithological units in the Mungana mineralized zone consist of the limestone, quartz greywacke, chert, chert breccia, siltstone, and sandstone of the Chillagoe Formation, and possibly some basalt flows, but the detailed geological picture is complicated by faulting, folding, stratigraphic lensing and tonguing, and extreme alteration in places. Rhyolitic and possibly doleritic dykes also occur.

There is much confusion about the true nature of the lodes and, in particular, about the origin of the pipe-like deposits at the Girofla and Lady Jane mines (see also page 23). Many outcrops are so strongly brecciated, silicified, or altered to soft, clayey material that the original rock type cannot be recognised. Most of the breccias and some of the other rock types are considered by Broadhurst (1952) to be volcanic, whereas Jensen (1920b) regarded them as crush breccias.

Jack (1891) and Skertchly (1897) were convinced that some of the lodes (Griffith, Girofla) were mineralized cave deposits in limestone. Jensen (1920b) originally thought of a south-east-trending fissure lode with a number of mineralized branches dipping into the main fissure and controlled by joints dipping north-east. He revised his opinion somewhat in 1941, after more information had become known, and considered the Mungana belt as a 'fairly wide fractured zone' within which the rocks had been broken into blocks with differing attitudes and had been subjected to considerable minor faulting. Broadhurst (1952, 1953) believed that the lodes occur in a line of breccia-filled volcanic vents or diatremes; during our 1958 survey, however, no proof could be found for this hypothesis, and Jensen's explanation is probably nearest the truth (see also page 23).

Factors that led to the closure of the mines included: excessive influx of water, difficult stoping ground, low grades in the bulk of the ore, fires at the Lady Jane, closure of the Chillagoe smelters, and, naturally, exhaustion of the higher grade ores.

Since 1930 some private companies, smaller syndicates, and the Federal Government have investigated the area geologically, geophysically, and by drilling, in order to re-assess its potential, but results were not sufficiently encouraging to warrant re-opening of any of the mines. In 1930 electric prospecting methods were employed by the Imperial Geophysical Experimental Survey in the Griffith* area (Broughton Edge & Laby, 1931, pp. 127-134), and four drill holes were put down to depths between 150 and 200 feet. Broken Hill South Ltd investigated the Mungana area geologically from 1947, and in 1948 requested the assistance of the Bureau of Mineral Resources. This was given in the form of a geophysical survey in the Mungana, Redcap, and Zillmanton areas in 1949, during which electromagnetic, magnetic, and self-potential methods were used (Langron, 1957). In the Mungana belt the only electromagnetic indications (and those weak) were confined to the Lady Jane sector, where some well-defined anomalies were due to mineralization or to the presence of a ferruginous clay and 'ironstone' zone: test drill holes on the 1930 anomalies near the Griffith had encountered only such ferruginous clay and ironstone and little or no mineralization.

In 1956 and 1957 the Chillagoe Prospecting Syndicate put down some drill holes on Moffats Hill and on the Griffith Lease.

Girofla (23, a) (Jensen, 1941; CSIRO, 1952; Broadhurst & Edwards, 1953).

The Girofla mine, which lies nearest Mungana on the north-western end of the zone of workings, was the biggest single mine in the Chillagoe district. It has produced an estimated 220,000 tons of ore (Broadhurst & Edwards, 1953), which, judging from the reported average recovery grades, should have yielded 29,600 tons of lead, 5900 tons of copper, and 1,750,000 ounces of silver. The mine was discovered in 1888 and worked until 1914. From 1920 to the closure of the smelters in 1926, the mine was worked by the State Government. Operations started from two or three open cuts, but before long a shaft was sunk which ultimately reached a depth of 823 or 840 feet, and levels were developed at 100, 200, 300, 410, 510, 610, 710, 810 feet.

The lode consists of three vertical pipe-like bodies, two of which cropped out at the surface as siliceous and ferruginous cappings originally called the North Blow and the South Blow (Jack, 1891). These two pipes, which had a diameter of 20 to 30 feet at the surface, broadened at depth, and joined together at about 150 feet. The composite pipe had its maximum diameter of 250 feet at the 410-foot level, but narrowed again to approximately 60 feet farther down. A fourth orebody (North Lode) was discovered in 1921 at the 100-foot level and was worked down to the 400-foot level.

The pipes are filled with chert breccia with a clayey matrix, which was silicified at the surface. The upper three levels yielded mainly flux ore. At 410 feet large quantities of secondarily enriched copper-lead ore were mined, and from the 510-foot level downwards lead sulphide ore was worked.

The mineralization of the Girofla lodes has been described by Broadhurst & Edwards (1953), who report that the primary ore consisted of abundant pyrite, pyrrhotite, and marcasite, lesser amounts of galena, sphalerite, chalcopyrite,

* 'Griffith' in the older references, 'Griffiths' in many of the later ones.

jamesonite, and tetrahedrite, and sparsely distributed arsenopyrite and stannite, in a sideritic gangue. Copper had largely been leached from the upper three levels, but lead had been accumulated in the siliceous ferruginous cappings as cerussite and a lead silicate, with an average grade of 26 percent lead. The average grade of the primary ore was of the order of 0.5 to 1 percent copper, 8 to 15 percent lead, 7 to 10 ounces of silver per ton, and 10 percent zinc.

At about the 410-foot level, strong secondary copper enrichment had taken place, with covellite and chalcocite replacing pyrite; ore from this level assayed 6 to 10 percent copper. The precipitating influence of the limestone wall-rock also caused some copper enrichment on the periphery of the copper-leached ores in the higher levels.

Microscopic work showed that the supergene ores were, in turn, partly oxidized to copper carbonates, cuprite, native copper, and limonite, owing to the downward movement of the groundwater level concomitantly with erosion (Broadhurst & Edwards, 1953). The presence of supergene sulphides at a depth of 400 feet, although groundwater level is only 30 feet below the surface, may be explained by the free water circulation afforded by solution channels in the limestone.

The Girofla is worked out as a copper mine. Possible reserves of lead ore below 800 feet in the pipe-like orebody with relatively small diameter are probably short of the minimum tonnage required for an economical re-opening of the mine, especially as water presents a mining problem at that depth.

Lady Jane (23, b)

The Lady Jane mine, in limestone less than half a mile south-east of the Girofla, was the second-largest producer at Mungana. Mining started in 1899, and the Lady Jane was a very important producer until 1909, when cave-ins and underground fires (caused by spontaneous combustion of the ore) disrupted activities. Attempts to extinguish the fires by flooding did not succeed because the high permeability of the limestone permitted the water to drain away and even to reach the Girofla shaft. The mine was finally re-opened in 1923 and worked by the State Government until 1926.

The total recorded production is reported to be some 102,000 tons of ore averaging 5.3 percent copper, 16.7 percent lead, and 12.2 ounces of silver per ton (Broadhurst, 1953). (But, if these figures are translated into metal, and added to the Girofla figures, the two together exceed the reported total for the Mungana area.)

Four shafts were sunk, the main one reaching a depth of 460 feet, and levels were driven at 60, 100, 150, 210, 290, 320, and 420 feet. The lode had the form of a small pipe at the surface (Jensen, 1941), and, at the 200-foot level, was 200 feet by 67 feet in size, elongated in a general south-easterly direction. The pitch was stated to be steeply to the south-south-west. Connected with the main lode were three smaller ones containing irregular bunches of copper ore.

Broadhurst (1952) described the Lady Jane lodes as being '. . . in the upper funnel-shaped part of a vent, which is elongated along the strike of the line of vents'.

High-grade (10 percent) copper carbonate ore persisted from the upper levels to a depth of about 150 feet, where it changed to good-grade lead sulphide ore veined by high-grade copper and copper-lead carbonate ore. The main lead sulphide orebody at this level carried about 9.8 percent lead, 3 percent copper, and 12 ounces of silver per ton, but owing to the numerous rich copper ore veins, two to four feet thick, throughout the lead ore, the Lady Jane was generally regarded as a copper mine.

Between the 290 and 320-foot levels the ore contained 3 percent copper, 18 percent lead, and 10 ounces of silver per ton, and at 320 feet was enriched in supergene copper sulphides. This high-grade ore, carrying about 13 percent copper, was mined from stopes above the 420-foot level.

Below the 150-foot level it was possible to mine copper and lead from separate stopes in separate operations; in other parts of the mine the ores were mixed and were mined simultaneously.

Other Mines

The other workings in the Mungana area have not contributed much to the total production, and have reached only shallow depths.

The *Dorothy* mine (23, c), about 2000 feet south-east of the Lady Jane, is one of the oldest mines in the Chillagoe field. Mineralization occurs in coarse-grained garnet-calcite rock, but only the enriched surface ore has been mined, the primary ore—at a depth of about 50 feet—being generally below economic grade. Moreover, the lode was much faulted at depth. The old main shaft, now fallen in, started from an open cut and reached a depth of 165 to 200 feet, revealing orebodies at the 50-foot and 100-foot levels averaging 5 percent and 10 percent copper respectively. The ore occurred largely as nodules of azurite and malachite containing some copper oxides, and in the primary zone as disseminated chalcopyrite and bornite. Basalt crops out on the north side of the lode, and contains some veinlets and granules of native copper (CSIRO, 1955b).

Griffiths Hill (23, i), also one of the earliest workings in the field, is about 2400 feet south-east of the Dorothy mine, and comprises an open cut and several small shafts, the deepest of which, Griffith No. 1, went down to 220 feet. The open cut, 300 feet long by 150 feet wide, and about 80 feet deep, was worked for cupriferous iron flux (Jensen, 1940); it appears to lie on a branch (lode) of Jensen's main fissure zone, and strikes 070°. The ore at the surface consisted of nodules of copper carbonates in a siliceous ferruginous breccia, and was locally concentrated into rich pockets near a limestone lens. An intrusive body of quartz porphyry was exposed in the open cut.

The Griffith No. 1 Shaft was connected with the *Calumet* shaft (23, h) by means of a cross-cut driven 538 feet north from the 200-foot level. At the Calumet the ore occurred in bands of ironstone, up to three feet wide, containing nodules of malachite and cuprite.

The *Malachite* lode, 300 feet north-east of the Griffith open cut, and the *Nordville* (23, g), north-west of the Griffith, are two small interconnected workings on probably the same fault, and have yielded a few tons of rich copper ore whose grades ranged up to 15 percent, and, in one parcel, even 49 percent copper.

The Magazine Face open cut (23, f), on an east-west garnetiferous or ferruginous branch of the lode that extends from the Dorothy to Griffiths Hill, yielded ore assaying up to 12 percent copper. The ore consisted mainly of boulders of copper carbonate and chalcopyrite in soft, clayey gangue.

The *Red Dome* (23, e) is a hill south of Magazine Face, and between the Dorothy and the Griffith workings. Mineralization occurs in a jasperized breccia near its contact with a much-weathered porphyry. Many small shafts and costeans have yielded some cupriferous iron flux. Gold values ranging up to 7 dwt per ton were reported from some of the workings.

Many other small workings—e.g., the Hookworm, Moffat's, and Kaolin—yielded small quantities of cupriferous flux ores.

The *Red Hill* (or Ben Nevis?) (14) and the *Jubilee* (13) are small, isolated prospects, one 2½ and the other 4 miles north-west of Mungana, and are located on ironstone lodes in the contact zone around an intrusive microgranite porphyry. Surrounding calcareous sediments have been converted to calc-silicate rocks. The Red Hill shaft was more than 100 feet deep. At the Jubilee, malachite and chrysocolla were noted in ironstone and epidote-rich calc-silicate rock. No records of the production of these workings are available.

Redcap Area

(Morton, 1926b; Jensen, 1941; Broadhurst, 1952.)

The Redcap area (22), though larger than the Mungana area and containing more workings,, has never reached the same prominence in production.

The first lodes were known as early as 1888, and some rich secondary ores near the surface were mined until 1909; in later years the mines produced mainly flux ores. Output figures are very incomplete, as the smelter records did not show the sources of the ores. From what is known, it seems that even the most extensively worked mines—the Penzance, Queenslander, and Morrison—did not produce more than a few thousand tons of ore.

In 1949, geological and geophysical surveys were carried out in the Redcap area as part of the same programme that covered the Mungana area (Langron, 1957) (page 65). Geophysical methods (mainly electrical) were employed on both sides of Mount Redcap, and two sites were recommended to test an electromagnetic anomaly that might be due to mineralization; the axis of this anomaly trends from the Redcap opencut to the north-west, parallel to the Redcap fault. Drilling was carried out by Broken Hill South Ltd. the next year.

Earlier, in 1930, the Imperial Geophysical Experimental Survey had investigated the Redcap-Morrison line of mineralization by means of equipotential line and A.C. potential ratio methods, but follow-up drilling on recommended sites was soon abandoned because of poor results, and technical difficulties.

The Chillagoe Formation, in which the workings are located, here consists of intertonguing and lensing beds of limestone, calc-silicate rock, chert and chert breccia, basalt, limestone-conglomerate, quartzite, and conglomerate. A well-defined fault, forming the locus of the Redcap lode, separates the sediments from a hilly area of quartz-feldspar porphyry to the north-east. Hornblende-biotite adamellite and granodiorite have intruded both sediments and porphyry, forming calc-silicate rocks, and crop out to the north-west and south-east of the Redcap lodes. The origin of the breccias has been discussed on page 23.

There are several lode systems, the more important of which strike north-west.

The Redcap lode is the largest in the area; it more or less follows the Redcap Fault, and includes the Redcap mine (22, a), the Queenslander (22, b), and the Morrison Shafts (22, c), besides a few smaller workings. The orebodies are on the main fault or on secondary shears parallel to it; they dip about 45° south-west. At its north-western end the lode outcrop is 40 to 60 feet wide in garnet-ironstone, but its width decreases to the south-east; between the Queenslander and the Morrison shafts it is only 10 to 20 feet wide, and about 1000 feet south of the Morrison its place is taken by a chert band sandwiched between limestone and siltstone. The total length of the lode is nearly 7000 feet, and workings extend over about 3000 feet. Some short branches or ironstone take off from the main lode at angles of 45° to 90°. Brecciation is very common, and is particularly well developed at Mount Redcap, which had been regarded as an extinct volcano by Jack (1891), and as a diatreme by Broadhurst (1952). The type of mineralization seems to change from lead in the north-west to copper (mainly) in the south-east.

The *Redcap* mine (Morton, 1926b), probably discovered in 1891, was largely neglected until 1926. The original lease yielded lead ore with high silver values, but the lodes were small and irregular, so that mining remained spasmodic and on a very modest scale. In 1926 the lease was taken over by the State Government; an orebody 230 feet long and with an average width of 50 feet was proved, and a second low-grade orebody, apparently separated from the first by a strip of barren breccia, was found on the north-eastern side of the hill. A tunnel was driven south-east for 220 feet, 185 feet of which were in ore, and an open cut above the tunnel showed a width of 25 feet of ore. Other workings include a main shaft at least 150 feet deep, and another adit driven for 95 feet north-west.

The average lead content was 6.7 percent, but silver values were surprisingly low, generally considerably less than 1 ounce per ton. Ore reserves, assuming an average vertical extent of 64 feet for the orebody, were estimated at 40,000 tons. In 1926 and 1927, 3535 tons of ore yielded 240 tons of lead and 175 ounces of silver, but the closure of the Chillagoe smelters put an end to all activities. Broken Hill South Ltd included Redcap in their geological exploration programme between 1947 and 1951; more than 1400 feet of drilling showed the orebody to be a shallow structure pitching to the south-east and terminating against underlying porphyry.

The lode material is dark-brown to black, massive, siliceous, ferruginous, and manganiferous, and is commonly brecciated. Cerussite is disseminated through the lode as fine crystals, and a little galena, minium, and massicot were also noted. Pyromorphite occurs in occasional narrow seams, and in manganese-rich portions lead manganate has been reported. An ore sample from the face of the main tunnel at 125 feet assayed (Morton, 1926b): 12.6% Pb, 0.1 oz./ton Ag, 36.4% FeO, 15.0% MnO, 0.5% Zn0, and 11.0% insoluble.

The *Queenslander* (22,b), about 1000 feet south-east of Mount Redcap, was apparently worked for both copper and lead, but very little information is available, and the mine was closed in 1903. As usual the first tonnages were rich surface ores, whereas later yield consisted of flux ores. The mine had several shafts, now caved in. The main or Queenslander shaft was probably more than 200 feet deep, and had levels at 100, 117, and 200 feet. The ore from this shaft consisted of low-grade sulphides containing 1 to 2 percent copper; the No. 1 shaft traversed massive pyritic ore assaying 1 percent copper and 1 ounce of silver per ton, and containing small amounts of galena. From the bottom level of the Queenslander shaft the footwall was explored by a crosscut 600 feet to the south-east. Drilling to a depth of 700 feet revealed sulphides of zinc and other metals in garnet rock; the copper content of the ore ranged up to 1.5 percent. Galena, cerussite, sphalerite, and copper carbonates were noted in the dumps.

The original workings at the *Morrison* (22, c), some 2000 feet south-east of the Queenslander, were known as the 'Queenslander lead shaft', but were worked for copper after they were re-opened in 1899 by Chillagoe Railways and Mines Ltd. The mine was renamed the Morrison in 1905, and an orebody 440 feet long was proved to a depth of 120 feet, partly by drilling. Some 2000 tons of secondarily enriched ore were taken out below this level in 1908. Values at the 180-foot level ranged between 1 and 2 percent copper, but were somewhat higher at the 250-foot level. The deepest level was at 350 feet. The lode narrowed from about 15 feet at the surface to about 3 feet in depth; the footwall was a silicified schist or chert, and the hangingwall was limestone. By the time the mine closed down in 1909 the lode had been explored over a length of 700 feet.

The Penzance-McIlwraith lode system, one half to three-quarters of a mile south-west of the Redcap-Morrison line, follows another relatively important shear-zone. The system consists of two parallel lodes, six to eight feet wide and 120 to 150 feet apart, extending over three-quarters of a mile and striking south-east. The main, or western, lode dips 70° north-east, and contains the *Puppet* (22, e), *Cambourne* (22, f), and *Penzance* (22, g) workings; the eastern lode dips steeply to the south-west and contains the *McIlwraith* mine (22, g). The lodes occur in limestone, and are separated by fine-grained cherty basalt; garnet and ironstone replacements form the bulk of the intervening material in the Penzance-McIlwraith area. The mines were mainly worked for copper, though some lead ore was present, and a little cobalt was also found.

The *Penzance* and *McIlwraith* workings (22, g) are close together, and are connected by a crosscut at the 150-foot level. Their main shafts have been obliterated by three large open cuts: the Penzance (330 feet long, 100 feet wide, 100 feet deep), the McIlwraith, and the Magazine. The Penzance was one of the first mines opened in the Chillagoe district: in 1888 a lode, 400 feet long and 80 feet wide, was reported to have contained up to 40 percent and even 75 percent copper. The first yields came from carbonate ore with an average content of 4.5 percent copper and 4.5 ounces of silver per ton. Later flux sulphide ore assayed about 2 percent copper and 2 ounces of silver per ton. The deepest shaft went down to 200 feet. The McIlwraith lode was smaller and of lower grade than the Penzance, and had a main shaft 250 feet deep.

The *Cambourne* (22, f) contained a number of shafts, the deepest of which was 150 feet, and is better known for its cobalt mineralization (see page 117).

Other, smaller, workings on this lode system were the *President* or *Puppet* (22, c), the *Nellie* (22, h), and the *Belgravia*.

The Victoria lode (22, d) is a branch of the Redcap lode and dips 60° to the west (Jensen, 1941). It strikes north-south over a distance of 600 feet, and contains the *Victoria,* the *Tarantula* (perhaps originally spelt 'Triantular), and *Boulder* workings. The footwall is limestone and the hangingwall chert breccia. The mines were worked for either copper or lead in different sections. Franklinite associated with sphalerite was recorded from the Victoria.

Jensen (1941) mentioned another small lode—the West Victoria lode—on the western bank of Redcap Creek and west of the Redcape lode. Numerous shallow shafts and pits are aligned over half a mile on a gossan line 10 feet wide in this locality.

Ruddygore (25)

(Jensen, 1941; Broadhurst, 1949; Branch, 1960)

The *Ruddygore* orebody, situated two miles north-east of Chillagoe within a metasomatized granodiorite differentiate of the Almaden Granite, differs from all other copper lodes in the district: it is a disseminated, low-grade deposit of the so-called 'porphyry-copper' type. This was not recognised by the earliest investigators; both Skertchly and Jack, for instance, described the orebody as being in a porphyry dyke cutting the granite.

The workings include two open cuts and four shafts, the deepest of which reached 350 feet. Drives or levels existed at 100, 125, 225, and 325 feet, but production was confined to the 125-foot level and above. The largest open cut was 450 feet long and 80 feet wide, and in 1908 reached a maximum depth of 130 feet. Numerous small shafts and pits were found about 1000 feet south-east of the main Ruddygore workings.

From 1896 to its closure in 1909 the mine produced about 32,750 tons of handpicked ore for a yield of 1450 tons of copper. With the exception of the first 1100 tons of rich ore, the average grade of mined material was estimated at 1.5 percent copper, but the ore produced was handpicked to a grade of about 3.9 percent copper. The production figures again are incomplete, as they were often included in the aggregate smelter returns.

Three diamond drill holes were put down in 1907; one of them, extending 304 feet from the bottom of the No. 1 Open Cut, assayed 13.8 percent copper and 1.6 ounce of silver per ton over a three-foot length of core, probably from the enriched zone near the 100-foot level. From 1947 to 1949 Broken Hill South Ltd put down eight churn drill holes into various parts of the main metasomatized orebody, and three holes into a supposed extension, to depths between 8 feet and 60 feet. Copper values in these holes were generally less than 0.15 percent, the highest assay being 1.33 percent copper in a five-foot section. Mount Isa Mines Ltd put down nine diamond drill holes in the same general area in 1960. These holes were drilled to depths of between 170 and 304 feet. Six holes contained trace values only of copper mineralization. Values in the other three holes were: 36 feet of 1.25 percent Cu, 41 feet of 0.38 percent Cu, 38.5 feet of 0.41 percent Cu.

In 1959 the Bureau of Mineral Resources carried out a geophysical survey of the mine area (Horvath, 1959), which at the same time was mapped in detail (Branch, 1960) in order to aid the interpretation of the geophysical results. The following year W. B. Dallwitz and W. R. Morgan, of the Bureau of Mineral Resources, searching for evidence of other possible deposits of the Ruddygore type in the surroundings, outlined several bodies of highly leached ferruginous metasomatized granodiorite. The largest body of metasomatized rock found was estimated to contain about 500,000 tons per vertical foot, but only sub-surface testing can show whether economic mineralization exists in these bodies.

Branch (1960) recognised five varieties of granitoid rocks in the Ruddygore area, as determined by the relative proportions of quartz, hornblende, and biotite; their boundaries are gradational. They are intruded by leucocratic microgranodiorite (Broadhurst's 'aplite'), which has been considered to be the cause of metasomatism of part of the granodiorite and ultimately of its mineralization.

The mine is situated at the northern end of the largest mass of metasomatized granodiorite, which trends 335°, and crops out over a length of 1800 feet and a width of 400 feet. The degree of metasomatism increases towards the centre of the body. First signs are an alteration of the mafic minerals to epidote and chlorite, leading to an aggregation of bleached chlorite in fibrous clusters. The feldspars become cloudy, and orthoclase and some of the plagioclase are finally replaced by massive sericite.

The trends of the metasomatized zones follow the main vertical joint directions in the granodiorites (065° and 335°); a third, nearly horizontal, joint system is confined to the metasomatized areas, and was considered by Broadhurst (1949) to be one of the main controls of ore deposition.

The orebody is associated with stockworks, breccias, or areas characterized by a network of fine cracks that are the result of shattering of the rock around the microgranodiorite intrusion, either because of mineralization stoping, as advocated by Broadhurst, or because of active upward pushing by the micro-granodiorite, as suggested by Branch. Broadhurst describes the texture of the ore deposits as '. . . a system of anastomosing quartz veinlets averaging 2 inches, and up to 6 inches, wide, forming a network with a mesh of 2 or 3 feet.' Jensen (1941) stated that the ore occurred as nodular segregation masses, ranging from many feet in diameter to minute specks.

Except for the generally leached surface, the upper 40 feet of the deposit contained mainly copper carbonates, changing to chalcopyritic ore at greater depth. The richest ore, bulking 5 percent copper in places, was found in an underhand stope below the 100-foot level, where chalcopyrite was accompanied by probable bornite, and where secondary enrichment is thought to have taken place. These relatively rich ores terminated just above the 125-foot level, and at greater depth only very low values were found.

Zillmanton (24).

(Jensen, 1941; Branch, 1960.)

The *Zillmanton-Shannon* copper lode, from 2½ to 4 miles west of Chillagoe along the Chillagoe-Mungana railway line (Pl. 14), is the most persistent single lode in the Chillagoe district, and seems to occupy a faulted contact zone between Almaden Granite on the north and limestone to the south. The main workings were in the 3000-foot long eastern or Zillmanton part of the lode. In the 500-foot western or Shannon part, which has been displaced by step-faulting over a total distance of about 1000 feet to the south of the Zillmanton section, only shallow shafts were sunk and these have contributed little ore.

Work started in 1899, and during the years 1903 and 1904 Zillmanton was the largest mine in the district. Production figures again are not precisely known, as the output record was included in the Chillagoe Smelter's returns for the whole district, but the total figure is thought to have been in the vicinity of

35,000 tons of ore with an average grade of 4 percent copper. In 1910, 97 tons of copper and 3200 ounces of silver were obtained from 2253 tons of ore, and in 1911 the production consisted of 250 tons of copper and 8706 ounces of silver from 6306 tons of ore. Many difficulties arose from the soft, clayey nature of the ground (which allowed the shafts to warp under pressure)' and from the tremendous influx of water: pumping at a rate of 1,500,000 gallons per day in 1908, for instance, had very little effect, and the workings were frequently flooded. These difficulties on top of low metal prices and the lack of capital (the available money was spent on newly discovered mines outside the district) finally led to the closure of the mine in 1912, although according to reports some 25,000 to 30,000 tons of proved ore with a grade of 4 to 5 percent copper were still at hand.

Since 1913 a number of mining companies have held Authorities to Prospect over the area, but no development has been attempted. The Bureau of Mineral Resources carried out a geophysical survey over the Shannon lode in 1949 (Langron, 1957), and, combined with detailed geological mapping, over the Zillmanton section in 1959 (Branch, 1960). Of the methods employed only the electromagnetic readings indicated well-defined and, in places, strong anomalies, one of which coincides approximately with the inferred granite-limestone contact, another with a line of lode outcrops (Pl. 14). The axes of the anomalies probably indicate steeply-dipping shear zones made conductive either by their content of mineralized water, or by sulphide mineralization and magnetite. The anomalies extend for more than 8000 feet, in part over alluvium-covered areas where little prospecting has been done; testing by drilling is consequently warranted.

The lode, which strikes east-west and dips 55° to 70° to the south, can be traced for about a mile as a line of siliceous-ferruginous outcrops ranging in width from 20 to 60 feet, though the spread of rubble is much wider. A surface crust of travertine is in many places associated with the ferruginous rubble, and is possibly a residual from the weathering of a calcite-garnet-magnetite rock similar to that found in pits west of the Zillmanton area (Branch, 1960). The lode runs parallel with, and close to, the granite-limestone contact. In depth the lode is mainly a brecciated, siliceous garnet-hematite mixture with a troublesome hangingwall of soft clay or pug 30 to 100 feet wide, and a footwall in kaolinized granite. The best values Jensen stated to have been associated with the kaolinized footwall; the hangingwall carried scattered nodules of secondary copper minerals. In the underground workings the lode was intersected in several places by dykes or tongues of granite. The upper 100 to 200 feet of the lode contained mainly carbonate ore, and in the deeper levels the ore was predominately chalcopyritic.

In the Zillmanton section two main orebodies were opened up: a western body, about 140 feet long and 4 to 6 feet wide, worked by the Reid shaft; and an eastern body, about 270 feet long and 6 to 18 feet wide, and worked by the No. 1 and No. 2 Shafts. The Reid Shaft reached a depth of 376 feet, and bottomed in unpayable ore. It had drives at 200 and 300 feet. The No. 1 and No. 2 Shafts were both sunk to a depth of 350 feet, and levels were established at 100, 160, 250, and 350 feet. The shafts were connected via the 160 and 250-foot levels. When the mine closed in 1912 some 25,000 to 30,000 tons of proved ore assaying 4 to 5 percent were said to remain in the lower levels, and according to Jensen (1941) the grade improved in places on the bottom level.

Calcifer Area (27)

(Jensen, 1941)

The Calcifer group of mines, situated about 5½ miles south-east of Chillagoe, includes the Boomerang, Hobson, Harper, and Five Chain Bend workings, and was one of the first groups opened up in the Chillagoe field. By 1894, when the Calcifer smelters were opened by the Irvinebank Mining Company, the company had in the Boomerang Mine one of the district's main ore suppliers. The mines were first worked for some rich carbonate ore at the surface, but later, when the grades fell to 1 and 2 percent copper, only flux ore for the Chillagoe smelters was produced. From Warden's Reports and other sources a total production from the group of 26,450 tons of ore has been inferred, for a yield of 1555 tons of copper, 20,400 ounces of silver, and about 44 tons of lead-silver bullion.

The lodes are contact-metasomatic deposits in roof-pendants of the Chillagoe Formation within, and irregularly intruded by, the Permo-Carboniferous hornblende-biotite adamellite and granodiorite. The sediments are transformed into marble, chert, hematite/magnetite and garnet rocks, and quartzite. Much of the first production came from a surface accumulation of hematite-quartz boulders rich in cuprite, native copper, and carbonate.

The *Boomerang* (27, c) was worked in a 300-foot wide contact zone, dipping 45° south-south-west, at the junction of the granodiorite on the north and an embayment of altered limestone on the south. The lode-material was generally a garnet rock (Skertchley's 'eclogite', 1897) grading into siliceous hematite-magnetite rock containing veins and nodules of copper ore and, in places, stringers of cerussite. Large quantities of flux ore, with grades ranging from 1 percent to 4 percent copper, were supplied from this mine. Workings included open cuts, the largest of which was reported to have been 300 feet by 240 feet by 70 feet deep, and several shafts and pits.

The *Hobson* lode (27, d) lies about three-quarters of a mile east-north-east of the Boomerang and consists of garnet rock, siliceous ironstone, and much magnetite. Granite is exposed in an open cut 170 feet long, 80 wide, and 60 feet deep; its contact dips about 30° to the north-east. A shaft close to the open cut entered granite at the 100-foot level; an easterly drive at the 150-foot level first penetrated 30 feet of chalcopyritic ore at the contact zone, and then passed through magnetite, which gradually gave way to garnet rock before the limestone was entered.

The main *Harper* workings (27, f) are situated about 3300 feet east-south-east of the Hobson on what may be described as a faulted contact lode with a north-south strike and a dip of 55° to the west. Granite is exposed on the eastern side, and altered limestone on the western side of the lode, which is about 1½ miles long and generally brecciated. Numerous workings are aligned on the lode; the most important are several shafts 200 and 300 feet deep, and an open cut 160 feet long, 85 feet wide, and about 90 feet deep.

Levels in the shafts at depths of 110, 150, and 200 feet passed through more than 100 feet of lode material containing ore nodules consisting principally of malachite, cuprite, and chalcopyrite in an envelope of ferruginous clay, kaolin, and ironstone.

Broadhurst (1953) described the Harper as being situated in a tongue of tuffs and volcanic breccias, with a synclinal structure that was 'probably formed in association with a volcanic vent'. Jensen (1941) considers that the Harper structure is a down-thrown wedge of contact rocks. We are inclined to the same view on the grounds of photo-interpretation and the presence of a wedge of Featherbed Volcanics, which can be explained in this way without having to resort to the concept of a volcanic vent.

At the northern end of the Harper lode is the *Five Chain Bend* mine (27, e), which had three shafts. The ore was contained in a garnet-calcite gangue.

Chillagoe Group

(Jensen, 1920a, 1941)

Scattered around Chillagoe, and particularly in the area south-east of the township, are many workings and copper and lead prospects. They occur in the limestone and calc-silicate rocks of the Chillagoe Formation at or near their contact with the Permo-Carboniferous hornblende-biotite granodiorite intrusions that crop out extensively to the east and south of Chillagoe. Most of the deposits are of the contact-metasomatic type; some appear to be fissure lodes or faulted contact-metasomatic deposits. Among the more important mines are the Chillagoe Consols, Atherton, Christmas Gift, Lyonite Hills, Otho line, Little Hensey, Big Hensey, Fortunata, and Ti-tree.

The *Chillagoe Consols* (26, a), half a mile north-west of Chillagoe, was an important lead producer in the district, second only to Mungana mines. Output figures (incomplete) show a total of 30,500 tons of ore won during the period 1903-1926 for a yield of 450,000 ounces of silver and 6500 tons of lead. Peak periods of production were 1903, 1906-1909, and 1922-1923. By 1923 most ore above the 118-foot level was worked out, and winzing and drilling failed to intersect further shoots. After 1923 all production came from isolated and smali rich veins that remained to be mined above water-level.

Workings included an open cut and several shafts. The open cut was approximately 175 feet long, 75 feet wide, and 70 feet deep; the main shaft was sunk to a depth of 145 feet. The mine suffered repeatedly from copious influxes of water.

The deposit was probably a fissure lode striking north-west and dipping to the south-west, and was exposed at the surface as porous ferruginous outcrops, gossanous in places and containing cerussite and galena. Both hangingwall and footwall consisted of limestone. One of the main orebodies was 80 feet long and 15 feet wide, and was worked to a depth of 80 feet; it carried 29 percent lead and 18 ounces of silver per ton. Other rich ore shoots are reported to have contained between 15 percent and 48 percent lead, and from about 20 to 35 ounces of silver per ton. The average grade of all ore was about 20 percent lead and 15 ounces of silver per ton. Below 70 feet sphalerite became increasingly abundant.

The *Atherton* (26, c) lode, 1½ miles south-east of Chillagoe, strikes west-north-west, and was only 300 feet long. The lode is said to be in a shear which may pass into a contact lode at depth (Jensen, 1941). Granodiorite probably occurs at shallow depth in the workings—some was found on the dumps. Limestone crops out on the north side, chert breccia on the south side of the lode.

A few hundred yards to the north-east of the Atherton is the *Christmas Gift* (26, d), a sinuous north-dipping iron-garnet lode on the boundary between Permo-Carboniferous granite and recrystallized limestone and calc-silicate rock. Farther to the north-east in the same contact-zone are the workings of the *Lyonite Hills* (26, e): these are remnants of a roof-pendant in the granite and consist of brecciated iron-garnet deposits in recrystallized limestone. The Christmas Gift/ Lyonite Hills zone has been prospected by means of numerous shallow shafts, adits, and open cuts to a depth of 90 feet. The lode outcrops are diverse: some parts are very siliceous and high in silver content; others are manganiferous or sideritic; some are cupriferous garnet rocks; others are ferruginous and carry lead. Mineralization is patchy—the output came in small parcels of either high-grade lead ore or high-grade copper ore. One parcel is stated to have given 4000 ounces of silver. About 8500 tons of ore won from the Christmas Gift, between 1910 and 1927, yielded 27,700 ounces of silver, 500 tons of lead, and 85 tons of copper. Rich sphaleritic ore with up to 40 percent zinc existed but was disregarded for lack of demand and smelting facilities.

In one of the Lyonite Hills lodes a new lead mineral was first discovered: Chillagite (or Lyonite). It is a yellow to brownish molybdo-tungstate of lead with the formula $3PbWO_4$, $PbMoO_4$.

The *Otho* line of lode is a 50 to 300-foot wide garnetiferous belt running from a point half a mile east of the Chillagoe railway station in a south-easterly direction about two miles along the contact between limestone and granite. The lode is composed of garnet, hematite, and jasper. Workings are concentrated mainly in the north-western part of the lode and consist of numerous fallen-in shafts. No production figures are known, but silver and lead were the main metals produced. Jensen (1941) found a copious growth of the 'copper-plant' (*Polycarpea spirostylus*) from the central and south-eastern sectors, and he recommended diamond-drill testing of these areas as copper prospects.

The two Hensey lodes crop out between two and three miles to the south-east of Chillagoe. The *Little Hensey* (or *Upper Hensey*) line (26, h) is a contact-fissure lode in rough limestone country. The lode strikes north-west or west-north-west, dips steeply south-west, and is composed of quartz, jasper, and garnet. A tongue of granite intrudes the limestone near the southern extension of the lode. Workings extend for some 500 feet along a zone 5 feet wide, and include several shafts and an open cut. The greatest depth reached was 300 feet. The ore was bunchy and yielded lead, silver, and some copper. No production figures are known, but it is reported that ore won during the early part of the century assayed about 18 percent lead, 6 percent copper, and 17 ounces of silver per ton.

The *Big Hensey* (or *Lower Hensey*) line (26, i and j) is less than half a mile east of the Little Hensey and runs parallel to it. The lode, which is exposed for two miles along the granite-limestone contact near the Chillagoe-Almaden road, dips steeply south-west, and consists of a brecciated ferruginous quartz-jasper-garnet mixture; its southern part follows the curved contact to the *Fortunata* shafts (26, k), where the lode is widest and contains much garnet and vesuvianite.

Silver-lead and copper ore was won from a great number of shafts, mostly from the 75-foot level. Very little information is available on production figures.

The *Ti-tree* (26, g) is a large but low-grade copper deposit 2½ miles south-east of Chillagoe. Mineralization shows on three low hills, the centre one of which contains the main lode, exposed over a length of 1500 feet on the south-western edge of a roof-pendant in Permo-Carboniferous granite, striking north-north-west and dipping 40° to 60° east-north-east. It is a true contact-metasomatic deposit, with granite near the footwall and a garnet-limestone rock as hangingwall. The lode material is jaspery hematite-magnetite-garnet rock with 1 to 3 percent copper minerals. The garnet in places is very coarse and ranges up to 5 inches across. Large quantities of flux ore were supplied to the Chillagoe smelters, but the quality was poor owing to the predominance of garnet. The average recovery grade was 1 percent copper and 0.6 dwt of gold per ton; chemically the ore had an average composition of 31 percent SiO_2, 33.5 percent FeO, and 25.5 percent CaO. In 1941 Jensen estimated that 350,000 tons of flux ore were available, containing at least 3500 tons of copper.

Drilling in 1906-1907 revealed the occurrence of garnetiferous rock of variable thickness to a depth of 433 feet. One hole intersected a true thickness of 20 feet of garnet rock, the richest 5 feet of which assayed 2.9 percent copper, 0.6 dwt gold per ton, and 1.2 ounces of silver per ton.

Workings on the main lode include an open cut, measuring 200 feet by 60 feet by 40 feet deep, and several shafts, one of which reached primary ore. Production during the period 1923-1942 totalled 32,800 tons of ore for a yield of 400 tons of copper, 18,800 ounces of silver, and 1760 ounces of gold.

Muldiva Mines (35)

(Ball, 1914a; Jensen, 1923)

The Muldiva silver-lead and zinc mines are situated about 8 miles west-south-west of Almaden, on the north side of the Almaden-Tate road. Muldiva was one of the first mining centres opened up in the Chillagoe district: a smelter had been erected by 1891, but was dismantled in 1893 owing to a drop in metal prices. The mines were worked intermittently and on a small scale between 1893 and 1912, after which the Chillagoe Company Ltd acquired the leases and continued operations. The main period of production appears to have been 1909-1914; from 1917 to 1926 there was intermittent activity and moderate output until the closure of the Chillagoe smelters in 1927.

Total returns up to the end of 1926, compiled from Warden's Reports, amounted to about 19,000 tons of ore, yielding 315,000 ounces of silver, 1150 tons of lead, and 270 tons of copper. Apart from a few tons in 1924 and 1926 no zinc production was recorded, no doubt because of lack of demand.

In 1955 five diamond drill holes were put down by Metals Exploration Ltd to depths of 350, 156, 120, and 192 feet; assay values of intersected lode material were low.

The lodes appear to be contact deposits, in limestone and chert of the Chillagoe Formation, which are metamorphosed by Perma-Carboniferous adamellites cropping out in the immediate vicinity to the north, west, and south. Some of the calc-silicate minerals formed are garnet, wollastonite, actinolite, diopside, and epidote. Workings include the Eclipse, Paisley, New Moon, and Li-moon (or Ly-ee-moon), which occur in that order over a stretch of half a mile from the Almaden-Tate road north-west to the northern granite body. Known orebodies appear to be largely worked out, and further ore-shoots could be expected only at depth.

In general, the proportion of zinc in the ore increases with depth. Small quantities of bismuth in several of the ore-shoots spoiled the market value of the silver-lead ore, particularly in the Paisley mine. Cerussite and anglesite were the common ore minerals in the oxidized zone.

The *Eclipse* mine (35, a) occurs in a rock composed of garnet, calc-silicates, and brecciated quartz-hematite on a hill slope at the contact of granite (southern side of the hill, near the base) and metamorphosed limestone and calcarenite (top of the hill). Malachite, azurite, chrysocolla, galena, sphalerite, and pyrite are among the minerals found on the old dumps.

Two adits have been driven at heights 80 feet and 60 feet from the top of the hill, one in the direction of strike, the second across the strike. Other workings include two shafts, 60 and 80 feet deep, a winze to a depth of 165 feet, and an open cut 90 feet by 60 feet by 50 feet deep. Warden's Reports in 1926 mentioned the presence of an orebody 70 feet wide, 80 feet long, and 40 feet in depth, exposed in a winze from the top adit; it was stated that 10,000 tons of ore assaying 25 percent zinc were developed; for some reason, however, these 'did not break up to export requirements'.

The *Paisley* mine (35, b), about one quarter of a mile north-west of the Eclipse, is situated on a hill in metamorphosed limestone, calcarenite, and chert. The ore minerals occur in a garnet-calcite gangue; with increasing depth the association becomes pyritic and siliceous. One of the main workings was an open cut 170 feet by 120 feet by 50 feet deep, with a 160-foot deep shaft in the centre. Among the other workings are smaller open cuts, many shafts and prospect holes, and the Linedale Tunnel, which had a length of 300 feet. Rich silver-lead ores were taken out, in particular from the main open cut, but some of the output was rejected by the smelters because of the bismuth it contained.

An assay plan for 1914 shows values of 11.45 ounces of silver per ton, 13.95 percent lead, and 2.72 percent copper, over a length of 130 feet and a width of about 5 feet at the 150-foot level.

After the Paisley was taken over by the State Government in 1921 a new shaft was sunk to 150 feet; from then on there was intermittent activity until the Chillagoe smelters closed in 1927.

The *New Moon* orebody lies on the granite contact north of the Paisley and dips steeply to the south.

The *Li-moon* orebody, situated in the granite some 110 yards north of the Paisley, strikes east-west, and has a clayey gangue containing disseminated sulphide ore rich in silver but unfortunately also with a high bismuth content.

Cardross Area

(Ball, 1917a, 1918a)

The Cardross group of mines lies 20 miles west-north-west of Mungana, on the south side of the Mungana-Blackdown road. Originally known as the Klondyke or Bedford, the centre was called Arbouin before finally being designated as the Cardross group. Both Arbouin and Cardross were small settlements during the heyday of the area.

By far the most important workings were grouped on the so-called L-line (5) in a north-north-east-striking zone about 2 miles long and 1/3 mile wide.

Other workings sometimes included in the Cardross group are the Spaniard (6) and the Mountain Maid (7), respectively 4 and 6 miles south of Cardross; the Noonday leases to the south-west (not located during the 1958 field season); and numerous other small and scattered workings to the east and north.

The first leases were taken up in 1898 by Linedale's West Chillagoe Coy Ltd, which was merged with the Irvinebank Mining Co. in 1904. In 1907 this company withdraw from the field, and was succeeded by the Scottish North Queensland Exploration Co., which went into liquidation in 1911. Its leases were transferred to the Mammoth Copper Mine Ltd, a company floated in 1907. A copper blast furnace was installed at Cardross in 1912, and by 1915 mining had reached its peak with a production of 591 tons of copper, 769 ounces of gold, and 29,179 ounces of silver from 8090 tons of ore. After this, owing to difficulties imposed by World War I, production rapidly declined and within a few years the mines had all closed down. No figures are available for the years after 1918. The smelter, which had been in use for only a few short periods, was sold for removal in 1921. Several attempts to re-open some of the mines were made in later years, and a few tons of ore were won from 1932 to 1934.

The total recorded production has been of the order of 18,000 tons of ore for a yield of 2000 tons of copper, 2200 ounces of gold, and 87,200 ounces of silver. Very few figures are known for the early period up to 1909, because they were included in the total output for the Chillagoe district.

The lodes are distinguished from the rest of the Chillagoe copper deposits because they were emplaced in the gneiss and schist of the Dargalong Metamorphics, and are described by Ball (1917a, 1918a) as '. . . very irregular composite fissure systems . . . with the commercially valuable ores occurring bunched at intervals in an enmeshed series of fissures'. Particularly in the main area, or L-zone, the lodes form a network of intersecting veins and shears which generally dip to the west. In places the fissures are clean-cut and have fresh wall-rocks, but more commonly the lodes consist of sheared and altered zones which locally contain rich ore-shoots. The alteration consists of kaolinization, the formation of muscovite, and silicification—partly in the form of quartz-veining. Ferruginous caps are normally lacking on the surface outcrops, and gossans are rare: Ball considered that '. . . it is doubtful if, but for the relatively high gold values, any sinking would have been done on the formations'. The relative paucity of iron in the deposits, compared with the lodes in the limestone country of the Chillagoe-Mungana area, was considered a disadvantage because it made the Cardross ores unsuited for use as flux ore. Another disadvantage of the Cardross area was its remoteness from the railway and the limestone quarries.

The longest ore-shoots were those of the Chieftain (600 feet by 6 feet), Clansman (200 feet by 3 feet), and Spaniard (200 feet by 2 feet); they seem generally to pitch flatly southwards. Pyrite, chalcopyrite, much arsenopyrite, and magnetite, in various proportions, are the common primary metallic minerals. The gold content of the Cardross ores has been relatively high, with values reaching half an ounce or even 1 ounce of gold per ton, and was actually the decisive factor when the sinking of a shaft was being considered. The total yield of 2200 ounces of gold (recorded) is of the same order as the yield from the Mount Wandoo gold mines. Galena and sphalerite were found in only a few mines (notably the Caledonia). Small quantities of wolframite, cassiterite, and traces of bismuth and molybdenite have also been recorded, particularly from the Baker's Camp lodes (not located during the 1958 survey). The presence of such minerals as magnetite, tourmaline, wolframite, and locally some cassiterite and topaz, suggest deposition under generally high temperatures.

Owing to the absence of carbonate rocks, a rich zone of secondary enrichment could form at groundwater level and below, at various depths between 50 and 160 feet. Copper minerals from this zone include chalcocite, covellite, chalcopyrite, and bornite, and grades ranged from 8 to 20 percent copper, and even exceeded 30 percent.

The primary sulphide zone did not contain more than an average of 6 or 7 percent copper. In the leached and oxidized upper 100 feet of the lodes and at the surface the principal copper minerals were the carbonates malachite and azurite, and the copper arsenates scorodite (essentially an iron arsenate) and olivenite; cuprite has also been recorded.

Among the 60 leases or so in the L-zone, the most important was the Chieftain, followed by the Caledonia, Clansman, Keppoch, Albin Macgregor or Allan, Klondyke, and Lochinvar.

The *Chieftain* (5, a) — or Macao in the early days — was by far the best producer, and is reported to have contributed 95 percent of the total yield of the Mammoth Copper Mine Ltd—the operating company for the longest and most active period in the mine's history. Its main shaft went down to 373 feet, and levels were developed at 110, 131, 160, 225, and 305 feet. The largest lode, 600 feet long, had an average width of 6 feet. Only low copper values were found in the upper 100 feet of the leached zone, but the enriched ore at greater depth contained from 10 to 30 percent copper. However, the rich shoots appear to have been exhausted.

The *Clansman* (5, e)—originally known as the Lamington— had a main shaft of 200 feet deep, two other shafts, and a number of open cuts. Levels were put in at depths of 22 feet, 45 feet, 80 feet, and 125 feet. Ore from the Clansman was especially rich in gold, and also contained wolframite. At the 125-foot level the lode was 2 feet wide and assayed 20 percent copper, 15 dwt of gold, and 10 ounces of silver per ton over a length of 80 feet.

Workings at the *Caledonia* (5, c) at Klondyke Creek comprised a number of shafts 40 to 75 feet deep, and yielded chalcopyritic ore with pyrite, sphalerite, and some galena. A typical sample of oxidized ore assayed 2.5 percent copper, 10.8 ounces of silver per ton, 9 dwt of gold per ton, and 36.0 percent iron. A sample of sulphide ore contained 9.6 percent copper, 2.9 ounces of silver and

1 dwt of gold per ton, 18.5 percent iron, 36.0 percent silica, and 15.0 percent aluminium oxide. Diamond drill holes on the lease appear to have struck ore containing 15 percent copper at a depth of 150 feet in one place, and 'dense sulphide ore' at a second locality, also at 150 feet. A third drillhole struck 5 feet of 20 percent ore (Ball, 1918, a).

The *Albin Macgregor* or *Allan* leases (not located in 1958) adjoin the Chieftain lease along their northern boundaries. Workings include shafts with a depth of at least 200 feet, and levels at 55, 70, 100, and 166 feet. The ore produced showed copper values between 8 and 27 percent (the latter percentage from enriched ore), and the last assay rcorded, from 198 feet depth, gave a result of 8 percent copper over a width of 8 inches.

Although the assay values quoted above, and others mentioned in Ball's report, seem attractively high, it must be pointed out that, according to Ball (1918a, page 18): '. . . the ore deposits of Cardross are on the whole neither very high grade nor of very great size. Rich ore-shoots seldom crop out at the surface, and the few found have not been of startling magnitude.' The width of these rich ore-shoots is rarely more than two or three feet and their length is generally of the order of several tens of feet, lengths of a hundred feet or more being exceptions.

Nevertheless, as Ball also stated (1918 a, page 19), '. . . the medium to low grade formations are persistent', and it is felt that exploration and development of the lesser leases has been neglected. Three old diamond drill holes on the Caledonia leases struck 4 to 10 feet of ore with reported values of 10 percent and 20 percent copper at a depth of 150 feet; and it is surprising that these results have never been followed up, and, as good enriched ore and medium-grade primary ores are known to occur at some depth below the surface in the Cardross area, further test drilling seems warranted.

The *Mountain Maid* (7) and the *Spaniard* (6) are two mines respectively 6 and 4 miles south of the central L-group. At the Mountain Maid the outcrop consisted of a tourmaline-bearing cellular gossan containing malachite and azurite. The host rocks—gneiss and quartz-mica schist—are kaolinized and iron-stained at the surface. Several shafts were sunk, the deepest of which was 185 feet. The Spanish lode forms a long line striking 330° in gently undulating quartz-mica schists. Shafts and trenches have been opened up over a distance of about 400 feet.

Small workings are known in the Pandanus Creek and Welcome Creek areas, and include (?)*Buchanan's* (8) and (?)*Jessica*. Dumps reveal the presence of pyrite, arsenopyrite, and chalcopyrite.

A group of scattered small workings 1½ to 2 miles north-west of Cardross in gently undulating mica schist is known locally as the Arizona group. These workings consist of shallow shafts and pits in altered material stained with copper carbonates.

Dargalong Group (21)

(Jack, 1891; Q.G.M.J. 1906a; Ball, 1917c; Jensen, 1941)

The Dargalong silver-lead lodes, situated approximately 8 miles south-west of Chillagoe in granulite, mica schist, gneiss, and amphibolite of the Dargalong Metamorphics, were first mentioned in Warden's Reports for the year 1889. Work was done intermittently, and the main periods of activity appear to have been between 1909 and 1915, and between 1923 and 1925. The total production for these years was some 667 tons of ore which yielded 126 tons of lead and 20,680 ounces of silver, corresponding to an average recovery grade of 18.8 percent lead and 31 ounces of silver per ton. The copper content was negligible: only 2.2 tons of copper were obtained.

The lodes occur in a north-west-trending shear zone. According to Ball (1917c) the main Dargalong lode is made up of '. . . a number of nearly parallel, sometimes overlapping and sometimes intersecting formations', whereas Jensen (1941) thought that the main Dargalong lode is a continuous shear, with a zone of fracturing containing diagonal branch lodes on the western side of the main lode. The main lode can be traced for a distance of two miles (Ball) to four miles (Jensen), and dips 60° or more to the south-west. The rich ore-shoots appear to have been very short, ranging in width from 6 inches to 12 inches, and according to Jensen '. . . lie en echelon on the stratification coming into the main lode at an angle but not extending far from the main 'lode'. The lode, sensu lato, is between 6 inches and 6 feet thick, and is composed of 'ironstone' and quartz. Where the lode traverses mica schist the grade of ore is higher than where it passes through the other rock types.

High-grade oxidized silver-lead ores, including cerussite, anglesite, and massicot, have been extracted in small quantities near the surface. Below the groundwater level the ore is low-grade, complex, and siliceous, and consists of argentiferous galena, pyrite, sphalerite, and some chalcopyrite. Bismuth and stibnite were known from some of the shoots.

Workings generally were small, disconnected, and shallow. The *Jubilee* (21, a) was the most extensively worked and had a shaft 200 feet deep. In the 90-foot level of its No. 1 shaft the lode was 2 feet wide and assayed 25 percent lead, 50 ounces of silver per ton, 2 percent copper, 12 percent zinc, 12 percent iron, and 20 to 25 percent sulphur.

An extension of the lode on the western slope of Mount Delany (16) shows copper carbonates at the surface.

Bamford Area (58,c,d,e,f)

Near the Dover Castle tin mine (see page 103) there are several workings from which silver-lead ore has been won intermittently since 1890. The workings were then known as the Lappa-Lappa mines, and are situated in the Featherbed Volcanics about 4 miles north-west of Petford.

The *Comstock* lode (58, c), which is on a hill less than a quarter of a mile from the Dover Castle tin mine, is siliceous with iron-stained and gossanous portions. Several veins up to 4 feet wide have been worked in pink to grey-green quartz porphyry. They are generally steeply-dipping to vertical, and pinch and swell in width from a few inches to 2 or 3 feet. Silver values were high in the early period: Jensen (1919) reported 38.5 ounces of silver per ton and 35.8 percent lead in galena ore. In 1961 the lease holder of the Dover Castle tin mine, Mr Bagden, had re-timbered the Comstock shaft and had extracted from it a parcel of ore apparently very rich in galena; however, he told us that there was very little good galena ore left in the lode, and that the percentage of sphalerite increases markedly with depth.

Small but rich shoots of galena ore were worked in white quartz porphyry at the *Silver Bead* (58, d), a few hundred yards west of the Comstock. The lodes apparently trend north-west, but are somewhat erratic. The mine kept up an intermittent production between 1919 and 1926.

The *Better Luck* mine adjoins the Silver Bead to the north. Galena ore found on the dumps is siliceous and pyritic. Mining was from a 3-foot-wide lode, known at its southern end as the *Sarah-James,* and the main period of activity was around 1920.

Scattered Mines

Torpey's Crooked Creek silver-lead mine (46) (Dunstan, 1905a) is 3 miles east-north-east of Almaden and can be reached by an old washed-out track 5 to 6 miles long. The mine lies in sediments of the Mount Garnet Formation, which here consists of conglomerate, sandstone, quartz greywacke, and siltstone.

The lode was described by Dunstan (1905a) as an irregular deposit, and, although some lead carbonate was exposed at the surface, there was little evidence for the presence of the rich galena ore found in depth.

A main shaft was sunk to 125 feet in 1904, and was deepened to 365 feet in 1912. Levels were developed at depths of 30, 70, 125, and 300 feet. In 1904 ore was stoped from a shoot of solid sulphides, 25 to 35 feet wide, pinching to 13 feet at the 125-foot level, and assaying about 30 percent lead. In this mine also sphalerite became increasingly abundant at greater depths. Gangue minerals were pyrite and fluorite.

Ore at the 300-foot level was reported to contain 22 percent lead and 18 ounces of silver per ton in a lode 2 feet wide. At 365 feet the orebody had become unpayable because of increasing hardness and sphalerite content, and decreasing grade and dimensions.

The main production years were from 1904 to 1907 and from 1912 to 1914. An attempt was made to re-open the mine in 1924 when a demand for zinc existed, but the attempt came to nothing and the mine has remained inactive since that year. Production figures are not complete: the total output since 1912 is estimated at 6000 tons of ore, which yielded 84,000 ounces of silver and 920 tons of lead. In addition, in 1904, some 2000 tons of ore, for which no returns are known, is on record as having been milled, but no figures are available for the years between 1904 and 1912.

Conroy's lead workings (47, e) are located 1¾ miles north-north-east of Koorboora in fine-grained sandstone of possible Carboniferous age. The lode, generally limonitic and kaolinitic, is gossanous in places, and is here and there stained by manganese oxides. Galena, cerussite, and malachite were noted on the dumps.

Manipota (Maniopoto) (31) (Jensen, 1941) is a lode situated 5 miles north-west of Almaden, and was discovered in 1905. It is a wide contact lode composed of siliceous-ferruginous garnet rock, striking north-west for more than a mile along the boundary between limestone on the south and granite on the north. A 5-foot-wide ore-shoot carrying high-grade lead carbonate was opened up at the 60-foot level of one of the shafts and assayed 32.5 percent lead and 2.3 ounces of silver per ton. Production came from several shafts, open cuts, and trenches, and totalled about 790 tons of ore for a yield of 1340 ounces of silver and 150 tons of lead. The last development work was done in 1926 when 'a considerable tonnage of high-grade lead ore' was reported; unfortunately its silver content was low.

The *Gibraltar* (30, j) is the only working in the group of gold and fluorite mines in the Fluorspar area which yielded copper. The lode, situated in porphyry of the Featherbed Volcanics several hundred yards north of the Australia Flag gold mine, was opened up in 1897 and prospected over a width of 40 feet. A few hundred tons of ore were won, assaying between 7 and 20 percent copper.

About 3 miles south-east of Petford, close to the road from Petford to Emuford, lies the *Emerald Hill* copper mine (53). The lode is siliceous and ferruginous and carries pyrite, chalcopyrite, sphalerite, galena, cuprite, malachite, azurite, and radiating clusters of actinolite. Workings include 5 shafts and an adit. No production figures are available.

The *Silver Spray* (52) lead mine lies in conglomerate, shale, and greywacke of the Mount Garnet Formation, on the bank of Back Creek, some 8 miles south-east of Petford. The siliceous lode carries galena, sphalerite, chalcopyrite, and pyrite, and was worked by means of 4 vertical shafts, an adit, and several prospecting pits and tranches. The lode is probably part of a north-south fault system.

Smaller copper and lead prospects are found north and south-east of Ootann (40, 41, 42, 44), but are not known to have had any production worth mentioning.

The following table (Table 3) sets out, in rounded figures, the production of the more important copper, lead, and silver mines. The figures are compiled from various sources and are nearly all incomplete because the records of the Chillagoe smelters usually did not differentiate between the returns of the individual mines and centres, especially during the peak period of 1900 to 1909. Where it is suspected that this has led to more than the average discrepancies between recorded and actual production, the figures have a± sign added to them. Figures for the Redcap group of mines are probably the least complete and have therefore been given two ± signs.

TUNGSTEN, MOLYBDENUM, BISMUTH

The Chillagoe district has accounted for most of the wolframite and molybdenite production in Queenslands, and was, until 1920, the world's largest producer of molybdenite. By far the most important centres were Wolfram Camp and Bamford Hill; minor quantities of wolframite also came from the Neville and Mavis Bruce mines (47, p) in the Koorboora area; from the Mistake and other mines in the Emuford district; and from the Scardon's area (45) north of Almaden. Molybdenite was also won from the Khartoum area (38) south-west of Almaden.

Wolframite was first found in 1894, almost simultaneously at Wolfram Camp and Bamford Hill, and enjoyed its biggest boom period during the years of the first World War, when prices between £100 and £200 per ton were being obtained. In 1921 production almost stopped because the Queensland deposits could not compete with the post-war large-scale production in the United States, India, and China, which developed under the stimulus of prices higher than were paid in Australia under the tariff fixed by the Commonwealth Government. Since then production has been small and intermittent, and has been governed chiefly by the erratic fluctuations of the price of wolfram. A minor boom occurred from 1938 to about 1945; production struggled on until about 1955, and finally died out in 1958.

Although molybdenite was discovered at about the same time as wolframite, the mineral could not be sold for lack of demand until 1900. Its price then rose quickly from £52 per ton in 1900 to almost £200 per ton in 1902. In 1913 the price increased sharply to £325, and reached £500 per ton in 1914—the beginning of the war boom. In 1920 production collapsed, and has since been intermittent and negligible.

Bismuth has been a by-product, produced in far smaller quantities than wolframite or even molybdenite. The mineral is difficult to separate from wolframite because of its similar specific gravity, and was therefore often sold as a mixed wolframite-bismuth concentrate. A percentage of less than 3 percent in the mixed concentrate was considered an impurity, and was penalized, whereas percentages of more than 3 percent were paid for.

TABLE 3

Production Fgures (Incomplete) of the Principal Copper and Lead Mines.

Name of mine or group of mines	Main periods of recorded production	ORE (Tons)	COPPER (Tons)	LEAD (Tons)	SILVER (Ounces)	GOLD (Ounces)	Main references
Mungana Mines	1894-1897 1901-1914 1921-1927	333,600	7,910	31,835	3,228,600	?	Jensen (1920, 1941) Broadhurst (1952, 1953)
Redcap Mines	1896-1897 1906-1911 1925-1930	13,000±±	300±±	525±±	23,500±±	?	Morton (1927) Jensen (1941) Broadhurst (1952, 1953)
Zillmanton	1902-1930	35,000	1,500 ?	—	?	?	Jensen (1941) Branch (1960)
Ruddygore	1896-1909	32,750	1,450	—	60,000	?	Broadhurst (1949) Branch (1960)
Calcifer Mines	1894-1926	26,450	1,555	(400 bullion)	20,400	—	Jensen (1941)
Chillagoe Consols	1903-09; 21-26	30,500	1.5	6,500	450,000	—	,, ,,
Ti-tree	1923-1942	32,800±	400±	7±	10,800±	1,760±	,, ,,
Muldiva Mines	1893; 1909-26	19,010	270	1,150	315,000	—	,, (1923)
Cardross Mines	1899; 1902-22; 1931-1939	18,000±	2,000±	—	87,200±	2,200±	Ball (1918)
Christmas Gift	1910-1927	8,500	85	500	27,700	—	Jensen (1941)
Lyonite Hills	?	2,000±	0.1	190±	6,500±	—	,, ,,
Torpey's Crooked Creek	1912-13; 1924	6,000±	1.0	920±	84,000±	—	Dunstan (1909)
Dargalong Group	1909-1915 1923-1925	670	2.5	130	20,700	—	Jensen (1941) Ball (1917)

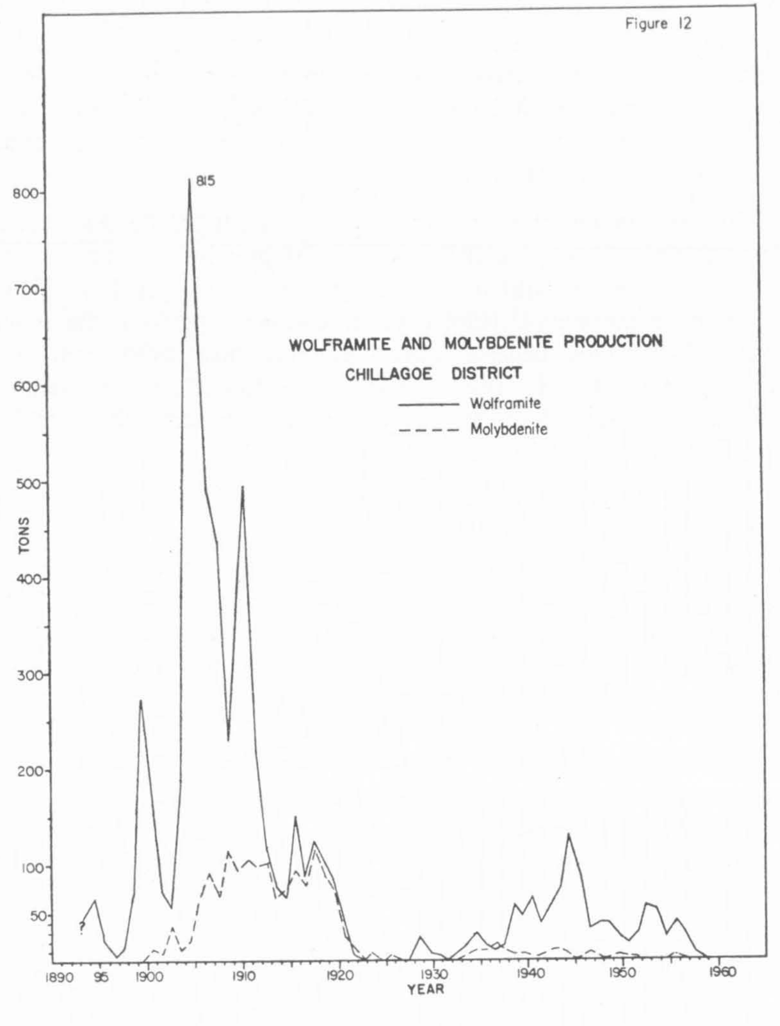


Figure 12
WOLFRAMITE AND MOLYBDENITE PRODUCTION
CHILLAGOE DISTRICT
Wolframite
Molybdenite
815
?
TONS
800
700
600
500
400
300
200
100
50
1890
95
1900
1910
1920
1930
1940
1950
1960
YEAR

The total value of the production from the two main centres, Wolfram Camp and Bamford Hill, has been estimated at roughly £1,150,000.

Wolfram Camp (60)

(Cameron, 1903, 1904; Dunstan, 1905b; Ball, 1913a,b, 1919a, 1920; Williams, 1923; Clappison, 1941; Morton & Ridgway, 1944b; Morton, 1945; Ridgway, 1946; Blanchard, 1947; Queensland Department of Mines, 1953; Connah, 1954)

Wolfram Camp, 15 miles north-west of Dimbulah by road, has been Queensland's most prolific wolframite and molybdenite field. Production up to 1960 amounted to about 5400 tons of wolframite concentrate, 1455 tons of mixed wolfram-bismuth concentrate, 1355 tons of molybdenite concentrate, and 80 tons of bismuth concentrate.

The first production of wolframite came from detrital deposits concentrated in creeks and in the 'loams' at the surface. The price of wolfram was then £10 per ton. It rose slowly until it became—at about £56 per ton—high enough to attract more attention. Detrital deposits continued to form the main source until, about 1906, they became exhausted, and most subsequent production was from lode deposits. In 1900 a market was found for molybdenite, which added to the attraction of the field, and Australia became the world's largest producer of this mineral (Daly, 1959).

In 1906 the Irvinebank Mining Company began to buy its way into Wolfram Camp, and by 1907 owned, or had a controlling interest in, most of the important claims. A battery was opened in 1908, and the company continued operations until 1917, when its mill and many of its mines were taken over by the Thermo Electric Ore Reduction Corp. Ltd. In the meantime a French company, the Société Française des Métaux Rares, had bought several mines and had erected a costly plant designed to treat low-grade mixed metal ore, but after some short and unsuccessful trial runs in 1912 operations had ceased and the company had gone into liquidation. The Thermo Electric Ore Reduction Corp. Ltd constructed a ten-million-gallon water dam and a 20-head battery, and equipped some of the largest mines with haulage and compression units; however, the sudden collapse of the market in 1920 forced it into liquidation.

An attempt to rejuvenate the field was made in 1926 by Queensland Rare Metals Co., who erected a battery on the site of the old Irvinebank works, but adverse market conditions soon caused the abandonment of the attempt.

The Queensland Government assisted the field by taking over control of the battery from 1942 to 1956. In 1958 the battery was operated by Kensington (Qld) Pty Ltd for the recovery of molybdenite, but, when the site was visited in 1961, it was abandoned and the battery had been completely dismantled.

In 1959, at the request of Kensington (Qld) Pty Ltd, the Bureau of Mineral Resources carried out tests with a portable scintillometer detector over a number of workings to determine whether or not the orebodies showed any well-defined radioactivity (Daly, 1959). This method was tried because it was known that many molybdenite samples were slightly radioactive, and because conventional geophysical methods were unsuitable. However, the field method failed to indicate more than the slight erratic values generally encountered over granitic rocks. Examination of one of the radioactive specimens in the Bureau of Mineral Resources laboratory in Canberra showed the radioactivity to be associated with xenotime, an yttrium phosphate in which part of the yttrium may be exchanged for cerium and thorium (Roberts, 1959).

The workings are situated in granite which has intruded the sediments of the Hodgkinson Formation and massive (?)Permian porphyries. The granite contact dips north at 50° or more; sediment remnants on top of some of the granite hills show that the granite boundary was more or less horizontal; the exposures are, therefore, in the roof area of the intrusion. The northern periphery of the granite is greisenized to various degrees, and the mineralization is confined to the greisen, in particular along and near the northern boundary in a zone 2 miles long, and up to 2500 feet from the contact (see inset, Plate 13).

The deposits at Wolfram Camp may be classified as:
a) detrital surface deposits, b) flat lodes, c) disseminated ore, d) segregations, and e) quartz pipes. Of these, the detrital deposits yielded most of the initial output, but the quartz pipes have provided the most important part of the production.

a) The detrital deposits were the first to be worked, in creeks and gullies around Wolfram Camp, and in 'loam' deposits at the surface. They must have represented a large percentage of the total ore won, but were worked out by 1906.

b) The flat lodes occurred only in the high parts of the field, near the roof of the intrusion where the former granite boundary was flat and had induced, on cooling, a system of flat contraction joints which subsequently became filled with mineralized quartz. These lodes were never of any significance.

c) Disseminated orebodies in greisen. This kind of deposit, which was an important source of rare metals in some of the mines, is known locally as 'spotted dog' or—where containing finely disseminated molybdenite—as "spotted dog lig'. Clappison (1941) was in favour of directing more attention to prospecting these disseminated but relatively large deposits, and considered that the future of the field largely depended on them.

d) Segregations and pockets of ore are scattered through the greisen zone, but are small, and can only be found by chance.

e) Quartz pipes have been the most extensively worked deposits. They are irregular and tortuous, of varying shape and size, and show inconsistent pitches commonly changing in attitude. The pitch may range from horizontal to vertical. Most of the pipes are inclined towards the granite contact, and in some places follow the contact downwards. They commonly change direction where abutting joints, faults, and barren quartz reefs, and are commonly greatly enriched at contacts with faults. There is no sharp boundary between pipes and surrounding greisen: the quartz filling gradually passes first into greisen and then into only slightly altered granite.

Of the 250 or so pipes known, only a small number have been worked to depths greater than 50 or 100 feet, and very few have reached a depth of more than 500 feet. Branching is common and many of the off-shoots, though rarely extending more than 30 or 40 feet from the main pipe, carry rich concentrations of the rare metals. The pipes are roughly circular or elliptical in section, and have diameters ranging from a foot to more than 30 feet, though the average is about 5 to 6 feet. Maximum dimensions reported are 45 feet by 30 feet, 34 feet by 14 feet, and 28 feet by 18 feet.

The greater part of the pipe filling is white to blue glassy quartz, generally containing less than 1 percent wolframite and molybdenite. Ore occurs in shoots at various intervals, and it appears that the extent of 'blanks' between the ore-shoots increases with depth. There is no constant relationship between ore-shoots and 'blanks'. Vugs in the pipes range in diameter from a few inches to several feet, are up to 20 feet long, and are generally lined with quartz crystals.

The ore-shoots commonly contain from about a hundredweight to several tons of ore with grades between 1 and 50 percent. Williams (1923) thought that there was a general impoverishment at depths greater than 200 to 300 feet, but since his report was written pipes have been worked successfully to 400 and 500 feet. No control for the distribution of the shoots is apparent, but it is stated that bends in the pipes are usually favourable loci for ore concentration.

Amongst old leases and workings located during the 1958 survey were the Tully, Forget-me-not, Larkin Amalgamated, Leisner, Murphy & Geaney, Pinwell, Mulligan, Harp of Erin, Enterprise, Victory, Finnigan, Avoca, Killarney, and Nil Desperandum. The Four Mile workings (61) lie about 2 miles to the west-north-west of Wolfram Camp in a tongue of granite bounded on the east and west by Featherbed Volcanics, and on the north by sediments of the Hodgkinson Formation. Only seven men were engaged on the Wolfram Camp workings in 1958; in 1961 three families were active on the Forget-me-not and Harp of Erin leases.

Wolframite—here a ferberitic variety—predominates over molybdenite in most pipes, and occurs at random in the ore-shoots, whereas molybdenite is usually concentrated on the outer edges (Morton & Ridgway, 1944b), with a preference for the footwall side of the pipe. Though generally separate, in places the two minerals are intergrown. An assay of a molybdenite specimen showed 93.5 percent MoS_2, 3.38 percent Bi_2S_3, 1.15 percent SiO_2, 0.15 percent Al_2O_2, and 0.57 percent FeO. The bismuth in this specimen was present as films 0.002 to 1.0 mm. thick, within the foliation planes of the molybdenite (CSIRO, 1940).

Bismuth is very commonly intergrown with wolframite, or is present as small rounded blebs in the mineral.

In addition to the actual ore minerals—wolframite, molybdenite, and native bismuth—minor amounts of scheelite, bismuthinite, arsenopyrite, chalcopyrite, pyrrhotite, sphalerite, galena, stibnite, pyrite, tetrahedrite, calcite, tourmaline, cassiterite, and topaz have been recorded (Ball, 1920). Arsenopyrite is common in some of the pipes, and sporadic aggregations of pyrite, and, in one place, of pyrrhotite are known.

The following comments concerning the future prospects of the field are worth noting: the old pipes are not an atractive mining proposition; they are so unpredictably irregular that it is necessary to follow them step by step and efficient haulage from greater depths consequently becomes a problem. New pipes are difficult to find: geophysical methods are apparently ineffective, and drilling (although recommended by Clappison in 1941 and by Williams in 1923) would probably offer less than reasonable chances of success—even the largest diameter pipes would make an uncommonly poor target for a drill, particularly as the drill-site would have to be haphazardly chosen. Capital expenditure on the development of the lower-grade disseminated ores is discouraged by the erratic behaviour of the tungsten market and the fact that at present there is no known evidence pointing to large reserves. However, this type of orebody is a more favourable drilling target; also, the molybdenum market is considerably more reliable than the tungsten market, and the discovery of a large body of 'spotted dog lig' containing as little as 0.3 percent molybdenum could provide a good mining prospect. This is probably the only sort of possibility for any substantial revival of the field—the reserves remaining in the old pipes offer only limited scope to individual syndicates at times when the price of tungsten is high and stationary for a reasonable period.

Bamford Hill (57)

Cameron, 1904; Ball, 1913a, 1914b; Morton, 1940; Blanchard, 1947; Levingston, 1955)

A second important wolframite-molybdenite field, Bamford Hill, is situated 2½ miles along a track north-north-west from Petford. The geological setting and the pattern of mineralization are very similar to those at Wolfram Camp: quartz pipes occur along a stretch, 1½ miles long and a quarter of a mile wide, of greisenized granite and in close proximity to its contact with the intruded (?)Featherbed Volcanics (see inset, Plate 13). However, greisenization is not as intensive as at Wolfram Camp. Here, also, the first ore was won from rich detrital deposits at the surface which were exhausted by 1906, whereafter the quartz pipes became the chief producers.

The first discovery of wolframite in this field was made in about 1893, and the first real boom took place during World War I. A State Battery was opened in 1917 and allowed the working of lower-grade ore. After the crash in 1920 production stayed insignificant until a small revival after 1938. The State Battery closed down in 1949, and by 1958 the field was completely deserted. The total production, in round figures, up to the end of 1945 is given by Blanchard (1947) as: 1880 tons of wolframite, 100 tons of wolfram-bismuth concentrates, 165 tons of molybdenite concentrate, and 20 tons of bismuth concentrate.

Among the leases and workings located during the 1958 survey were the *K.Y., Haymaker, Brandon, Gillian and Bridge, Osbourne, Nelsen's, Rose of Queensland, Rollison, Plum Pudding, Ballarat, Tiger's Tail, Sunny Corner,* and *Shady Corner* (57). The deepest working was probably one of the Brandon shafts, which was about 608 feet along the incline. Production figures are not complete. The *Eight Mile* mine (59), in a small granite outcrop 3 miles north of Bamford Hill on the east bank of Emu Creek, was also worked for wolframite and molybdenite.

The minerals encountered in the 70 quartz pipes worked have been described by Ball (1915) and include, apart from the ore minerals wolframite, molybdenite, and bismuth, also small quantities of scattered sphalerite, pyrite, chalcopyrite, galena, fluorite, kaolin, magnetite, and various tungsten, molybdenum, and bismuth minerals such as scheelite, powellite, and bismuthinite. Many of the sulphides are commonly found concentrated in the vugs, and the proportion of sulphides seems to increase with depth.

The wolframite, which is nearer ferberite than hubnerite in composition, has a high content of tungstic acid. An analysis by the Government Analyst in 1905 gave the following results: 73.0 percent WO_3, 7.81 percent MnO, 14.15 percent FeO.

There is less information on the Bamford Hill workings than on those at Wolfram Camp, but the conditions are essentially the same, and a large-scale resumption of mining operations, in the event of a return of favourable tungsten prices, cannot be envisaged.

Khartoum district (38)

(Saint-Smith, 1917a, 1917c)

Khartoum was a small mining settlement about 9 miles south-west of Almaden, and 2½ miles west-south-west of Ootann. Molybdenite had been mined from several workings since 1914, and Saint-Smith had great expectations of the district because of 'the large tonnage of highly-payable ore already fully proved and developed', the absence of impurities, and various other factors.

However, by 1918 all the proved ore had been extracted and no further ore was discovered, and since 1919 the district has not been mentioned in Warden's Reports. Production figures are not known.

The country rock is grey to pale pink, medium-grained, hornblende-bearing biotite granite (?Herbert River Granite) which is intruded by numerous and extensive dykes and stocks of a fine-grained acid granite containing biotite (?Elizabeth Creek Granite). Parts of the granite are greisenized, and small pegmatite veins have been reported. Numerous quartz reefs occur '. . . along the margins of, and also constitute extensions of, the later acid intrusions' (Saint-Smith, 1917a). They have no preferred direction of strike, are commonly sinuous and low-dipping, and the amount of dip varies in each individual lode. According to Saint-Smith they consist of a series of slightly overlapping lenses, and are accompanied by numerous stringers and veinlets of quartz branching off the main lode. Molybdenite values were usually highest in the widest parts of the lodes. In the Kitchener mine the highest values were found in the steeper-dipping portions. The only ore mineral of any importance is molybdenite.

In the upper 35 feet of the lodes the mineral is generally decomposed and leached out, or has been altered to powellite or molybdite. At the Kitchener mine the concentrate was said to have assayed 93 percent MoS_2, and hand-picked ore from the dump contained 96.5 percent MoS_2.

Some wolframite has been recorded from Jackson's Lode and Mount Riddell and two other leases. Bismuth is known only from the Jackson's Lode. Sulphides are extremely rare in all the lodes: the Corporal Lease was the only locality where some galena, chalcopyrite, and up to 8 percent cassiterite were found, and a little pyrite occurs in two or three of the leases.

The most important mine in the area was the *Kitchener* (38, d), and second to it was the *Ajax* (38, c). The Kitchener, located on Tate Spring Creek, was originally opened up by a prospector named Riddell, and later taken over by Alexander Macdonald, who erected a ten-head stamp battery and flotation plant in 1917. The main shaft was 130 feet deep at the time of the Saint-Smith inspection. The lode, at the 70-foot level, dips 25° to the north, but the dip changes several times and ultimately reaches 45° at the deepest part worked, between the 120-foot level and the bottom of the shaft. The average thickness of the lode between the two levels was 4½ feet, and Saint-Smith estimated the average tenor of the ore at 3.4 percent molybdenite.

The Ajax lode was situated several hundred yards west of the Kitchener on Middle Creek. Its main shaft reached a depth of 92 feet.

Koorboora area

(Ball, 1911)

Several of the tin mines in the Koorboora area, for example the Two Jacks, contained varying amounts of wolframite in the upper parts of their lodes, but in only three mines was the wolframite sufficiently concentrated to be mined. The mines are situated in steeply-dipping micaceous sandstone and shaly siltstone of the Mount Garnet Formation, which are heavily iron-stained near the surface.

The *Neville* (47, p), a little more than one mile south-south-east of Koorboora, was an important wolfram mine between 1904 and 1909, and was then considered as one of the greatest single wolfram mines in the world. It was worked by the Irvinebank Mining Co. and had yielded 550 tons of wolframite by 1909. War-time demand resulted in some further production in 1918, increasing the recorded total output to 580 tons of wolframite from 8583 tons of ore.

Nearly all ore came from one small but very rich shoot shaped as a more or less spiralling pipe, 10 to 20 feet in diameter, extending down to 140 feet. At greater depth only low-grade ore was found. The average grade in the upper 80 feet was 10 percent wolframite; between 80 feet and 120 feet the ore contained about 20 percent wolframite; below this was 20 feet of 4 percent ore. In the lower workings cassiterite made its appearance, and sulphides became increasingly abundant from the 200-foot level downwards.

The Neville was worked intermittently by prospectors for a long time after its demise as a company mine.

The *Telegraph* wolfram and tin workings adjoin the Neville mine; the orebody carried cassiterite, galena, chalcopyrite, and bismuth with the wolframite, commonly intimately intermixed. Workings were reportedly unpayable below 90 feet, and the mine has long been abandoned.

One mile north - west of the old Neville mine is the *Mavis Bruce* wolfram lode, discovered in 1943 (Morton, 1944b, 1946). The ore occurs in bunches, up to about 1 foot across, of almost pure wolframite in a spurred lode pipe, along a major joint striking north-north-west and dipping 20° to 55° to the west. The lode is altered near the surface to a kaolinite-quartz-chlorite-limonite mixture. The abundance of gossanous limonite points to a considerable original proportion of sulphides.

Although conditions looked promising, further development failed to discover any large quantities of economic ore, and after 1947 the mine was no longer mentioned in Warden's Reports. The total production consisted of some 75 tons of wolframite concentrate.

During a visit in 1961 we noted that the workings in the Koorboora area locally carry small quantities of fluorite and molybdenite.

Scardon's area

(Ball, 1911)

Situated 5 to 6 miles along a bush track north of Almaden, the Scardon's area may be divided into a western group of mines around Shannon's Hill—

Scardon's Bottom Camp—and an eastern group on Convict Creek—Scardon's Top Camp. The greatest amount of activity has been around *Scardon's Top Camp* (45, b), where the workings lie close to the contact of granodiorite and leucogranite with folded sandstone of the Mount Garnet Formation. Wolframite and molybdenite occur in white to clear glassy quartz veins which appear to be controlled by joint systems. Boundaries between the quartz lodes and the granite are gradational. The first production came from shoad deposits, but when these were exhausted shafts were sunk into the primary ore, which persisted to 70 feet (the bottom of the deepest shaft). Workings are concentrated along a zone trending 280°.

Scardon's Bottom Camp (45, a) workings were largely for shoad deposits, but two shallow shafts were eventually sunk on a narrow quartz lode in the granite.

The total production up to 1911 was reported to be roughly 30 tons of wolframite concentrate (Ball, 1911).

Emuford area (51)

Several of the mines in the Emuford district fall within the boundaries of the area under discussion, and can be easily reached by road from Petford. Many of them were worked for wolfram, others for tin, fluorspar, and copper, but no production figures are available. These lodes were generally small and insignificant.

The *Mistake* mine (51, e), about 7¼ miles south-south-east of Petford, was opened in 1915, primarily for wolfram. Since then, in addition to fluorspar, wolframite has been produced intermittently. For a description of the mine see page 113.

The *Mystery* mine (51, k), 1 mile south of the Mistake workings, occurs in pink granite close to its contact with conglomerate and quartz greywacke of the Mount Garnet Formation. Much of the host rock around the now abandoned mine is greisenous. Wolframite was worked in patches down to 180 feet in the main shaft, and bismuth, galena, chalcopyrite, and copper carbonates were noted in small quantities. A parcel of 9 percent copper ore was extracted from the mine in its early stage. The quartz gangue contained some fluorite and topaz.

Some wolframite has been won from the shallow *Gold Rod* workings (51, f) in granite and greisen south of the Mistake mine.

The *Spotted Dog* (51, b) lies about 1 mile north-west of the Mystery. Wolframite occurs here in sediments of the Mount Garnet Formation.

The *Sydney* (51, i) is one of a group of tungsten prospects south of the Mystery mine. A shaft, 31 feet deep, with levels at 15 feet and 26 feet, has been sunk in a mineralized quartz vein in granite striking 325°.

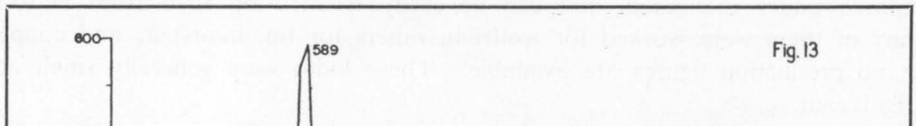
Sunnymount area (48)

Some wolframite has been won from the *Tommy Burns* tin mine (48, f) just west of the Sunnymount Battery (see page 101).

The *Indicator* wolfram workings are located 5 miles west of the old Spinifex railway siding on the now abandoned Mount Garnet line. Host rocks are sandstone and siltstone that are commonly chloritic. The mine is not far from pink granite and massive grey porphyry of the Boxwood Ring Complex. Shafts were sunk to depths of more than 100 feet on a thin vein, and produced some 15 tons of ore during the years 1917 to 1919.

TIN

Tin mining has mainly been centred in the Koorboora and Sunnymount districts and north-west of Bamford Hill. The recorded production of some 5890 tons of cassiterite is small compared with that of the much more important Herberton Tin District, which borders the area to the south-east and which has been mined for tin since 1879. The first tin in the Chillagoe district was found near Koorboora more or less accidentally during the search for a suitable dray



road from the newly discovered Chillagoe copper workings in the west to the shipping centre of Cairns in the east. Mining of alluvial cassiterite was soon in progress. Between 1900 and 1917 many of the lodes in the Koorboora area and—from 1908—in the Sunnymount area were extensively worked. A battery was erected at Sunnymount in 1910. Production declined after 1912, principally owing to labour trouble, but it seems that the old lodes must have been approaching exhaustion, for, from 1917 to 1920, despite the very high tin prices prevailing, production was practically confined to the comparatively newly discovered Two Jacks mine. After the Two Jacks closed in 1920 tin mining was intermittent and on a generally low level of activity. In 1952 Bird and Markwell erected a ten-head stamp battery at Sunnymount, which has since been treating most of the tin ores from the district. The latest pick-up in production came in 1959 with the development of a new, rich ore-shoot in the old Dover Castle tin mine, which has been virtually the only tin producer in the Chillagoe district since 1958. Owing to the high tin prices of the last few years, interest in the metal has been high, and the area has recently attracted some attention from some of the larger mining companies. An Authority to Prospect in the Sunnymount-Koorboora area was granted to Broken Hill Pty Co. Ltd in 1960.

The mineralization in the Koorboora and Sunnymount areas is closely similar to that in the Herberton district: the lodes are ill-defined bodies of mainly chloritized, kaolinized, and to some extent pneumatolytically altered sandstone, siltstone, and quartz greywacke, and merge gradually with the unaltered host rock. They contain ore-shoots that tend to be irregularly pipe-like and are apparently controlled by fissure and joint intersections that have served as migration channels. The ore-shoots change gradually to barren rock.

The granite responsible for the hydrothermal-pneumatolytic alteration (chloritization, formation of muscovite, garnet, tourmaline, cassiterite, wolframite) is undoubtedly present at no great depth in the Koorboora area: at the Mountain Maid (54), for instance, blocks of granite have been found on the dumps, and in the Sunnymount area the granite batholith is widely exposed just east of the mines.

Most of the lodes in the Koorboora and Sunnymount areas carried some wolframite in their upper parts, and a couple of mines have been worked exclusively for wolframite (see page 95). In the bottom parts of the lodes an increase in the proportion of base-metal sulphides is commonly noticeable, and as treatment of the complex ore is costly the mining of deeper ore-shoots of this type has little attraction.

Koorboora area (47)

(Cameron, 1904)

The *Shakespeare* tin mine (47, k), situated near the Almaden-Petford road on the site of the old Koorboora settlement, is one of the earliest and most extensively worked mines in the area, but carried comparatively low-grade ore, judging from the reported production figures: 203 tons of cassiterite from 14,539 tons of ore between 1901 and 1947.

Two lodes were opened up: a western lode carrying galena, chalcopyrite, pyrite, and arsenopyrite in addition to cassiterite; and a more important eastern lode of ferruginous and chloritic material striking north-west and dipping north-east, which has accounted for the main portion of the output. Open cuts and shafts yielded payable tin to a depth of 200 feet. The host rocks generally contain much mica and sericite as a result of pneumatolytic action.

The *Argo* workings (47, h), now collapsed, are on a small lode 1 mile south-west of the Shakespeare. Adits, 262 and 115 feet long, were connected with shafts 60 feet and 65 feet deep.

Just north of the Argo are the *Southwick* workings (47, g), opened in 1905, and including a shaft with a depth of 240 feet and a drive 137 feet long. Production came from a small rich seam striking north-west, and included 15 tons of cassiterite from 240 tons of ore in 1905. and 13½ tons of cassiterite from 38 tons of ore in 1915.

The *Tennyson* mine (47, m) (Blanchard, 1947) is about three-quarters of a mile south of the Koorboora railway siding, and was worked from 1905-1916 mainly by the Irvinebank Mining Coy. It was re-opened in 1926 by Queensland Tin and Metal Mines N.L., only to close one year later. The host rocks are commonly pneumatolytically altered, and consist of chloritized and greisenized sandstone and siltstone striking about 20°. A dyke in the workings is assumed to have influenced the deposition of the ore. This dyke, referred to in the literature as the Tennyson dyke (not to be confused with the Tennyson Ring Dyke), consists of numerous fragments, ranging up to several feet in length, of chert, quartzite, rhyolite, and porphyry, in a light-grey tuffaceous matrix. The ore occurs in shoots in chloritic material occupying fissures that evidently opened after the dyke formed, as the fissures cut the dyke; and also as small veins and irregular pipes against, or close to, the dyke.

Workings are grouped around the Central Shaft (186 feet deep), and Eade's Shaft, 260 feet away. The Central Shaft has plats at 88 feet, 145 feet, and 174 feet. Eade's is an inclined shaft on the footwall side of the orebody; it is 185 feet long and has levels driven south at 80 feet, 114 feet, and 175 feet.

Ore-shoots occur as pipe-like bodies within chloritized host rock which forms a 4 to 8-foot wide lode dipping steeply west; the ore-shoots are tortuous and irregular, and occur on both sides of the Tennyson dyke. Cassiterite values were reported to be from 2 to 3 percent. At depth much of the tin ore is intimately intergrown with galena, sphalerite, pyrite, and chalcopyrite, and it was necessary to market a mixed concentrate. This was one of the reasons why Morton (1927) regarded further mining below the 175-foot level as uneconomic.

Available but incomplete production records mention a yield of about 701 tons of mixed concentrates from 10,897 tons of ore (Blanchard, 1947). The main productive period was from 1904 to 1916.

The *Fair Play* (47, o) lies half a mile east of the Tennyson, along the track to the Neville wolfram mine, and was worked intermittently to a depth of 200 feet. In 1908 a shoot 40 feet long and 2 feet wide, carrying 15 percent cassiterite, was located. Production from 1901 to 1947 amounted to 462 tons of cassiterite from 6339 tons of ore.

The *Two Jacks* (47, r) lease, including the Three Jacks and New Dalnotter lodes, is located about 2 miles east-north-east of the former Koorboora settlement, and was one of the latest-worked deposits in the area. The workings are situated in chloritized and sericitic Mount Garnet sediments exposed as an inlier in rhyolites of the Featherbed Volcanics. The sediments are fine-grained micaceous siltstones, generally strongly brecciated and traversed by northerly to north-westerly faults which, in places, appear to displace the lodes. The ore-shoots pitch north-west and dip north-east, and form discontinuous lenses between which the crushed country rock carries low values.

The cassiterite is very fine-grained and is, in places, associated with tourmaline. Fine-grained pyrite is visible as films on joint planes. Between 1906 and 1921, 457 tons of cassiterite were produced from 11,321 tons of ore. An attempt to re-open the mine in 1926 failed. In 1960 and 1961, when they were granted an Authority to Prospect in the Koorboora-Sunnymount area, the Broken Hill Pty Co. Ltd dewatered the mine down to the 185-foot level, where ore had been extracted over a length of 30 feet and an average width of 4½ feet. Between the 120-foot and 140-foot levels large quantities of ore had been mined from a lode measuring 80 feet by 8 feet. The Broken Hill Pty Co. Ltd found the values and remaining tonnages inadequate, and subsequently relinquished their Authority to Prospect.

The *Mountain Maid* (54) is situated in fine-grained quartzitic sandstone and quartz siltstone at the northern rim of the Tennyson Ring Dyke, 2 miles east of the Two Jacks mine. Fine-grained hornblende-biotite granite occurs on the dumps, indicating the presence of granite at shallow depth.

There are records of many other mines in the Koorboora area, including the *Iolanthe, Reform, Pioneer, Portia, King Arthur, Iago, Now or Never, Atlantasaurus, Sunday* (Levingston, 1958), *Money Moon, Proserpine,* and others, but none of these mines were located during the 1958 survey.

Sunnymount area (48)

The mines in the Sunnymount area, separated from the Koorboora area by the Tennyson Ring Dyke, were discovered some twenty years after the finds at Koorboora.

The *Tommy Burns* (48, f) (Ball, 1917b), discovered in 1908, was the first and most important of these workings. The mine is situated about 2 miles west of the old Sunnymount rail siding, and can be easily reached from Petford by track. The host rocks, again, are quartzose, commonly ferruginous, micaceous, and feldspathic sandstone and slate, mineralized along and at the intersections of fault planes and indistinct joints. The lode consists of green chloritic and red kaolinitic material containing disseminated pink garnet, and contains ore-shoots that are richest near the surface, but which show much decreased values in the deeper workings. This is also evident from the production figures for the main period of activity between 1909 and 1913: these show how the average recovery grade declined from 13 percent in 1909 to about 2½ percent in 1913. The best shoots were confined to a narrow band pitching 45° west-wards from the open cut. The total amount of concentrates won between 1909 and 1913 was 370 tons from 5934 tons of ore.

Main workings include an open cut 35 feet deep, which, for the first 14 feet, yielded ore with a tenor of 10 to 25 percent cassiterite. From the floor of the open cut a shaft was sunk to a depth of 62 feet. At 106 feet below the level of the hill top an adit was then driven 253 feet; it located several large shoots of good ore. A second adit was tunnelled for 377 feet at 100 feet below the No. 1 adit, and in 1915 a third adit was driven 650 feet north-west at 280 feet below the hill crest. In 1958 the then owner, H. Bird, planned to drive south-west from the north-western end of this adit in the hope of locating the ore-bodies met in the upper levels, and had progressed 165 feet at the time of inspection. The only ore to be seen at this time was at 84 feet from the start of Bird's adit; here cassiterite, wolframite, and traces of copper were noted.

Two miles south-east of the Tommy Burns is the *Christmas Gift** lease (48, 8) (Levingston, 1958), also held by H. Bird. The lode differs from most of the other lodes in the area in that it is a cassiterite-bearing quartz vein; it has a thickness of about 15 inches, striking north-west and dipping nearly vertically south-west. The vein is about 140 feet long and is cut by a porphyry dyke in its north-western end, and terminated by a fault at its south-eastern end. Workings include two shafts and an adit driven for 320 feet south-south-west at about 100 feet below the vein outcrop, connecting with the main shaft at 140 feet. Some galena is present in addition to cassiterite. Though small, the ore-shoot was very rich: in the ten years after its discovery in 1936, 104 tons of concentrate valued at £18,973 were obtained from only 664 tons of ore. Levingston (1958) recommended driving through the porphyry dyke, as experience in the Herberton district has shown that veins commonly continue on the other side of a transecting dyke.

The *Cyclone* (48, d) is an abandoned tin mine situated about half a mile west-north-west of the Tommy Burns; in 1958 open cuts and five collapsed shafts were located in impure fine-grained quartzite striking 310°. Records show that in 1916 some 4 tons of concentrate were obtained from 74 tons of ore.

About half a mile south-west of the Tommy Burns is the *Prince Alfred* mine (48, c) (Ball, 1919b), formerly known as the Seaman mine. Cassiterite is

* One of three prospects with this name discussed in this Bulletin.

associated with tourmaline rock, vein quartz, and chloritic material. Old workings include collapsed shafts; one is reported to have been 166 feet deep. After extensive development work had located some ore with a grade of 7 or 8 percent cassiterite, 36 tons of concentrate were obtained from 481 tons of ore treated at the Gurrumbah mill (outside the area) in 1911. The lode was 20 inches wide at the south-eastern end of the 90-foot level, and contained 15 percent cassiterite, but drives at the 120-foot and 150-foot levels proved disappointing, and the lode was unpayable at the bottom of the shaft. Dumps were reworked in 1949, but the mine has been abandoned since. From 1909 to 1915, 1902 tons of ore were crushed for a yield of 182 tons of concentrate.

Other workings located in the Sunnymount area include the *Cabbage Patch* (48, e), *O'Shea's Prospect* (48, b), *New Years Gift* (48, h), and *Kerosene Tin* (48, a).

Emuford area (51)

The *Chance* mine (51, a) lies about 6½ miles south-east of Petford and 1 mile from the Petford-Emuford road, and was worked for several years by H. Bird. Cassiterite occurs in shoots in greywacke and quartz greywacke striking north-west, and a fault striking 190° is visible nearby.

Another tin mine in the area is the *Brown Snake* (51), situated 10 miles on the road south-east from Petford, and actually just outside the boundary of the area investigated. Cassiterite occurs in a quartz-veined chloritic lode in vertically tilted greywacke, shale, and some conglomerate striking 340°. Granite with greisenous margins crops out immediately west of the mine. Workings include two shafts, one of which is about 70 feet deep. In addition to tin, a small amount of copper has been won.

Bamford area (58)

About 2 miles west-north-west of Bamford Hill lies a group of tin and silver-lead workings originally known as the Lappa Lappa mines (not to be confused with Lappa Junction). The lodes are well-defined, with definite hangingwall and footwall, and are located in porphyries of the Featherbed Volcanics.

Amongst these mines the *Dover Castle* (58, b) (Denmead, 1935; Levingston, 1960) takes first place in significance; in 1959 and 1961 it was the only producing tin mine within the boundaries of the area mapped. The lode was discovered in 1890, and from 1906 was worked by the Irvinebank Mining Co. Production after 1919 was very low and came mainly from reworked dump material. In 1958 the mine was sold to C. Bagden. At this time the shaft was 300 feet deep, and local opinion considered that the lode was exhausted, for experience had suggested that all tin mines in the district lost their value at depths exceeding 200 feet. Nevertheless, after sinking the old shaft a further few feet Bagden struck a rich new ore-shoot, and in 1961 the shaft had reached a depth of 560 feet on the incline, with no evidence of declining values.

The lode trends north-east for more than 250 feet, dips from 55° to 80° south-east, and swells and pinches from a few inches to several feet. A calcite leader is used as an indicator to follow the richest part of the lode, a high-grade layer less than one inch thick. At the shaft bottom the lode—in 1961—was about 6 feet wide and was reported to have an average grade of some 8 to 10 percent. Cassiterite occurs very finely disseminated in irregular patches and networks in a matrix of quartz, sericite, and chlorite, representing the hydrothermally altered porphyry that forms the host rock. The average grain size of the cassiterite ranges from 0.05 to 0.1 mm; observed maximum grain size is about 0.3 mm.

The ore is treated at the Sunnymount Battery, where, according to Bird, a concentrate assaying about 74 percent is obtained. The recovery grade is said to be about 6 to 7 percent. From 1906 to 1958 the total production amounted to 203.5 tons of concentrate from 2335 tons of ore. In 1959, after the new ore-shoot had been opened, production suddenly jumped to a record annual figure of 99.5 tons of concentrate from 1030 tons of ore. In 1960 a further 58.8 tons was won from 691 tons of ore, bringing the total quantity since 1906 to 361.5 tons of cassiterite. An average recovery grade of nearly 9 percent can be calculated.

A stone's throw north-east of Dover Castle is the (*King*) *Midas* lease (58, a), held by T. Rice in 1958 but subsequently taken over by Bagden. Tin mineralization occurs in altered porphyry, and the richer concentrations are in heavily iron-stained gossanous layers up to half an inch thick. The lode strikes 355°, and dips 70° to 85° east, but size and values are inferior to those at the Dover Castle. Workings include two main shafts and 40 feet of trenching along a north-eastern line. The mine has been worked to a depth of 180 feet, but is now water-logged. In 1960 some 70 tons of ore yielded about 7 tons of concentrate, but owing to the presence of galena the last operating shaft (No. 2) was abandoned; and work on the mine stopped.

Should the Dover Castle and the Midas lodes continue along their observed strikes, Bagden hopes, in due course, to find rich values at their intersection.

Some other workings are the *Christmas Gift* (58, g—not to be confused with 48, g, which has the same name), west of the Dover Castle, and the *Federal* tin mine (57, v), about 1½ miles north-west of Petford near the porphyry-granite contact. Cassiterite in the Federal is associated with tourmaline.

An isolated tin mine, without an access road, is the *Eight Mile* mine (62), situated 6½ miles north-west of Wolfram Camp in white sugary microgranite which is a local variety of the hornblende-bearing biotite granite cropping out in the area. Two shafts were located in 1958, but no particulars are known.

Gold

From the beginning of the century gold was recovered as a by-product of the copper-lead ores at the Chillagoe smelters. After 1930, in addition, several mines were worked primarily for their gold content; discoveries of rich, though small, gold lodes in the Fluorspar area in 1930 led to a minor and short-lived rush. The total production of the Chillagoe district is low. The main gold centres were the Fluorspar area and Mount Wandoo.

Fluorspar area (30)

(Reid, 1933a,b; Denmead, 1934a,b; Jensen, 1941)

Access to the Fluorspar area, which is situated along Crooked Creek about 10 miles south-east of Chillagoe, is by means of an overgrown and abandoned bush track branching off the Chillagoe-Almaden road.

With the exception of the Federal Flag mine, the gold lodes are located in biotite-hornblende adamellite and granodiorite not far from their contact with the Featherbed Volcanics. Outcrops of 'Metal Hills' granite (p. 48) in the close vicinity are composed of more basic granodiorite and quartz diorite. The granites are traversed by numerous greisenized aplite veins which probably occupy major joints and are generally low-dipping. Consequently, wherever the land-surface was suitable, several of the mines were worked by adit. Post-greisen faulting opened up small cracks and joints several inches wide that became filled with quartz, calcite, fluorspar, zeolites, and clay minerals. Where such leaders cut through the greisen veins, kaolin is generally formed, and presumably acted as a precipitant for the gold that was originally sparingly distributed throughout the greisen veins, and which would have been brought into contact with the kaolin by the last of the hydrothermal solutions carrying fluoride minerals (Jensen, 1941).

The gold is concentrated in small but commonly extremely rich shoots in the kaolin; values of several ounces of gold to the ton are normal, and figures of 20 ounces or more to the ton are also on record. Ore from very rich pockets was dollied, and the maximum reported value was 777 ounces from 9 tons of ore from the Federal Flag mine in 1932. Such richness spurred the prospectors and claim holders to feverish activity throughout the area in the thirties, and hundreds of shafts were sunk and numerous adits were driven. The mines were worked from 1930 to about 1938; records of production are very incomplete, but from what is known at least 5050 ounces of mixed bullion and fine gold were extracted by dollying and smelting from about half a dozen mines. Several hundreds of ounces of silver were won as a by-product.

The more important mines were the Federal Flag, Hiker, Blue Ensign, Golden King, White Ensign, Australian Flag, and New Zealand Flag. Some lesser workings were the Leg Theory, Ironbark, Golden Queen, Golden Crown, and Golden Hill.

One of the first discoveries was the *Golden King* (Retchford's); 13 tons of weathered greisen and soil yielded 123 ounces of gold, but further work disclosed only small scattered patches of payable material.

The *Federal Flag* (30, m) (Reid, 1933) was the richest mine. It is situated near Convict Creek, in rhyolite porphyries and volcanic breccias of the Featherbed Volcanics. A very coarse quartz-feldspar porphyry (probably a dyke) crops out in several places around the mine. Production came mainly from a calcite-fluorite-kaolin vein which was enriched in gold at its intersection with a pyrite (?marcasite) leader, and which had a maximum width of 12 inches. The main shaft, 144 feet deep, is steeply inclined, and has apparently reached an intrusion of acid granite in depth, as is indicated by dump material.

At the *New Zealand Flag* (30, f) a quartz-halloysite vein 3 inches thick contains gold-enriched kaolin at and near its intersection with a flat-dipping joint which carries much iron oxide. Denmead (1934) thought that a ferrous iron solution percolating along the joint acted as a precipitant for the gold.

Mount Wandoo (10)

(Ball, 1918b; Reid, 1932b,d,e; Rutledge & Morton, 1933; Morton, 1935a)

The Mount Wandoo workings are situated 10½ miles west-south-west of Mungana along an abandoned bush track. Gold-mining leases were held as early as 1901, and alluvial gold was worked for some time, but by 1908 the field was deserted. There is little information from this earlier period.

In 1915 leases were taken up again by Alex Macdonald, and by 1932 much development work had been done. The 'Gold and Rare Metals Limited' company worked the lease until 1934, after which the workings were let under tribute. Mining stopped in 1937. During this period a ten-head stamp battery had been erected, and a dam for water supply, tramline, and roads had been constructed. In 1948 Broken Hill South Ltd took up some leases, but relinquished them the same year after trenching had shown very low values, of 1 dwt per ton or less.

The total production for the years 1933 to 1937 amounted to about 2100 ounces of fine gold and 7500 ounces of silver. The ore was sold to the State smelters, either as crude ore or as concentrate.

Mining was centred on two hills on the eastern bank of Muldiva Creek; the more northerly of these, Mount Wandoo, rises 250 feet above the level of Wandoo Creek. Country rocks consist of granulite and gneiss of the Dargalong Metamorphics, together with some mica schist to the north of the hills, and are intruded by some irregular pegmatite veins. The regional strike of foliation is about 330°, and the dip is about 50° north-east at Mount Wandoo. The main workings were concentrated within a zone of altered ferruginous and micaceous gneiss, about 300 yards long. Mineralization seems to have impregnated the whole belt, but is concentrated in more ferruginous and kaolinized veins and fissures which appear to be largely controlled by faulting and jointing. Rutledge & Morton (1933) noted two types of deposit—the more important fissure deposits, and the pipes that are probably formed along the intersection of two joints or fissures. The fissures are generally steeply dipping and much branched, and are sometimes referred to as stockworks. Almost all gold is contained in the sulphide minerals arsenopyrite, pyrite, and chalcopyrite.

There were about half a dozen workings, of which the Hardman shaft was by far the most important. This shaft started at the surface in gold values of about 8 dwt per ton, which at shallow depth increased to 12 dwt per ton. At a depth of 45 feet water-level was reached, and sulphide ore started to come in—this was arsenopyrite in kaolin containing 25 dwt per ton. A large average sample from 100 feet below the surface contained about 2½ ounces of gold per ton.

The maximum shaft depth reached was 190 feet, with a winze going down to 209 feet. Levels were driven at 101, 117, and 125 feet. Ore was stoped above the 125-foot level over a width of 8 feet, which assayed 11.17 dwt (fine gold) per ton from the bulk samples. The richest find here was a 2 or 3 inch thick vein assaying 10 ounces 17 dwt of gold and 15½ ounces of silver per ton over a length of 19 feet. The winze from shaft bottom to 209 feet followed an orebody 1 foot to 5 feet wide, with a length of at least 50 feet, and assaying about 14 dwt per ton.

Pipe-like orebodies were met in the Reid and Wendy shafts; the one in the Wendy shaft was 4 feet by 4 feet in section and yielded 22 dwt of gold per ton.

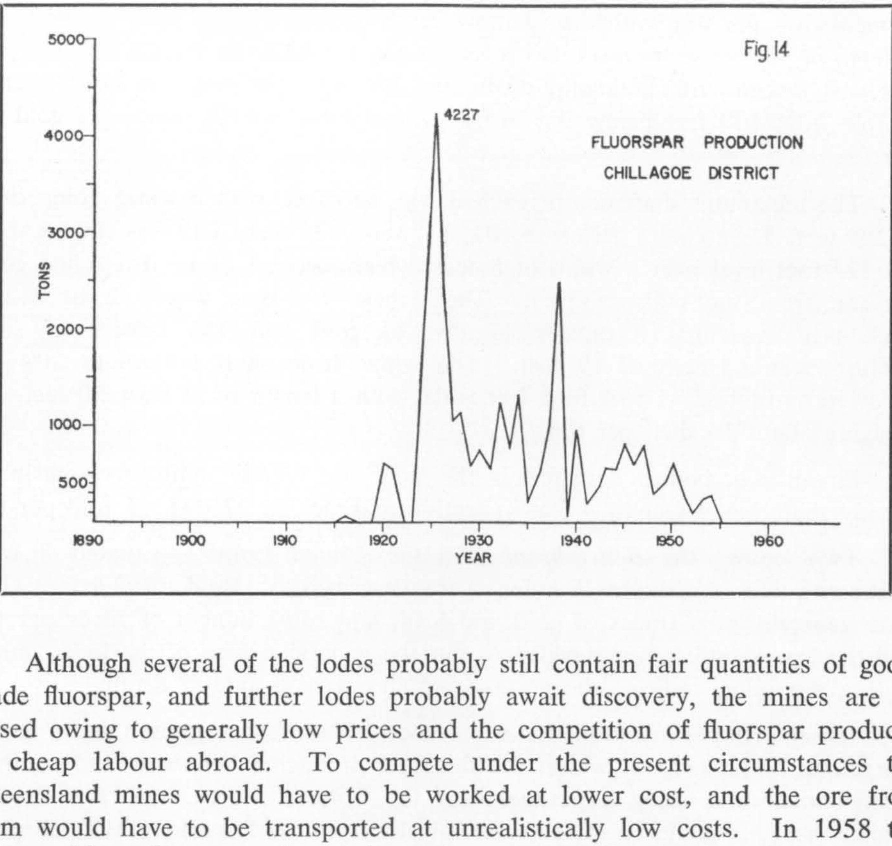
Two leases—the *Beaverbrook* and the *United Empire*—situated 8 miles west-south-west of Mount Wandoo were described by Reid (1932c). There were generally only traces of gold and lead, and some ounces of silver per ton, and the leases were never developed, but the general nature of the lodes might, in Reid's opinion, indicate the presence of an enriched lode at depth.

Jensen (1941) mentioned the presence of auriferous greisen lodes in the Dargalong Metamorphics within the fluorspar-producing belt west and south of Mungana, and, drawing a parallel with the Fluorspar area, saw a reasonable chance that gold could be mined economically from the Dargalong Metamorphics. The gold occurs, as in the Fluorspar area, in rich patches in kaolinitic material formed at the intersections of greisen veins and thin quartz-fluorspar leaders.

The only mine worked for gold in the Chillagoe limestone belt was the *Lucky Tree* (Reid, 1932a; Morton, 1935b), situated in an alluvial plain at about 14 miles from Chillagoe and 7 miles north-west of Almaden. The ore occurred as pipes in metamorphosed limestone and contained copper, lead, and zinc minerals contaminated by some bismuth impurities. The gold content was not high at the surface (15 dwt per ton were reported from one of the samples), but seemed to increase in depth. No figures are known, but production must have been very insignificant.

FLUORSPAR

The Chillagoe Gold and Mineral Field has been Queensland's largest producer of fluorspar. Many of the mines are in the area covered by this Bulletin; others are in the (Rocky) Tate River district. Production started in 1917 with the shipment to New Caledonia of 20 tons from the Mistake mine (51, e).



Although several of the lodes probably still contain fair quantities of good-grade fluorspar, and further lodes probably await discovery, the mines are all closed owing to generally low prices and the competition of fluorspar produced by cheap labour abroad. To compete under the present circumstances the Queensland mines would have to be worked at lower cost, and the ore from them would have to be transported at unrealistically low costs. In 1958 the only workings that showed any signs of recent activity were the Mistake mine and small deposits south of Almaden; the main production in that year came from the Tate River and Bullock Creek areas, south of the region discussed in this paper.

Fluorspar occurs in fissure lodes either in the Permo-Carboniferous granites or in the Dargalong Metamorphics, and is in either case probably introduced by the youngest and most acid phase of the Permo-Carboniferous granites (Elizabeth

Creek Granite). This explains why no fluorspar has been found in the Chillagoe limestone areas: these are intruded by the less acid and slightly older adamellites and granodiorites (Herbert River and Almaden Granites).

The mineral, as a rule, occurs in isolated lenses or in series of lenses, or in sporadic bunches and patches in otherwise barren veins of quartz and brecciated country rock. White, opaque quartz, locally termed 'Bone' because of its coralline or bony appearance, forms the footwall, and in many places, also the hangingwall of the shoots. The fluorspar is generally clear and white, but also green, purple, and brownish. Both fluorspar and quartz occur in more than one generation: brecciated fluorspar has been cemented by later fluorspar, and quartz and chalcedony have replaced fluorspar along cleavage fractures, or have—in rare places—completely replaced octahedral fluorspar crystals.

Within the area under discussion the main fluorspar centres are:

1—a group west of Mungana (15);

2—north and south of the Dargalong lead mines (18, 19, 20);

3—the Fluorspar group (30, h, k, l);

4—workings south-west of Almaden;

5—the Mistake mine, Emuford district (51, e).

Mungana fluorspar mines

(Ridgway, 1945)

Fluorspar was first mined here in 1924 from workings along the original 'Fluoric' line of lodes, later known as the Relief, Midway, and Peter Pan claims (15, f.g.h). This is a large lode system composed of sub-parallel overlapping, and branching fissures, cropping out intermittently over a distance of four miles and trending north-west. The host rocks are the Dargalong Metamorphics, which range from predominantly mica schist in the north-west to granitic gneiss in the south-east.

The best known workings on this lode system are the Condon-Ogilvie, Runner Away, Muldiva, Peter Pan, Midway, Relief, and Pharlap. Other mines in the general area but not forming part of the Fluoric lode system are the Curley's, Dead Dog, and Simpson. Most of these workings have been described and illustrated with plans by Ridgway (1945).

The Pharlap (15, j) is at the southern end of the Fluoric lode system 6.8 miles by road south-south-west of Mungana. The lode strikes 295° in granulite, and dips almost vertically south-west. Workings comprise 6 shafts (the deepest reaching 105 feet), open cut, trenches, and costeans over a distance of some 700 feet. Since Ridgway's examination (1945) work has extended a hundred yards farther north to include two shafts, the deeper of which reached 65 feet. In the bottom of this shaft the fluorspar vein was 5 feet wide. Average grade of ore was 84 percent CaF_2 but water in these workings was a problem.

Much ore was extracted by stoping from the main lode, which was about 7 to 10 feet wide.

The *Relief* (15, h) lies about six miles south-west of Mungana, and on the Fluoric lode system. The lode here is much branched, and the main lode is the most easterly of the branches. According to local information some high-grade ore has been won; the deepest shaft is reported to be 100 feet deep, and has a 6-foot wide 'bony' fluorspar lode showing at the bottom. Most of the workings do not extend below 60 feet. Open-cutting has been almost continuous over 450 feet, but during the last few years the only work done has been the sinking of a 9-foot pit.

Immediately north-west of, and adjacent to, the Relief is the *Midway* claim (15, g), which comprises shafts, 26 and 56 feet deep, and trenches. From the deeper shaft 60 tons of 90 percent fluorspar was won. A vein 2 feet wide was seen in the 26-foot-deep shaft. Ore from the Midway averaged 88 percent CaF_2.

The *Invicta* has two shafts 25 and 26 feet deep, and is situated north of the Peter Pan. A vein of fluorspar 6 inches wide is present in the bottom of the shafts.

The *Peter Pan* workings (15, f) adjoin the Midway claim. In a now inaccessible timbered shaft 33 feet deep the fluorspar vein was 3 feet 6 inches wide. West of this a shaft 60 feet deep was sunk, and bottomed on 5 feet of fluorspar. 'Bone' quartz forms the footwall and granitic gneiss the hangingwall. Workings indicate a lens some 250 feet long.

In the same lode system and about three-quarters of a mile north-west of the Peter Pan lies the *Muldiva* (15, e) with workings spread out over 100 feet along the 3-foot wide lode. The deepest shaft was 50 feet.

The *Runner Away,* or *Soldier Bill* (15, d), lies about one quarter of a mile north-west of the Muldiva. Two shallow open cuts opened up this lode for a distance of 58 feet. The 3-foot-wide vein carried 9 inches of clean fluorspar. No development has been carried out since 1945.

About three-quarters of a mile north-west of the Runner Away, the main *Condon - Ogilvie* workings (15, c) occur in mica schist striking 305°. Workings on the other three branches are only shallow. From the main line of lode some clear, high-grade ore (95 percent) has been won. Soft ground made the western branch of the lode difficult to work. Two ore-shoots were mined over stretches of 70 and 140 feet. Three shafts have been sunk, and more than 1500 tons of good-grade ore have been taken out, according to local inhabitants.

Simpson's workings (15, i) are situated on Harry's Creek, a tributary of Wandoo Creek, about 3 miles south-west from the Relief and Midway workings on Muldiva Creek. The lode is very distinct, and occupies a fissure striking north-west and dipping steeply south-west in the Dargalon Metamorphics. It has been worked over a distance of 1100 feet. The average width of the fluorspar was 2 to 3 feet, and the average grade of ore was 85 percent CaF_2. The deepest working was a 70-foot shaft.

Curley's mine (15, a) comprised shafts and trenches over a length of 450 feet in granulite and gneiss with amphibolite intrusions. The deposit lies about nine miles by road west of Mungana. The lode strikes 200°, dips 85° west, and is about 3 feet wide. 'Bone' quartz occurs on the footwall and country rock in the hangingwall. Some of the fluorspar sold assayed up to 92 percent CaF_2; average grade was 88 percent. The main period of production was around 1937.

Other localities in the Mungana area from which fluorspar has been won include the Dead Dog Creek, where trenches on a 15-inch vein have yielded 9 tons of ore, and an occurrence near Windy Gully on the Wandoo track west of Muldiva.

Dargalong area (18, 19, 20)

(Ridgway, 1945)

In the Dargalong area the most important workings are those of the *Jackson* group (20), about four miles south-east from the Pharlap, and virtually on the projected continuation of the Fluoric lode system. The group consists of a long line of workings along a 'bone'-type quartz lode which can be traced—with some breaks—through muscovite granite. The deposit lies about nine road miles south-west of Chillagoe. Access is by the Bolwarra road and thence across country for about three miles. The lode strikes along Little Dargalong Creek at 330°, and dips nearly vertically. It consists of two roughly parallel veins, the more easterly of which has been worked over 800 feet, the other over 135 feet. Fluorspar veins are up to 6 feet wide, bounded by quartz and chalcedony. The fluorspar is clear and commonly contains 85 percent CaF_2, or more. Workings include trenches, costeans, and shafts, the deepest being 90 feet. The most recent lease of this property was taken up in 1958 by Messrs. Black and Fitzgerald.

Less than half a mile south of the Jackson two fluorspar veins with some branchings were opened up over stretches of 210 feet and 25 feet.

About 1 mile east of the Pharlap mine, and on Muldiva Creek, is a fluorspar mine which was probably known as Stewart's. Fluorspar occurs in a fissure lode in granulite, mica schist, and gneiss in the vicinity of augen gneiss and intrusive andesite. The lode strikes 320° and dips 75° south-west. Visible workings extend over 300 feet, and have exposed a vein, 12 inches wide, of clear, white, and brownish fluorite with grades ranging up to 86 percent CaF_2.

Shaw's workings lie four miles east of the Pharlap mine on Muldiva Creek. The lode is in gneiss, strikes 320°, and has been worked over a length of 150 feet.

Approximately 1½ miles south-south-west of the Jubilee mine, Dargalong, a trench 10 feet long has exposed a fluorspar-quartz vein striking 355°.

Fluorspar group (30, h, k, 1)
(Ridgway, 1945)

The Fluorspar group of workings includes a number of gold mines and only one fluorspar lode of any significance: the *Perseverance* (30, h). Mining from the Perseverance lode, which is situated on the bank of Crooked Creek about 7 miles west by north of Almaden, was first reported in 1921, but records of production were not kept until 1923. The mine was worked from 1924 to 1928 by the 'Fluorspar Limited' company, and produced 7300 tons of ore during that period. There was some sporadic activity after 1944.

The lode is a fissure vein in hornblende-biotite granodiorite; it strikes east-north-east, dips nearly vertically south-east, and contains almost continuous lenses of fluorspar enveloped in 'bone' quartz. Workings, which include shafts, trenches, and open cuts, extend over a length of 1850 feet, though concentrated within a stretch of 1000 feet. The maximum width of the lode is 7 feet, the maximum depth worked rarely exceeds 50 feet. One shaft reached a depth of 100 feet, showing a fluorspar vein 2 feet wide at the bottom. The lode branches at its eastern end. Ridgway (1945), assuming the depth of the lode to be proportionate to its length, estimated that some 30,000 tons of ore might be available down to a depth of several hundred feet.

Samples assayed at the Chillagoe smelters in 1923 gave the following results:

	percent
average clean fluorspar	97.30 CaF_2
	1.11 $CaCO_3$
violet-tinted fluorspar	95.25 CaF_2
	1.64 $CaCO_3$
green-tinted fluorspar	96.06 CaF_2
	1.56 $CaCO_3$

Apart from the Perseverance, there are some small fluorspar veins about a mile east of the mine, and half a mile south-west of the Federal Flag gold mine.

Workings south-west of Almaden

The *Eaglehawk* mine (37, a) was re-opened at the end of 1951 by W. Black, and was worked until 1954. The lode, 9.3 miles by road south-west of Almaden, comprises three veins of colourless to green fluorspar separated by bone quartz striking 205° and dipping nearly vertically in hornblende-biotite adamellite.

The workings are shallow (up to 46 feet deep) and extend only 160 feet along the lode. The greatest vein width is about 1 foot. A State Government assay of a chip sample taken across the vein in 1958 gave:

	percent
CaF_2	69.0
SiO_2	23.7
$CaCO_3$	0.5
Fe_2O_3	0.7

About 1 mile east of the Eaglehawk, two small lodes with fluorspar veins 2 to 4 feet wide have been worked by Black, Fitzgerald, and others.

Emuford area

The *Mistake* mine (Saint-Smith, 1917b; Ridgway, 1945), a mixed wolfram-fluorspar mine, lies about eight miles by road south-east of Petford, and was the first fluorspar producer in the Chillagoe district. In 1920 and 1921 the 'Industrial Pigment Co. Ltd' worked the mine for a yield of 1140 tons of fluorspar.

The lode occupies a vertical fissure in granite and greisen, and strikes east of north. The granite is crushed near the lode, which is possible evidence of part of the important fault-line that separates the Mount Garnet Formation from the Hodgkinson Formation farther to the north.

The older development work has been described by Saint-Smith (1917b). The lode reached a width of 9 feet, and contained fluorspar shoots up to 6 feet thick, and averaging 3 feet. The best wolfram ore appears to have occurred in shoots in the middle of the orebody where finely granular wolframite transgressed the fluorspar in stringers. The lode was opened up over a distance of 500 feet at the surface, and, at the 160-foot level, workings extended for 400 feet along the lode. These workings are now inaccessible.

After having been idle for several years the mine was re-opened in 1958 by Black and McEwan, who sank a vertical shaft to 44 feet on the northern extension of the lode. From this level they had driven, at the time of inspection, 87 feet along the lode in fluorspar ore with a width of up to 4½ feet. Wolframite is fine-grained, and chiefly concentrated on the western side of the drive. There is some irregular quartz veining. Fracture planes filled with crushed fluorite and ferruginous clay commonly run parallel to the lode. At the 30-foot level the operators drove north for at least 25 feet, extracting fluorspar from veins up to 5 feet wide.

IRON

Contact-metasomatic iron deposits are common in the Chillagoe Formation along the contact zones of the granite intrusions. Most are small and discontinuous, but some have been worked to provide flux material for the Chillagoe smelters. The deposits are most abundant in the limestone members of the formation, and are usually described as 'ironstone', a term describing any lode with an appreciable iron content, though such lodes are commonly highly siliceous. In the richer 'ironstones' magnetite and hematite are generally the chief iron minerals, and are commonly associated with garnet, which, in places, predominates over the iron minerals. In some deposits, copper and lead minerals were present in sufficient quantities to be worked, as in the 'ironstone' breccias at the Harper (27, f) and at Redcap (22, a-b).

Mount Lucy (34) (Dunstan, 1905c, 1906) is the only iron deposit of any importance in the Chillagoe district; it was a regular producer of flux ore for the Chillagoe smelters. The upper part of a low hill, 150 feet high, and about three miles west of Almaden on the Chillagoe-Almaden road, is largely composed of a magnetite-hematite mixture with associated garnet. Granite crops out on all sides of the deposit, which is about 700 feet long by 50 feet wide, and has a vertical extent of about 50 feet. Workings consist of a number of open cuts on the higher-grade portions. The total recorded production has been 45,344 tons, which represents roughly 58 percent of the recorded output of the Chillagoe district. In 1905 Dunstan estimated the reserves at 350,000 tons.

The magnetite-hematite is separated from the granite in many places by a garnet skarn-rock. Dunstan ascribed the ironstone to surface weathering of garnet; Denmead (1934d) later came to a similar conclusion for magnetite-hematite ore in the Calcifer area.

An assay of Mount Lucy iron ore gave the following values (Dunstan, 1906):

	percent
Ferrous oxide	6.81
Ferric oxide	90.30
Manganese oxide	0.60
Alumina	1.22
Silica	0.57
Phosphorus	nil
Tungstic acid	nil
	99.50

Many of the other ironstone deposits in the Chillagoe district were worked for associated copper and lead, but some in addition yielded flux ore. The best-known of these were the *Ti-tree* (26, g), the *Boomerang* (27 c), and the *Hobson* (27, d).

Denmead (1934d), after examining the ironstone outcrops at Calcifer, concluded that they were surface concentrations of an original garnet-magnetite mixture, because in all shafts the iron ore became disseminated or disappeared at fairly shallow depth.

LIME

One of the predominant lithological units in the Chillagoe Formation is limestone. It occurs interbedded with chert, quartz greywacke, and siltstone in a north-north-west trending belt from near Almaden to the Walsh River (and beyond), a distance of some 35 miles within the boundaries of the area mapped. The belt has a maximum width of about four miles. The limestone, normally light grey and finely crystalline, is coarsely recrystallized to a white, soft marble, or to calc-silicate hornfelses where the limestone was impure, around granite intrusions. Most of the limestone quarried has been used for chemical and agricultural purposes: the sugar-cane districts of Cairns and Innisfail consume much of the product. In the past the lime was also used as a flux in the smelters.

The main deposit is at *Ootann* (43), 7 miles south of Almaden, and is the only centre in the Chillagoe district producing limestone at present. Limestone is quarried from bluffs forming part of a large roof pendant block of sediments in granite. Reserves are very large, and the leases—Crotty No. 1 and Crotty No. 2—are well situated here, because they are alongside the Cairns-Forsayth railway, and are in an area not depleted of wood.

Massive limestone is worked for burned lime, and coarsely crystalline calcite for crushed lime. The colour of the rock ranges from white to grey, pink, blue grey, and cream; veins of coarse calcite and siderite and some silica are present. The calcium carbonate content is generally about 97 percent; iron oxide ranges up to 1.7 percent, and the silica content is low. A calcium carbonate content of not less than 90 percent is required for marketing.

After blasting, the coarse calcite is hand-sorted for fine grinding in a ball mill, and is subsequently packed and shipped in 1 cwt bags. In 1958 production of crushed lime for agricultural purposes was at the rate of 30 tons a day. The massive limestone is broken in a jaw crusher into fragments not more than 4 inches across, and is then burnt in a roasting kiln. The burnt product is bagged in 204-pound bags. The output of burnt lime averaged about 30 tons per week in 1958, and is used mainly in the refinement of sugar.

During the old mining days limestone was quarried as a flux mineral from several quarries near Mungana, Chillagoe, and Calcifer, and Messrs Sycamore and Demchok produced burnt lime near the Griffith mine only a few years ago.

'Earthy lime' (travertine), derived by weathering from the Chillagoe limestones, has been deposited in gullies and depressions, and is used in agriculture. The Mungana Lime Supply Co. for several years worked a deposit in a gully several hundred yards north of Rookwood Homestead; the workings measured 54 feet by 25 feet and had a maximum depth of 8 feet. The lime is soft and earthy and contains small amounts of scattered limestone nodules near the surface.

About 1 mile north of Rookwood, on the Wrotham Park road, the same company worked an open cut measuring 43 feet by 24 feet, and with a depth of about 6 feet.

A third deposit, *O'Shea's Earthy Lime* (33), is situated four miles north-west of Almaden on the Manipota track near Four Mile Creek. The pit here measures about 35 feet by 35 feet by 5 feet deep.

'Iceland Spar' (Morton, 1944a) in the form of coarse calcite crystals up to 9 inches across, occurs in veins near Deep Creek, 1 mile from Rookwood Homestead. The crystals are marred by cleavage planes and twinning lamellae, and their transparency is not perfect, so that they are not suitable for use in the optical industry.

Deposits of coarse white marble along granite contacts offer some economic potential as building and monumental stone. The marble has few impurities, and has been used locally for tombstones.

Minor Mineral Occurrences

Several minerals other than those described in the foregoing pages are known to be present in the district, but their occurrences are uneconomic and of mineralogical interest only.

Antimony — Only a few occurrences have been recorded from the area. A hundred yards north of the Mistake fluorspar mine (51, e) several prospect holes sunk on a hill on well-jointed granite and greisen have revealed stibnite and cervantite in two thin quartz veins 8 inches and 2 inches wide, and striking 035°. Stibnite has also been recorded from the deeper workings of the old Queen lease at Dargalong. Jensen (1941) mentioned antimony lodes at Scardon's Camp (45).

Clay — Bricks used in the Chillagoe smelter stack and buildings were made from local clays from the limestone areas around Chillagoe. One such deposit was situated about two miles from the town, and was worked to a depth of 8 feet. No investigations have been made of the clay reserves; there is no local demand for bricks, and, even if good clay reserves exist, brick-making without a local market is not an economic proposition.

Coal — Coal was found in 1910 by a Mr Conroy three miles north-east of Koorboora, in a very impure and small deposit (47, t) (Q.G.M.J., 1910). The deposit is one mile north of the Chillagoe railway and its discovery aroused great interest; mining was at a peak at the time and the Chillagoe smelters needed considerable quantities of fuel. At the instigation of the Chillagoe Railway and Mines Ltd several underlie shafts were sunk, but the coal and carbonaceous shale proved to be not of commercial value.

The coal is associated with flaggy sandstone and grey waterlaid tuff which occur near, and form part of, the base of the Featherbed Volcanics. The outcrop is of very limited extent and represents a small depositional area only. A thickness of 6 to 8 feet has been reported for the coal bed. The dips in the sediments are less than 5°. The coal is soft and crumbly and probably has an extremely high ash content. Samples taken for micropalaeontological investigations in 1961 proved devoid of spores and pollen, which were presumably destroyed by the heat of overlying extrusions.

Cobalt (Jensen, 1941) — The only cobalt known from the Chillagoe district occurs in the *Cambourne* lode (22, e), south-west of Mount Redcap. Two parallel lodes, each 6 to 8 feet wide and approximately 130 feet apart, are separated by fine-grained basalt and contain two shafts with a maximum depth of 150 feet. The East Cambourne lode dips to the south-west, the Main Cambourne lode dips steeply to the north-east. They are lined by garnet replacement rock through which runs a core of gossanous 'ironstone'. In both lodes cobalt occurs over about 100 feet as cobaltite associated with chalcopyrite and some chalcocite, and a little erythrite at the surface.

Although some rich patches and specimens were found, the bulk of the ore is low-grade and not of commercial value. Grab samples taken at random from the Cambourne lode by Shaw and Sycamore in 1953 showed no more than a trace of cobalt. Metal Explorations drilled the lode in 1956, but the results were discouraging.

Manganese — At Redcap, manganese 'wad', manganiferous 'ironstone', and nodular manganese ore occupy a large part of the lode exposure. Cerussite penetrates this manganiferous material. The MnO content is normally about 15 percent, and there are no indications that the deposit has any economic possibilities.

An isolated manganiferous outcrop (55) was noted in a railway cutting 1 mile west of Lappa Junction, near the Petford-Almaden road. The ore is highly siliceous and contains a psilomelane-type mineral associated with a joint-plane in rhyolite near its contact with the Palaeozoic sediments. A dyke of hornblende-quartz diorite is exposed nearby. The deposit is small and has no economic significance.

About a quarter of a mile north-west of Mungana, an old shaft (63) in highly manganiferous 'ironstone' shows copper staining, but was probably sunk for gold.

'Pyrolusite' has been identified in the Otho lode, south-east of Chillagoe (between 26, b and e).

Mica (Owen, 1942; Morton & Ridgway, 1944a) — The pegmatites in the Dargalong Metamorphics carry muscovite, but only in the *Mount Kitchin* area (3) has the mica been segregated in books large enough to be of any interest.

The Mount Kitchin mica prospects are located near Barker's Creek 30 miles west of Chillagoe and 11 miles south-west of Cardross. Mica was noted here in 1915, and in 1942 six leases were held. The quartz-feldspar-mica pegmatites occur in gneiss and granulite of the Dargalong Metamorphics as dykes and patches with circular outline, which at first were thought to be pipe-like bodies. Subsequent investigation, however, showed the 'pipes' to be pockets and segregations, cutting out at shallow depth, and the Mount Kitchin deposits were therefore written off as a commercial prospect.

The mica occurs in books up to 1 foot square. Much of the surface material is weathered and soft, warped, fractured, and stained, but good quality mica, free from inclusions and only little stained, has also been taken from this deposit. The mica seems to be most often associated with the quartz in the pegmatites.

The workings are concentrated in a zone striking about 070^0, and include open cuts and shallow vertical and inclined shafts; the deepest shaft went down to 33 feet on the old Wonder Lease. In 1941 the area produced about 2 cwt of roughly trimmed mica; in 1942 the leases were taken over as a war-time measure by the Controller of Mineral Production; the inadequate dimensions of the deposits were recognized, and there has been no subsequent production.

In 1891 leases to work mica were taken up in the Wandoo area, but no details are known. Jack (1898) noted mica at the head of Wandoo Creek, but gave no details.

Quartz — Appreciable tonnages of fine-grained, sugary, very pure quartzite from the *Silica Quarry* (26, b), about half a mile east of Chillagoe, have been used as metallurgical flux at the Chillagoe smelters. The outcrop extends along the railway line for several hundred yards. The quartzite is possibly a completely silicified limestone, in view of its sugary texture and extreme purity.

The only commercial quartz crystals produced in Queensland have come from a vug in the wolframite pipes at the *Enterprise* mine, Wolfram Camp (60, f). Dumps at the mine supplied several tons of quartz crystals, of which only 24 pounds were accepted as suitable for piezo-electric uses. The vug that contained the quartz crystals was about 300 feet below the surface, and there are probably others present in the wolframite pipes.

Titanium — Rutile in lode form occurs in two areas in the Chillagoe district. Lode rutile was first reported in 1945 from the Muldiva Creek area in schist, augen gneiss, and quartzite of the Dargalong Metamorphics, intruded by irregular pegmatitic and aplitic veins. Rutile, in the form of subangular to angular grains, occurs in thin bands up to half an inch thick in an equigranular quartz-feldspar rock. Some mica is visible along the foliation planes. Clear quartz veins run parallel to the foliation and rutile seams, giving the rock a gneissic appearance. A basic dyke striking north-east cuts the 'lode'. Weathered parts of the rocks have a somewhat saccharoidal texture, and are firm, yet crumbly when struck. The 'lode' strikes 290° and dips 60° south-west, and is contained within an area of about 600 feet by 90 feet. The middle layer of the 'orebody' carries the highest concentration of rutile—about 40 percent—and is up to 9 inches thick.

In 1953 Dowsett Engineering (Aust.) Pty Ltd took up a lease on the deposit. Eleven prospecting holes were sunk. In 1955, 6 tons, 8 cwt of ore were treated at the Great Northern Battery, Herberton, for a yield of 1 ton, 13 cwt, 2 qr of concentrate, reputed to contain 86 percent titanium oxide.

The tonnage available seems too small to attract commercial interest, and from surface observations the chances of locating extensions of the lode or other deposits appear remote.

A lease application was made for rutile mining in the Lappa area in 1953 —the Patrick No. 2. No further details are known.

Uranium — The areas indicated on the map of radioactive anomalies in the Chillagoe-Einasleigh-Gilberton region (BMR, 1955), and some of those noted during the 1958 magnetometer and scintillometer aerial survey, were investigated on the ground by means of geiger counter traverses, without success.

For some time a uranium prospecting permit was held over a section of the Featherbed Volcanics north-east of Almaden. Results of prospecting are not known.

An unidentified uranium mineral associated with wolframite and tungstic ochre in a quartz lode in greisen has been recorded from the Tommy Burns tin mine.

The occurrence 'at a wolfram mine at Lappa' of torbernite associated with wolframite, molybdenite, and bismuth in a quartz-topaz-hematite lode in granite also appears in records.

CONCLUSIONS AND RECOMMENDATIONS

The rapid intensive development of the Chillagoe Field is a thing of the past, and is not likely to be repeated. The easy-to-find surface deposits of the copper and lead contact lodes have probably all been discovered, and most of their richer parts have been mined out. Single discoveries may still be made, but would not lead to a large-scale re-opening of the field. Several orebodies are undoubtedly still present at depth, but they would be difficult to find and assess, and the irregularity and comparatively small size of the contact deposits in the area generally makes them not very attractive at present. However, should further exploration be contemplated in the future, then attention should be given to the Zillmanton and the Cardross areas as the first logical test targets: Zillmanton, because geophysical work has pin-pointed a possible ore-bearing zone 1½ miles long, with well-defined anomalies, and with alluvium-covered stretches that have never been adequately prospected; furthermore, a drill-hole in Reid's section is reported to have intersected ore assaying 3 percent copper between the 260 and 361-foot levels; Cardross, because drill-holes have shown

4 to 10-foot sections of 10 to 20 percent ore, a zone of secondary enrichment is commonly well developed, the grade of the primary ore appears to lie within a range of 2 to 6 percent copper, and (low-grade) lodes have been reported to be consistent and extensive. However, results of testing of Cardross by Broken Hill South Ltd in 1962/63 did not bear out the optimistic expectations.

Hopes for the presence of large tonnages of low-grade disseminated copper ore at Ruddygore have not been borne out by Mount Isa Mines Ltd's test-drilling in 1960, although it does appear that this programme by no means dispelled all prospects here: core recovery was unsatisfactory, and results were not exhaustive. Some testing of the large bodies of altered ferruginous granodiorite found by Dallwitz and Morgan (pers. comm.) in the area east and north-east of Ruddygore in 1961 may be warranted.

The largest known reserves of low-grade copper ore, some 350,000 tons of flux ore, are left at the Ti-tree deposit.

A revival of wolframite and molybdenite mining on a large scale seems improbable: most pipes have probably been found, and their upper parts have been depleted. But, although the pipes are too small and difficult to locate for mining at any scale at depth, there remains a possibility that the disseminated type of ore might exist in sufficient quantity to make it a mining proposition.

Although tin mineralization in the Chillagoe district has not reached the same intensity as in the neighbouring Herberton area, there is scope for surprises, as the example of the Dover Castle mine has shown. This mine had been considered 'dead' when the shaft was at a depth of some 300 feet, but subsequent sinking opened up a further rich ore-shoot which has since been followed down to about 560 feet (1961) with no decline in values. Though this mine is of a type somewhat different from the other tin deposits in the district—it occurs in volcanics, instead of in sediments, and the lode is more sharply defined than usual—the example shows that local beliefs are not a reliable measuring stick, and it is conceivable that testing at depth in the Koorboora and Sunnymount areas may prove successful in places.

Fluorspar appears to be a mineral with a promising future. There is an ever-increasing world demand, particularly in the chemical industry—which, in the U.S.A., for instance, consumed 200 percent more fluorspar in 1957 than in 1950. Several of the lodes in the Chillagoe district contain considerable reserves, and, where the required 97 percent CaF_2 grade for acid-grade fluorspar is not present, lower-grade and disseminated ore can be beneficiated by flotation. However, to compete with imported ore from low-wage countries, costs would have to be reduced all round: the only obvious way in which this might be done is by a large-scale open-pitting operation, for which the fluorspar veins are not suited, although it is not inconceivable that the right circumstances might exist in the area.

At the time of writing a diamond drilling programme to prove fluorspar reserves was scheduled by the Queensland Department of Mines.

The once-significant minerals of the Chillagoe Field may not be mined again to any extent, but the area may still have prospects in minerals which held no interest in its hey-day. A widening industrial demand offers attractive prices for minerals which would not have been sought in the most active days of the area, yet the geological setting is right for some of them. An example is beryl, and the other minerals of beryllium. The metal commonly occurs in contact-metasomatic skarn rocks, in pegmatites, in high-temperature quartz veins, and in greisens; minerals commonly associated are fluorite (which adds to the attraction of the fluorspar lodes), topaz, wolframite, molybdenite, magnetite, and a variety of skarn minerals; and beryllium is often associated with alkalic granites. All these mineralogical and geological conditions are widely represented in the Chillagoe district, which therefore should be considered a favourable prospecting area for beryllium, particularly as improving extraction techniques may dispense with the necessity for the hand-sorting that favours low-wage producers.

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APPENDIX 1

INDEX TO MINE LOCALITY MAP (See plate 13)

Reference No.	Atherton RAAF, 1951 Run & Photo No.	Product	Name of Mine or Prospect
1	1/5029	Cu	?
2	2/5105	,,	?
3	3/5113	Mica	Mount Kitchin
4	1/5029	Cu	Arizona group of workings
5	1/5031	Cu (Au, Pb, Ag)	Cardross - Arbouin group:
a			Chieftain
b			Keppoch
c			Caledonia
d			Klondyke
e			Clansman
6	2/5105	Cu	Spaniard
7	,,	,,	Mountain Maid
8	1/5035	,,	Buchanan's ?
9	2/5101	Ti	Muldiva Creek Lode Rutile
10	2/5099	Au	Mount Wandoo mines
11	1/5037	Ca (earth)	Rookwood
12	,,	,, ,,	,,
13	2/5099	Cu	Jubilee
14	,,	,,	Red Hill
15		F	Mungana Fluorspar mines:
a	2/5099		Curleys
b	,,		Dead Dog
c	,,		Condon - Ogilvie
d	,,		Runner Away
e	,,		Muldiva
f	,,		Peter Pan
g	,,		Midway
h	,,		Relief
i	3/5119		Simpsons
j	3/5119		Pharlap
16	3/5121	Cu	Mount Delaney
17	,,	,,	?
18	3/5121	F	?
19	4/5179	,,	?
20	3/5121	,,	Jackson Group:
a			Jackson
21	3/5121	Pb, Ag, (Cu)	Dargalong Group:
a			Jubilee
22	2/5097	Cu, Pb	Redcap Group:
a			Redcap
b			Queenslander
c			Morrison
d			Tarantula, Victoria
e	2/5097	Cu	Belgravia, Puppet
f	,,	Cu, Co	Cambourne
g	,,	,,	McIlwraith and Penzance
h	,,	,,	Nellie
23	,,	Ag, Pb, Cu	Mungana Mines:
a			Girofla
b			Lady Jane
c			Dorothy
d			Moffatt's
e			Red Dome
f			Magazine Face
g			Nordville
h			Calumet
i			Griffiths

Reference No.	Atherton RAAF, 1951 Run & Photo No.	Product	Name of Mine or Prospect
24	2/5095	Cu	Zillmanton:
a			Shannon shafts
b			Zillmanton shafts
25	2/5093	"	Ruddygore
26	3/5125	Pb, Ag, Cu	Chillagoe Mines:
a		Pb, Ag	Chillagoe Consols
b		Si	Silica Quarry
c		Cu	Atherton
d		Pb, Ag, Cu	Christmas Gift
e		" " "	Lyonite Hills
f		Pb, Cu	?
g		Cu	Ti-tree
h		Pb, Ag, Cu	Upper Hensey (west end)
i		" " "	Big Hensey (west end)
j		" " "	Big Hensey (east end)
k		" " "	Fortunata
27	3/5125		Calcifer group:
a		Pb, Ag, Cu	?
b		Cu	?
c		"	Boomerang
d		"	Hobson
e		Cu, Ag	Five Chain Bend
f		Cu	Harper
28	3/5125	"	(small workings)
29	4/5175	"	?
30	4/5173		Fluorspar Group:
a		Au	Leg Theory
b		"	Hikers
c		"	Ironbark
d		"	Blue Ensign
e		"	Retchfords (Golden King)
f	4/5173	Au	New Zealand Flag
g		"	?
h		F	Perseverance
i		Au	Australian Flag
j		Cu	Gibraltar
k		F	?
l		"	?
m		Au	Federal Flag
31	5/5137	Pb, Ag, Cu	Maniopota workings
32	"	Cu	?
33	"	Co (earth)	O'Sheas
34	"	Fe	Mount Lucy
35	5/5135		Muldiva Mines:
a		Cu	{ Muldiva
		Cu, Pb, Zn	{ Eclipse
b		Pb, Ag, Cu	Paisley
36	5/5235	F	?
37	6/5187	F	Fluorspar workings, Almaden
a			Eaglehawk
38	7/5029		Khartoum District:
a		W	Mount Riddell
b		Mo	Murrays
c		"	Ajax
d		"	Kitchener
39		Mo	(small workings)
40	7/5029	Pb, Cu	?
41	"	Cu	?
42	"	Pb, Cu	?
43	"	Ca	Crotty Nos. 1 & 2
44	"	Cu	David

Reference No.	Atherton RAAF, 1951 Run & Photo No.	Product	Name of Mine or Prospect
45	4/5171		Scardon's workings
a		W	Scardon"s Top Camp
b		W, Mo	Scardon's Bottom Camp
46	5/5139	Pb, Ag	Torpy's Crooked Creek Mine
47			Koorboora Mines:
a	6/5181	Sn	Bismarck Creek (alluvial)
b	"	"	?
c	"	"	?
d	"	"	?
e	"	Pb, Ag	Bonzer Conroy's
f	"	Sn	?
g	"	"	Southwick
h	"	"	Argo
i	"	"	Iolanthe ?
j	6/5181	Sn	Proserpine
k	"	"	Shakespeare
l	"	"	Try Again ?
m	"	Sn, Pb, Ag	Tennyson
n	"	" " "	?
o	"	Sn	Fair Play
p	"	W	Neville, Mavis Bruce, Telegraph
q	7/5023	W	?
r	6/5181	Sn	Two Jacks
s	"	"	Dalnotter
t	"	C	(minor occurrence)
48	7/5023	Sn	Sunnymount Group:
a			Kerosene Tin
b			O'Shea's Prospect
c			Prince Alfred
d			Cyclone
e			Cabbage Patch
f			Tommy Burns
g			Christmas Gift
h			New Years Gift
49	8/5076	W	Indicator
50	8/5078	Sn	(alluvial workings)
51			Emuford Group (part of):
a	7/5019	Sn	Chance
b	"	W	Spotted Dog
c	"	Cu	?
d	"	Sn	?
e	"	F, W	Mistake
f	"	W	Gold Rod
g	"	Sn, Cu	Brown Snake
h	"	W	?
i	"	W	Sydney
j	"	W	?
k	"	W, Cu	Mystery
l	"	W	?
52	6/5177	Ag, Pb	Silver Spray
53	"	Cu	Emerald Hill
54	6/5179	Sn	Mountain Maid
55	"	Mn	(mineral occurrence)
56	5/5145	Pb, Cu	?
57	5/5145		Bamford Hill Mines:
a		W, Mo	Shady Corner
b		Mo	?
c		W, Mo, Bi	Sunny Corner
d		" " "	Canberra
e		" " "	Extended

Reference No.	Atherton RAAF, 1951 Run & Photo No.	Product	Name of Mine or Prospect
			Bamfield Hill Mines (Continued)
f		,, ,, ,,	Haymaker
g		,, ,, ,,	KY
h		,, ,, ,,	Davis
i		,, ,, ,,	Forget-Me-Not
j		,, ,, ,,	Brandon
k		Mo	?
l		W, Mo, Bi	Gillian Bridge
m		,, ,, ,,	Osbourne
n		,, ,, ,,	Ferguson
o		,, ,, ,,	Nelson's
p		,, ,, ,,	Rose of Queensland
q		,, ,, ,,	Rollinson
r		,, ,, ,,	Winters
s		,, ,, ,,	Plum Pudding
t		,, ,, ,,	Ballarat
u		,, ,, ,,	Tigers Tail
v		Sn	Federal
58	5/5143		Dover Castle Group:
a		Sn	King Midas
b		,,	Dover Castle
c		Ag, Pb	Comstock
d		,, ,,	Silver Bead
e		,, ,,	Better Luck
f		Pb, Zn	?
g		Sn	Christmas Gift
59	4/5165	Mo, W	Eight Mile Mine (Petford)
60	2/5083		Wolfram Camp Mines:
a		W, Mo, Bi	Forget-Me-Not
b		,, ,, ,,	Leisner
c		,, ,, ,,	Larkin
d		,, ,, ,,	Murphy
e		,, ,, ,,	Harp of Erin
f		,, ,, ,,	Enterprise
g		,, ,, ,,	Victory
h		,, ,, ,,	Finnigan
i		,, ,, ,,	Avoca
j		,, ,, ,,	Killarney
k		,, ,, ,,	Nil Desperandum
l	2/5083	W, Mo, Bi	Pinwell
m		,, ,, ,,	Mulligan
n		,, ,, ,,	Tully
61	1/5050	W	Four Mile workings
62	,,	Sn	Eight Mile mine
63	2/5097	Au, Mn, Cu	? (working at Mungana)

APPENDIX 2

MAPS, PLANS AND SECTIONS OF MINES ON THE ALMADEN, CHILLAGOE AND MUNGANA ONE-MILE SHEETS ON FILE AT THE GEOLOGICAL SURVEY OF QUEENSLAND OFFICE

PART 1

G.S.Q. Ref. No.	Area	Subject	Authority — Author or Owner	Scale (to 1″)
1/7	Bamford	K.Y. workings, plans and projected sections	Geological Survey Office	20 ft.
,,	,,	Ferguson United plan	,, ,, ,,	20 ft.
,,	,,	Plan showing positions of present workings (1953) based on plan by L. C. Ball	,, ,, ,,	4 ch.
,,	,,	Northern United plan	,, ,, ,,	20 ft.
,,	,,	Forget-me-not plan and sections (longit.)	,, ,, ,,	20 ft.
,,	,,	Brandon plan and sections (longit.)	,, ,, ,,	20 ft.
1	Chillagoe	Calcifer group of leases, plan	Chillagoe Railway & Mines Ltd.	8 ch.
2	,,	,, ,, ,, ,, ,,	,, ,, ,, ,,	8 ch.
3	,,	Fortunata ,, ,, ,, ,,	,, ,, ,, ,,	8 ch.
4	,,	Mungana ,, ,, ,, ,,	,, ,, ,, ,,	8 ch.
5	,,	Otho ,, ,, ,, ,,	,, ,, ,, ,,	8 ch.
6	,,	Redcap		
7	,,	Ruddygore ,, ,, ,,	,, ,, ,, ,,	8 ch.
9	,,	Redcap grp., Mungana grp., Villmanton grp.,		
	,,	Redcap grp., Mungana grp., Zillmanton grp., Calcifer grp., and Harper grp.	Chillagoe Gold and Min. Field (1940)	20 ch.
10	,,	Chillago, Consols M.L. 14	Chillagoe State Smelters & Mines	30 ft.
12	,,	Lady Jane section (longit.)	,, ,, ,, ,,	30 ft.
13	,,	,, ,, surface plan	Mungana (Chillagoe) Mg. Co. Ltd.	30 ft.
14	,,	,, ,, section	Chillagoe State Smelters & Mines	60 ft.
15	Chillagoe	Girofla section (longit.)	,, ,, ,, ,,	30 ft.
16	,,	,, ,, ,,	,, ,, ,, ,,	30 ft.
17	,,	Calumet & No. 1 Shafts 24 M (1901) section (longit.)	Mungana (Chillagoe) Mg. Co. Ltd.	30 ft.
19	,,	Queenslander 14 M plan	Chillagoe Railway & Mines Ltd.	30 ft.
20	,,	Queenslander 14 M Section (longit.)	,, ,, ,, ,,	60 ft.
21	,,	Nellie 5 M; work to 1905 plan	,, ,, ,, ,,	30 ft.

G.S.Q. Ref. No.	Area	Subject	Authority — Author or Owner	Scale (to 1″)
22	„	McIlwraith and Penzance 7 M plan	Chillagoe Railway & Mines Ltd.	30 ft.
23	„	„ „ „ 7 M 1905 sections (longit. & cross)	„ „ „ „	30 ft.
24	„	South Penzance work to 1907 plan		30 ft.
25	„	Redcap ML 683 plan	Chillagoe State Smelters & Mines	30 ft.
26	„	Ruddygore 25 M plan	Chillagoe Railway & Mines Ltd.	30 ft.
27	„	„ 25 M cross sections	„ „ „ „	30 ft.
28	„	Zillmanton plan	„ „ „ „	4 ch.
29	„	Zillmanton-Reid Shaft section (longit.)	„ „ „ „	50 ft.
30	„	„ 23 M, 250 and 350 ft. level plan	„ „ „ „	100 ft.
31	„	„ 23 M, longit. section	„ „ „ „	100 ft.
32	„	„ 23 M, No. 1 Shaft cross section	„ „ „ „	50 ft.
33	„	„ 23 M, No. 2 Shaft cross section	„ „ „ „	50 ft.
34	„	„ 23 M, No. 2 Shaft „ „	„ „ „ „	50 ft.
35	„	„ 23 M, proposed No. 4 air shaft cross section	„ „ „ „	50 ft.
36	„	„ 22 M, Reid shaft cross section	„ „ „ „	50 ft.
37	„	„ 22 M, Reid shaft working plan	„ „ „ „	50 ft.
38	Chillagoe	Eclipse - Muldiva ML 30 (1912) plan	Chillagoe Railway & Mines Ltd.	30 ft.
41	„	Chillagoe - Mungana area, geological map	AGGSNA Q502 plate 2 sheet 1 Jensen 1941	40 ch.
41A	„	Fluorspar - Silica area, geological map	AGGSNA Q503 plate 2 sheet 2 Jensen 1941	40 ch.
42	„	Fluorspar grp. of mines, geological map	AGGSNA	500 ft.
43	„	Harper grp. of mines, geological map	„	200 ft.
44	„	Blue Ensign plan of mines, geological map	„	50 ft.
45	„	Otho, Hensey, Ti-tree group, geological map	„	600 ft.
46	„	Federal Flag, sketch plan	„	50 ft.
47	„	Redcap plan	„	8 ch.
48	„	Mungana plan	„	8 ch.
49	„	Zillmanton, geological map	„	1,200 ft. approx.
50	„	Mungana, Kaolin workings sketch plan	„	20 paces
51	„	Red Dome workings plan	„	50 ft.
1/15	„	Girofla Mine, plan of all levels, showing work to 1925	Chillagoe State Smelters & Mines	30 ft.
	„	Girofla Mine No. 2 Longit. section	„ „ „ „	30 ft.
	„	„ „ Plan 100 ft. level	„ „ „ „	30 ft.

G.S.Q. Ref. No.	Area	Subject	Authority — Author or Owner	Scale (to 1″)
	,,	,, ,, Plan 200 ft. level	Chillagoe State Smelters & Mines	30 ft.
	,,	,, ,, Plan 300 ft. level		30 ft.
	,,	,, ,, Plan 410 ft. level	,, ,, ,, ,,	30 ft.
	,,	,, ,, Plan 510 ft. level	,, ,, ,, ,,	30 ft.
	,,	,, ,, Plan 610 ft. level	,, ,, ,, ,,	30 ft.
1/15	Chillagoe	Girofla Mine, Plan 714 ft. level	,, ,, ,, ,,	30 ft.
	,,	,, ,, Section (cross)	Mungana (Chillagoe) Mg. Coy.	30 ft.
	,,	,, ,, Longit. Section	Chillagoe State Smelters & Mines	30 ft.
	,,	Queenslander 14 M, plan work done to 1908	New Chillagoe Rlwy. & Mines Ltd.	30 ft.
1/22	,,	Lady Jane Section	Mungana (Chillagoe) Mg. Coy.	30 ft.
	,,	,, ,, Plan and Section Workings in 1887	,, ,, ,, ,,	20 ft.
	,,	,, ,, 300 ft. level plan	,, ,, ,, ,,	30 ft.
	,,	,, ,, Plan showing work to 1926	Chillagoe State Smelters & Mines	30 ft.
	,,	,, ,, Plan to 1928	,, ,, ,, ,,	30 ft.
	,,	,, ,, Longit. Sectn. showing work to 1926	,, ,, ,, ,,	30 ft.
	,,	,, ,, Plan work done March 1910-March 1911 150, 210 and 420 levels	Mungana (Chillagoe) Mg. Coy.	
AP/104	,,	Redcap Plans (30-39) accompanying report by Broadhurst 1953	Broken Hill South Ltd.	
1/22	,,	Redcap Plan diamond drill holes	New Chillagoe Rlwy. & Mines Ltd.	50 ft.
	,,	Lady Jane 210 ft., 150 ft., 120 ft. levels, cross section	Mungana (Chillagoe) Mining Co. Ltd.	30 ft.
	,,	Hensey 67 Plan (1904)	,, ,, ,, ,, ,,	30 ft.
	,,	Morrison Section (longit.), showing assay values (1904)	New Chillagoe Rlwy. & Mines Ltd.	30 ft.
	,,	Ti-Tree D.D. Bores plan	,, ,, ,, ,, ,,	50 ft.
	,,	,, ,, ,, section	,, ,, ,, ,, ,,	30 ft.
	,,	Wilson Lease D.D. Hole plan	Chillagoe State Smelters & Mines	40 ft.
	,,	,, ,, No. 1 D.D. Section	,, ,, ,, ,,	20 ft.
	,,	,, ,, No. 2 D.D. Section	,, ,, ,, ,,	8 ft.
1/22	Chillagoe	,, ,, No. 3 D.D. Section	Chillagoe State Smelters & Mines	8 ft.
	,,	,, ,, New Shaft Cross Section	,, ,, ,, ,,	8 ft.
1/28	,,	Mt. Wandoo Gold Mine, plan of workings	———	20 ft.
1/30	,,	Morrison Mine Cross Section, showing 3 schemes for testing lode deeper	Chillagoe Railway & Mines Ltd.	30 ft.
1/33	Mungana	I.G.E.S. Electrical Sec. Mungana Equipotential Reconnaissance	I.G.E.S.	100 ft.
1/38	Chillagoe	Queenslander 14 M section	New Chillagoe Rlwy. & Mines Ltd.	30 ft.
		,, ,, summary ore reserves (1908)	,, ,, ,, ,, ,,	

G.S.Q. Ref. No.	Area	Subject	Authority — Author or Owner	Scale (to 1")
AP/121	Mungana	Plans, Geological Mapping, Red Dome area &	Chillagoe Prospecting Syndicate	110 ft.
1/3	Herberton & Chillagoe	Sketch Map of Herberton and Chillagoe G & M. Field carrying geological information	———	6 mile
	Wolfram	Wolfram mining map	Geological Survey Office	5 ch.
AP/93		Redcap Area, including Queenslander, Morrison, Penzance, McIlwraith & Nellie plans & sections	Broken Hill South Ltd.	
AP/94	,,	Redcap area, plans and sections	,, ,, ,, ,,	
AP/95	,,	Ruddygore, plans and sections	,, ,, ,, ,,	
AP/96	,,	Girofla and Lady Jane, plans and sections	,, ,, ,, ,,	
AP/99	,,	Eastern portion of Mungana Lode, including Griffith, Calumet and Magazine. Face plans and sections.	,, ,, ,, ,,	
AP/108	,,	Mungana field, plans and sections 1-29	,, ,, ,, ,,	
AP/109	,,	Ruddygore, plans and sections	,, ,, ,, ,,	
AP/23	,,	Walsh R.	Chillagoe Oil Prospect	

MAPS, PLANS AND SECTIONS OF MINES ON THE ALMADEN, CHILLAGOE AND MUNGANA ONE-MILE SHEETS ON FILE AT THE GEOLOGICAL SURVEY OF QUEENSLAND OFFICE

Part 2: Plans by E. Broadhurst of the Mount Redcap area, accompanying final report to Broken Hill South Ltd, April 1948.

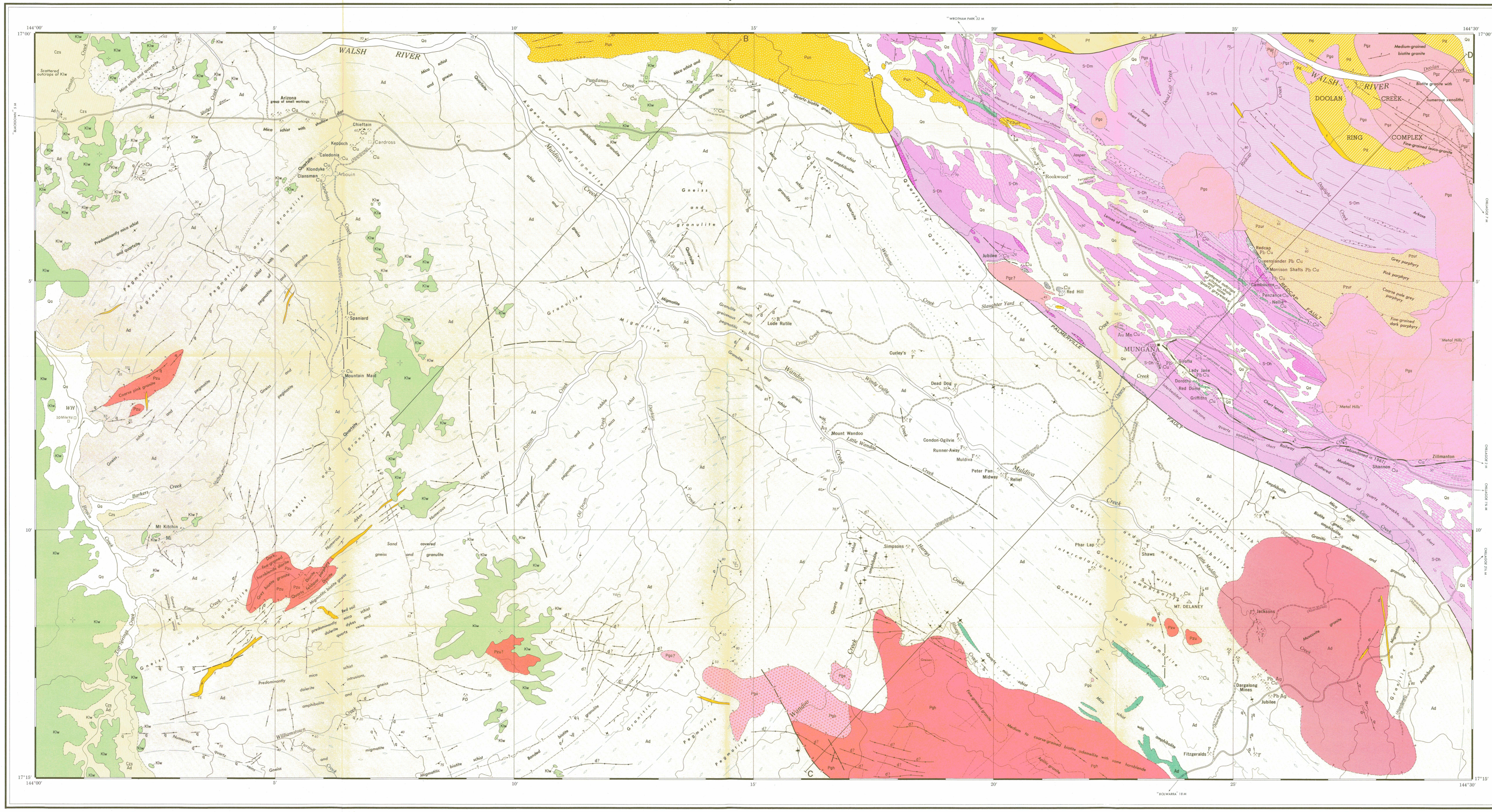
Q.G.S. Ref. No.	Subject
3/1	Regional Plan.
3/2	Outcrop and Boundary Map.
3/3	Surface Plan—Geological Interpretation.
3/4	Cross Section at 6,000 N.
3/5	Redcap Tunnel Level—early data.
3/6	Queenslander 117 ft. Level.
3/7	Queenslander 160 ft. Level.
3/8	Queenslander 200 ft. Level.
3/9	Queenslander Cross Section.
3/10	Queenslander Longitudinal Projection.
3/11	Morrison No. 1 Level.
3/12	Morrison No. 2 Level.
3/13	Morrison No. 3 Level.
3/14	Morrison Cross Section.
3/15	Morrison Longitudinal Projection.
3/16	Morrison Section showing assay values.
3/17	McIlwraith 60 ft. Level.
3/18	McIlwraith 80ft. Level.
3/19	McIlwraith 150 ft. Level.
3/20	McIlwraith 250 ft. Level.
3/21	McIlwraith and Penzance Cross Section; McIlwraith Longitudinal Projection.
3/22	Penzance Longitudinal Projection.
3/23	Nellie 70 ft. Level.
3/24	Nellie 95 ft. Level.
3/25	Nellie 145 ft. Level.
3/26	Nellie Cross Section.
3/27	Victoria 100 ft. Level.
	Plans prepared by M. L. Wade, April 1948 to August 1949, showing results of exploration during that period.
3/28	Redcap Tunnel Level—Assay Plan.
3/29	Redcap Longitudinal Section through Tunnel.
3/34	Redcap E-W Section 9210 N.
3/35	Redcap E-W Section 9010 N.
3/36	Redcap Assay Plan—Central Portion.
3/37	Redcap Assay Plan—Northern End.
3/38	Redcap Surface Plan.
3/39	Redcap Assay Plan—Southern End.
3/40	Redcap Assay Plan—Southern Extension.
3/42	Queenslander Cross Section across Main Shaft.
3/43	Queenslander E-W Section 7950 N.
3/44	Redcap Plans down No. 1 winze.
3/46	Redcap E-W Section No. 1 winze.

Q.G.S. Ref. No.	Subject
3/47	Redcap Plans down No. 1 winze.
3/48	Redcap N-S Section along west wall open cut.
3/49	Redcap E-W Section 9180 N.
3/50	Redcap Section through No. 1 Shaft and South Winze.
3/51	Redcap Tunnel Level—Geological Interpretation.
3/52	Redcap N-S Section No. 1 Winze.
3/54	Redcap E-W Section down No. 2 Shaft.
3/55	Redcap N-S Section along Eastern Lens.
3/56	Redcap E-W Section 8900 N, showing suggested d. d. hole Plans accompanying report by E. Broadhurst, Dec., 1949:
3/57	Redcap Geological Interpretation 1″ = 100′.
3/58	Redcap Geological Interpretation 1″ = 200′.
	Plans showing geophysical results, 1930 Survey, and plates accompanying geophysical report by Bureau of Mineral Resources, 1950:—
3/60	I.G.E.S. Equipotential Reconnaissance Survey, 1930.
3/61	Plate G84-1 Plan of Chillagoe-Mungana District, showing locations of areas surveyed.
3/62	Plate G84-2 Mungana Area: Geology, Geophysical Layout and axes of Electromagnetic Indications.
3/63	Plate G84-3 Mungana Area: Electromagnetic Profiles for Real Horizontal and Vertical Components.
3/64	Plate G84-4 Mungana Area: Magnetic Vertical Force Profiles.
3/65	Plate G84-5 Shannon-Zillmanton Area: Geology, Geophysical Layouts and Axes of Electromagnetic Indications.
3/66	Plate G84-6 Zillmanton Area: Electromagnetic Profiles for Real Horizontal and Vertical Components.
3/67	Plate G84-7 Zillmanton Area: Gravity Profiles and Plan showing Correlation between E. M. Axis and known ore.
3/68	Plate G84-8 Shannon Area: Electromagnetic Profiles for Real Horizontal and Vertical Components.
3/69	Plate G84-9 Shannon Area: Electromagnetic Profiles (Imaginary Components) and results of Resistivity Tests.
3/70	Plate G84-10 Shannon Area: Magnetic vertical force profile.
3/71	Plate G84-11 Redcap-Queenslander Area: Plan showing Geology, Geophysical Layouts and Axes of Electromagnetic Indications.
3/72	Plate G84-12 Redcap Area: Electromagnetic Profiles for Real and Imaginary Horizontal and Vertical Components.
3/73	Plate G84-13 Redcap Area: Gravity Profiles and Contours.
3/74	Plate G84-14 Redcap Area: Results of Magnetic Survey and Resistivity Tests.
3/75	Plate G84-15 Queenslander Area: Electromagnetic Profiles for Real and Imaginary Horizontal and Vertical Components.
	Plans showing results of drilling 1950-1951:
3/76	Redcap-Queenslander Longitudinal Projection.
3/77	Redcap-Queensland Cross-sections 74OON-84OON.
3/78	Redcap-Queenslander Cross-sections 86ON-960ON.
	Plans accompanying notes by C. J. Sullivan, August, 1951:
3/79	Redcap-Queenslander Longitudinal section.
3/80	Redcap Section through No. 1 Shaft and South Winze.
3/81	Redcap Section through No. 1 and 3 Diamond Drill holes.

MUNGANA
QUEENSLAND

AUSTRALIA 1:63,360 — 1 MILE GEOLOGICAL SERIES — SHEET 54 ZONE 7

FIRST EDITION 1964



Reference

QUATERNARY		Qa	Alluvium and soil
		Czs	Sand derived from Klw
LOWER CRETACEOUS	Wrotham Park Sandstone	Klw	Sandstone, conglomerate, some shale
			Dyke or vein (Predominantly air-photo interpretation) and analysis, δ - dolerite, q - quartz, qp - coarse quartz-feldspar porphyry, r - rhyolite
(LOWER TRIASSIC?) - UPPER PERMIAN	Undifferentiated Granites	Pgu	Hornblende granite, muscovite biotite granite, coarse pink granite
	Elizabeth Creek Granite	Pge	Pink biotite granite, micrographic-porphyry, fine-grained leuco-granite
	Featherbed Volcanics	Pf	Felsite, tuff, massive grey ignimbrite
	Almaden Granite	Pga	Grey, biotite-hornblende adamellite and granodiorite
	Almaden Granite?	Pga	Biotite-hornblende granodiorite and hypersthene-augite-quartz diorite
	Herbert River Granite	Pgh	Pale-pink to grey, medium-grained biotite adamellite, with hornblende
	Nychum Volcanics	Pun	Grey ignimbrite and pyroclastic basal agglomerate; Agglomerate
	Doolan Creek Rhyodacite	Pd	Grey or greenish, porphyritic rhyodacite and dellenite
PERMIAN ?	Undifferentiated Volcanics	Pvur	Grey, pink or dark, porphyritic micro-adamellite
LOWER DEVONIAN - (UPPER SILURIAN ?)	Mount Garnet Formation	S-Dm	Quartz greywacke, siltstone, with subordinate chert, conglomerate, sandstone and sedimentary breccia; Main conglomerate lenses; Main chert lenses
(LOWER DEVONIAN ?) - UPPER SILURIAN	Chillagoe Formation	S-Dh	Massive reef limestone
		S-Dh	Limestone breccia or conglomerate
		S-Dh	Bedded chert
		S-Dh	Conglomerate
		S-Dh	Quartz greywacke, siltstone, sandstone, some mudstone
		S-Dh	Basic volcanics
		S-Dh	Quartz sandstone, quartz siltstone
ARCHAEAN?	Dargalong Metamorphics	Ad	Muscovite granite, non-foliated
		Ad	Predominantly pegmatite and granitic gneiss
		Ad	Predominantly quartz-mica schist with quartzite
		Ad	Predominantly mica schist
		Ad	Amphibolite

CAINOZOIC — MESOZOIC — PALAEOZOIC — PRECAMBRIAN

- Geological boundary
- Syncline
- Fault
- 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
- 20 Strike and dip of strata
- Prevailing direction of dip of strata
- Vertical strata
- 75 Overturned strata
- Prevailing dip of highly deformed strata
- Strike and dip of disturbed strata
- Strike of disturbed vertical strata
- Top of bedding
- Direction of sedimentation — air-photo interpretation
- Trend lines — air-photo interpretation
- Joint pattern — air-photo interpretation
- Horizontal strata — air-photo interpretation
- 60 Strike and dip of metamorphic foliation and schistosity
- Vertical foliation and schistosity
- Generalized strike of vertical undulating foliation
- 20 Direction and plunge of lineation
- 30 60 Foliation with plunge of lineation
- 40 Strike and dip of platy flow in igneous rocks
- Vertical platy flow
- Gossan, ferruginous lode
- Mine, open cut or prospect
- Alluvial workings
- Ag Silver
- Au Gold
- Cu Copper
- F Fluorspar
- Ls Travertine
- Mi Mica
- Mn Manganese
- Pb Lead
- R Rutile
- Smelter (deserted or abandoned)
- Bore or well with windpump
- S Spring
- WH Waterhole
- Road
- Vehicle track
- Railway (abandoned in 1961)
- Telegraph line
- "Rookwood" Homestead
- Dwelling
- Yd Yard
- Site of former mining town, now abandoned
- Trigonometrical station
- 1123′ Height in feet, instrument levelled; datum: mean sea level
- PD Position doubtful

Compiled and published by the Bureau of Mineral Resources, Geology and Geophysics, Department of National Development, in conjunction with the Geological Survey of Queensland. Topographic base compiled by the Division of National Mapping, Department of National Development. Aerial photography by the Royal Australian Air Force; complete vertical coverage at 1:50,000 scale. Transverse Mercator Projection.

Geology, 1958, by: F. de Keyser and M.B. Bayly (B.M.R.); K.W. Wolff (Q.G.S.)
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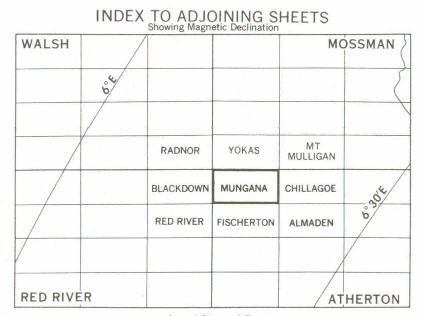
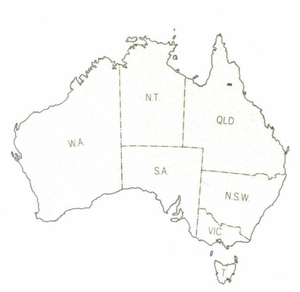
Drawn by: Drafting Section, Department of Mines, Queensland.

INDEX TO ADJOINING SHEETS

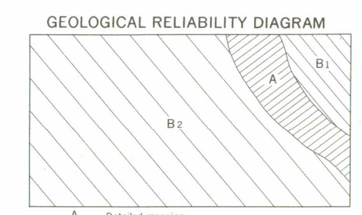




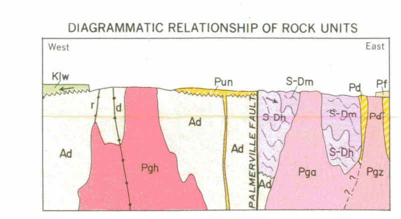
Scale
1 Mile to 1 Inch

MILES — KILOMETRES

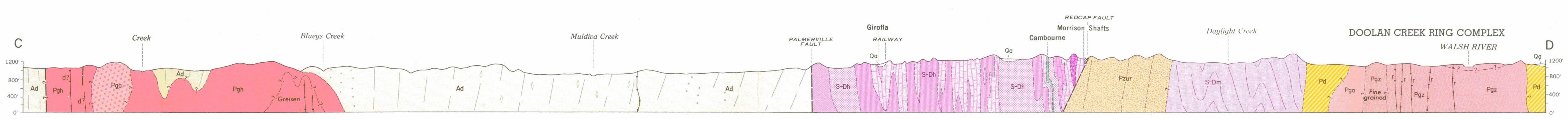
GEOLOGICAL RELIABILITY DIAGRAM



DIAGRAMMATIC RELATIONSHIP OF ROCK UNITS



Sections
(Vertical exaggeration ×2.5)



Printed by Mercury Press, Hobart

MUNGANA
SHEET 54 ZONE 7

Copies of this map may be obtained from the Bureau of Mineral Resources, Geology and Geophysics, Canberra, A.C.T., or the Geological Survey of Queensland, Brisbane.

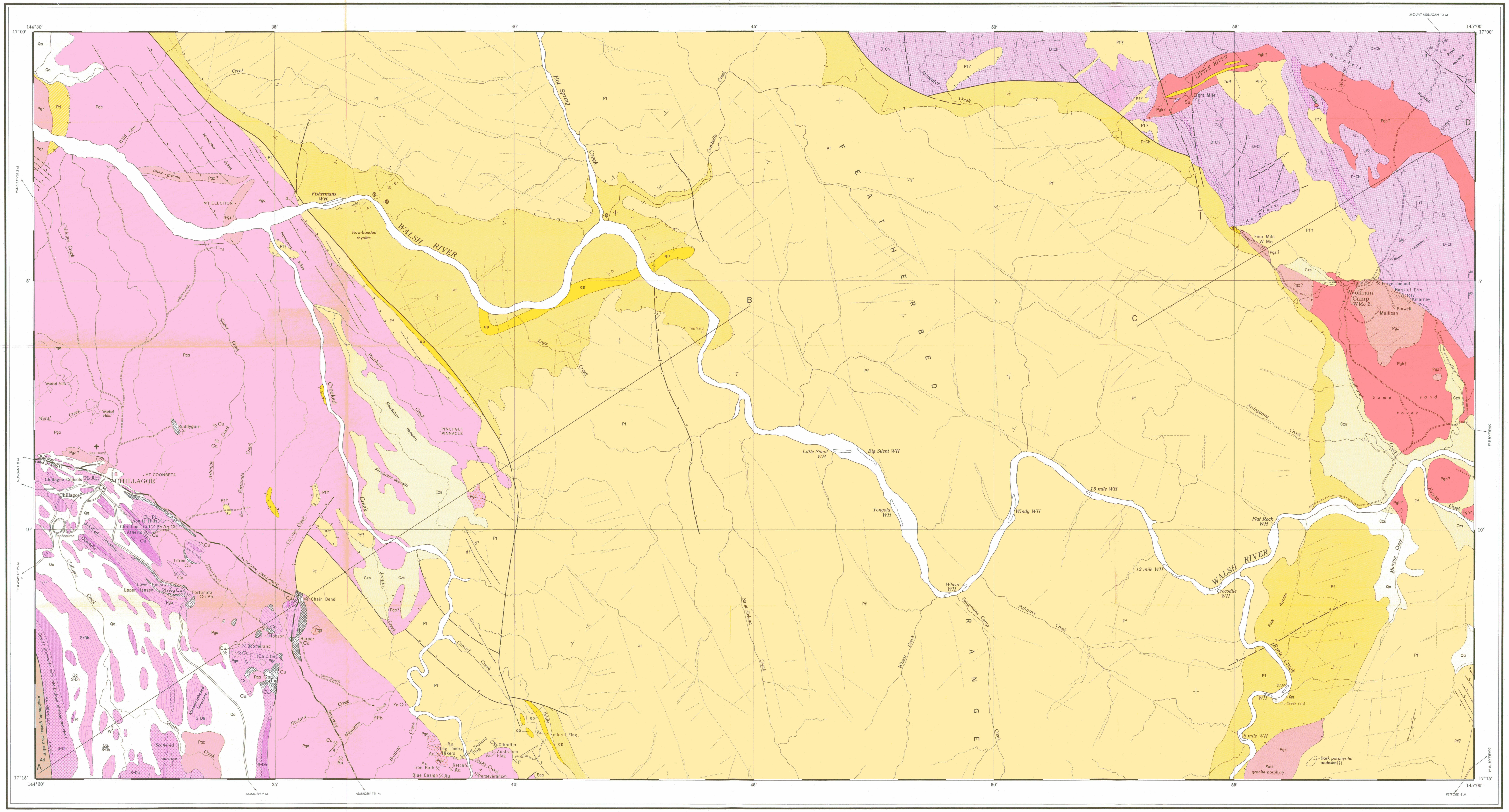
AUSTRALIA 1:63,360

CHILLAGOE

QUEENSLAND

1 MILE GEOLOGICAL SERIES SHEET 55 ZONE 7

FIRST EDITION 1964



Reference

CAINOZOIC	QUATERNARY		Qa	Alluvium and soil
			Czs	Granite sand and sheet flood deposits
PALAEOZOIC	UPPER PALAEOZOIC			Dykes: d - dolerite, q - quartz, qp - coarse quartz-feldspar porphry, r - rhyolite
		Elizabeth Creek Granite	Pgz	Pink, leucocratic, biotite granite, granite porphyry; aplite
		Featherbed Volcanics	Pf	Massive, dark grey ignimbrites
			Pf	Acid, pale-weathered flows and pyroclastics commonly flow-banded
		Almaden Granite	Pga	Grey, biotite-hornblende adamellite and granodiorite
		Almaden Granite?	Pga	Biotite-hornblende quartz diorite and granodiorite
		Herbert River Granite	Pgh	Soft pink to grey, hornblende-biotite adamellite
		Doolan Creek Rhyodacite	Pd	Grey or greenish, red-weathered, porphyritic rhyodacite and dellenite
	L. CARBONIFEROUS -MIDDLE DEVONIAN	Hodgkinson Formation	D-Ch	Micaceous and feldspathic greywacke, siltstone, shale, subordinate chert, conglomerate, breccia; Main chert lenses
	(LOWER DEVONIAN?) -UPPER SILURIAN	Chillagoe Formation	S-Dh	Massive reef limestone
			S-Dh	Limestone breccia or conglomerate
			S-Dh	Chert
			S-Dh	Quartz greywacke and siltstone
PRECAMBRIAN	ARCHAEAN?	Dargalong Metamorphics	Ad	Amphibolite, gneiss, mica schist, quartz schist

- Geological boundary
- Fault
- 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
- Overturned strata
- Dip < 15° (air-photo interpretation)
- Horizontal strata (air-photo interpretation)
- Joint pattern (air-photo interpretation)
- Trend lines (air-photo interpretation)
- Strike and dip of platy flow
- Platy flow, vertical
- Direction of sedimentation
- Top of bed
- Gossan, replacement lode, skarn rock
- Fe Magnetite - hematite rock
- Gn Garnet
- Hot Spring
- W Well
- Windpump
- Dam
- WH Waterhole
- •Cu Minor mineral occurrence
- Mine, open cut or prospect
- Ag Silver
- Au Gold
- Bi Bismuth
- Cu Copper
- F Fluorspar
- Pb Lead
- Mo Molybdenum
- W Tungsten
- Sn Tin
- Road
- Vehicle track
- Railway with station
- Landing ground
- Telegraph line
- "Chillagoe" Homestead
- Dwelling
- Site of former village, now abandoned
- Treatment plant, smelter (deserted)

Compiled and published by the Bureau of Mineral Resources, Geology and Geophysics, Department of National Development, in conjunction with the Geological Survey of Queensland. Topographic base compiled by the Division of National Mapping, Department of National Development. Aerial photography by the Royal Australian Air Force; complete vertical coverage at 1:50,000 scale. Transverse Mercator Projection.

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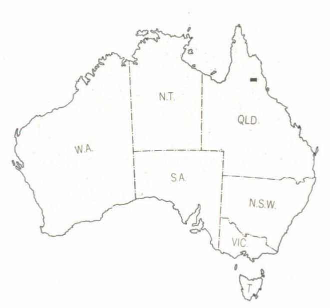
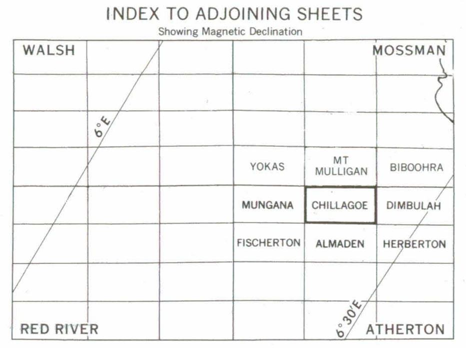


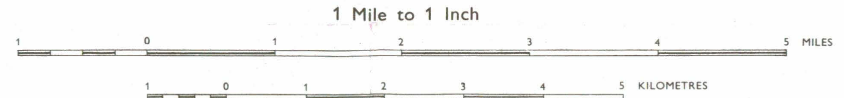
INDEX TO ADJOINING SHEETS

Showing Magnetic Declination

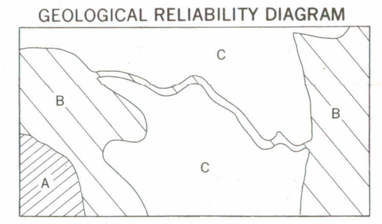


Scale

1 Mile to 1 Inch

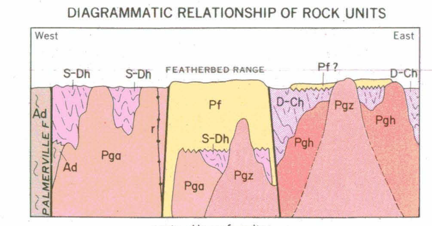


GEOLOGICAL RELIABILITY DIAGRAM



A Detailed mapping
B Reconnaissance: traverses and air-photo interpretation
C Air-photo interpretation only

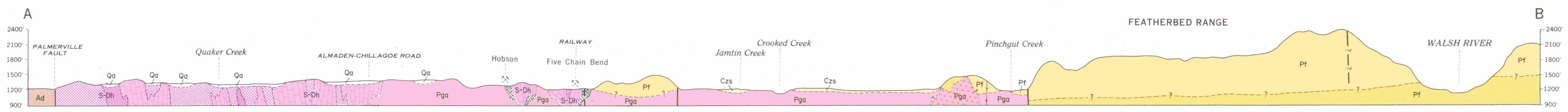
DIAGRAMMATIC RELATIONSHIP OF ROCK UNITS

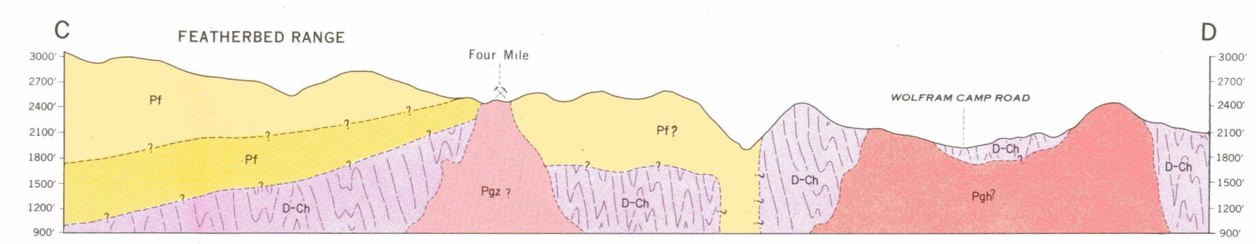


CHILLAGOE
SHEET 55 ZONE 7

Sections

(Folding diagrammatic)





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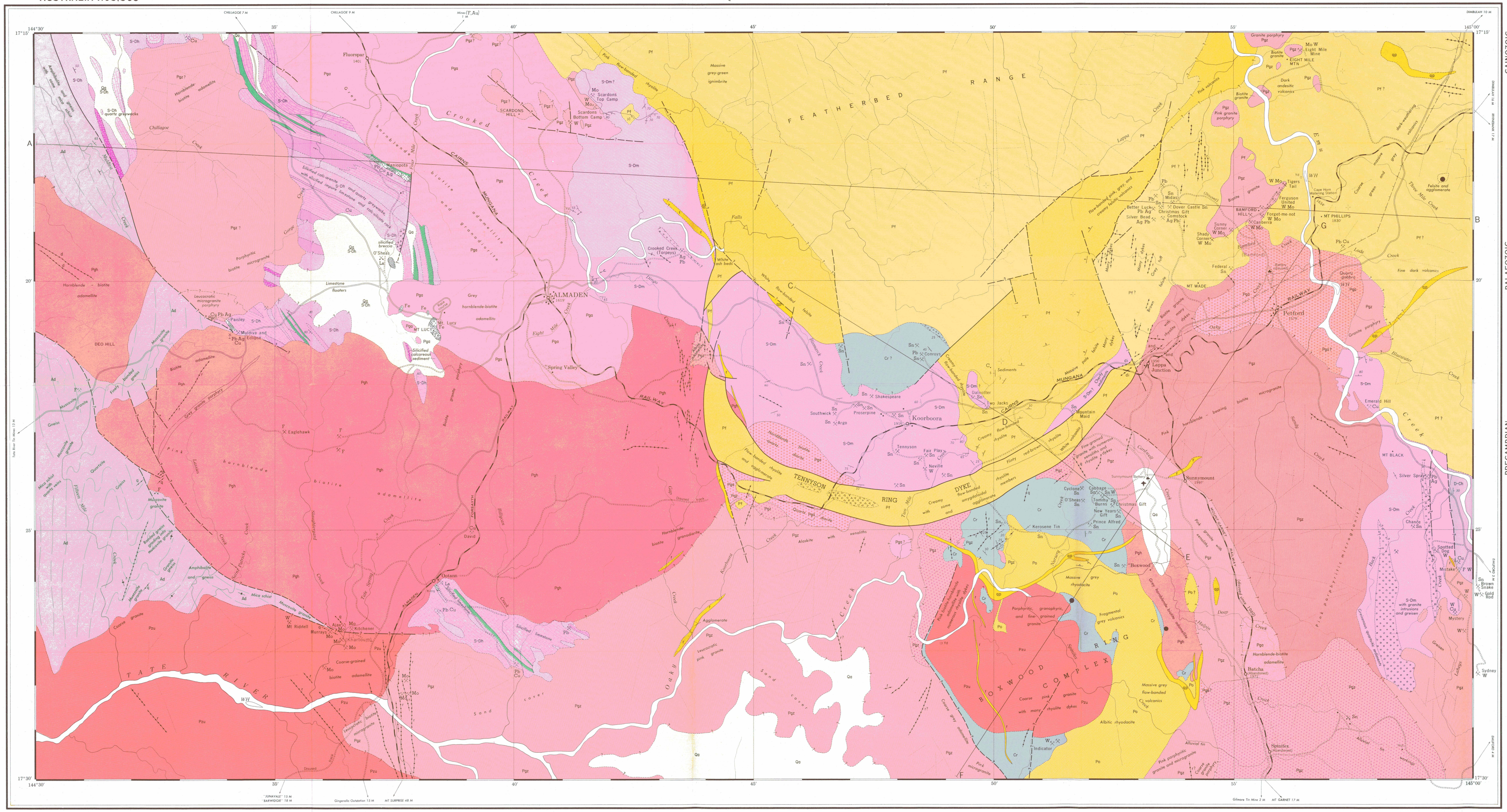
ALMADEN
QUEENSLAND

AUSTRALIA 1:63,360 — 1 MILE GEOLOGICAL SERIES — SHEET 60 ZONE 7

FIRST EDITION 1964



Reference

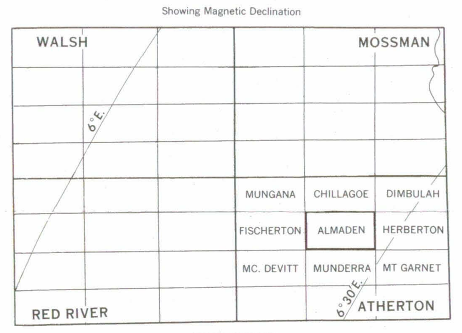
CAINOZOIC	QUATERNARY		Qa	Alluvium, soil, sand
PALAEOZOIC	(LOWER TRIASSIC?) -UPPER PERMIAN			Dykes and-andesite, d-dolerite, di-diorite, q-quartz, qp-coarse quartz-feldspar porphyry, r-rhyolite
		Undifferentiated Granites	Pzu	Undifferentiated Herbert River and Elizabeth Creek Granite (Tate River Area) Porphyritic, granophyric, fine-grained and medium-grained varieties of granite and adamellite (Ooky Creek-Boxwood Area)
		Elizabeth Creek Granite?	Pgz ?	Grey to pink, fine-grained, hornblende-biotite microgranite
		Elizabeth Creek Granite	Pgz	Pink biotite granite; granite porphyry; fine-grained biotite microgranite; aplite
			Pgz	Coarse, pegmatitic, leucocratic, pink-red microcline granite
		Featherbed Volcanics	Pf	Massive, dark grey and green acid ignimbrites
			Pf	Acid, pale weathered flows and pyroclastics, commonly flow-banded. Some flaggy sandstone and re-worked tuffs
				Main area of agglomerate
		Boxwood Volcanics	Po	Acid and intermediate, grey and dark green ignimbrites, flows, and pyroclastics
		Almaden Granite	Pga	Grey biotite-hornblende adamellite and granodiorite
		Almaden Granite?	Pga	Green-grey pyroxene-biotite-hornblende granodiorite, quartz diorite and quartz gabbro
		Herbert River Granite	Pgh	Pale pink to grey, medium-grained, hornblende-biotite adamellite
	CARBONIFEROUS	Ringrose Formation?	Cr	Micaceous quartz sandstone and siltstone; some conglomerate. Conglomerate lens
	L. CARBONIFEROUS ? -MIDDLE DEVONIAN	Hodgkinson Formation	D-Ch	Micaceous and feldspathic greywacke and siltstone, shale; some chert and conglomerate
	LOWER DEVONIAN (-UPPER SILURIAN?)	Mount Garnet Formation	S-Dm	Quartz greywacke, siltstone; some chert, shale, breccia and conglomerate. Conglomerate lens
	(LOWER DEVONIAN?) -UPPER SILURIAN	Chillagoe Formation	S-Dh	Reef limestone (fossiliferous)
			S-Dh	Limestone breccia and conglomerate
			S-Dh	Chert
			S-Dh	Quartz greywacke and siltstone
			S-Dh	Conglomerate
			S-Dh	Basic volcanics; calc-silicate rocks
PRECAMBRIAN	ARCHAEAN?	Dargalong Metamorphics	Ad	Gneiss, grading into muscovite granite; augen gneiss, mica schist, amphibolite, quartzite

Geological boundary
Fault
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
Dip <15° } air-photo interpretation
Dip horizontal } air-photo interpretation
Joint pattern } air-photo interpretation
Trend lines } air-photo interpretation
Vertical foliation
Strike and dip of platy flow
Platy flow, vertical
Volcanic vent
Direction of movement of sediment-bearing currents
Top of bed
Gossan and garnet-magnetite rock
Windpump
Earth tank
Dam
Waterhole
Cu — Minor mineral occurrence
Mine, quarry, open cut or prospect
Alluvial workings
Ag — Silver
Ls — Limestone, travertine
C — Coal
Cu — Copper
F — Fluorspar
Mo — Molybdenum
Pb — Lead
Sn — Tin
W — Tungsten
Au — Gold
Fe — Iron
Battery
Road
Vehicle track
Railway with station and elevation above mean sea level
Landing ground
Telegraph line
"Boxwood" Homestead
Dwelling
Yard
Site of former village, now abandoned

Compiled and published by the Bureau of Mineral Resources, Geology and Geophysics, Department of National Development, in conjunction with the Geological Survey of Queensland. Topographic base compiled by the Division of National Mapping, Department of National Development. Aerial photography by the Royal Australian Air Force; complete vertical coverage at 1:50,000 scale. Transverse Mercator Projection.

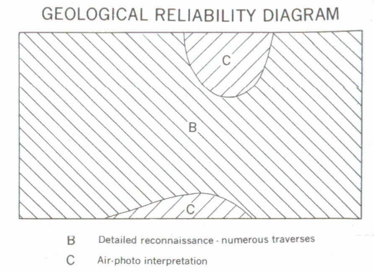
INDEX TO ADJOINING SHEETS

Showing Magnetic Declination

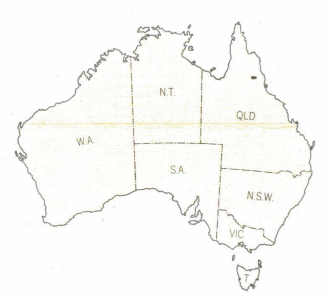


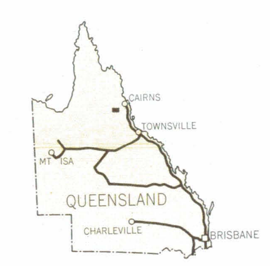
Scale
1 Mile to 1 Inch

GEOLOGICAL RELIABILITY DIAGRAM

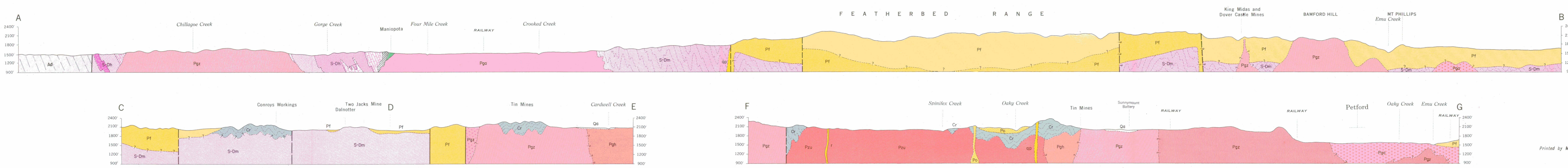


Geology, 1958, by: F. de Keyser, M.B. Bayly, and C.D. Branch (B.M.R.); K.W. Wolff (Q.G.S.)
Compiled, 1961, by: F. de Keyser, M.B. Bayly
Drawn by: Drafting Section, Department of Mines, Queensland

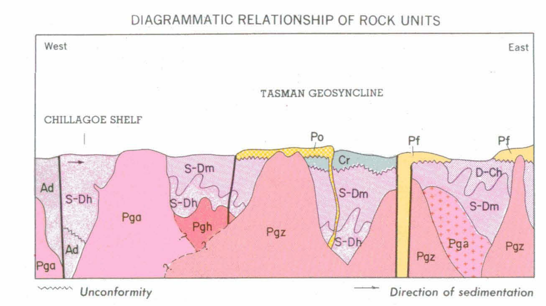




Sections



DIAGRAMMATIC RELATIONSHIP OF ROCK UNITS



ALMADEN
SHEET 60 ZONE 7

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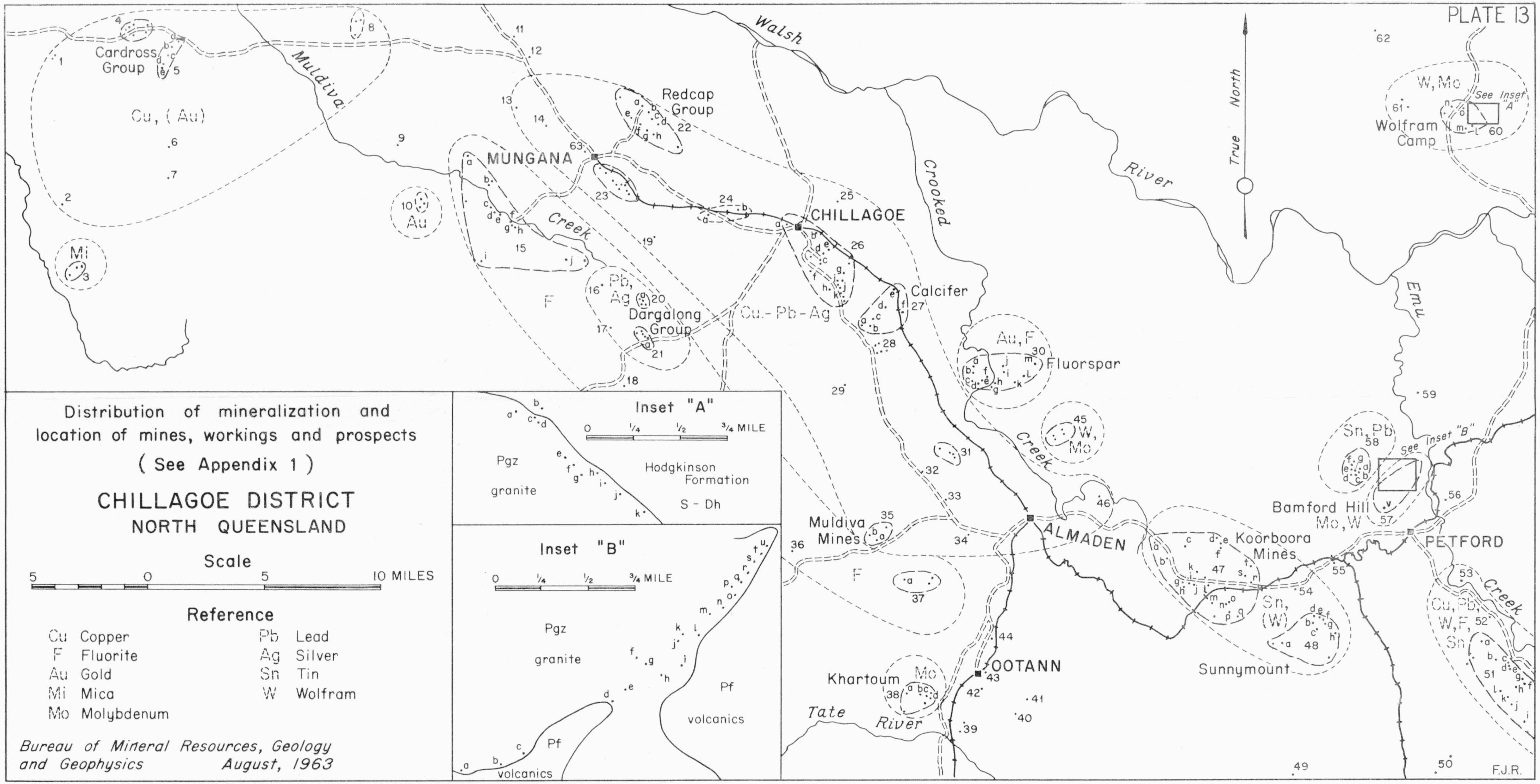
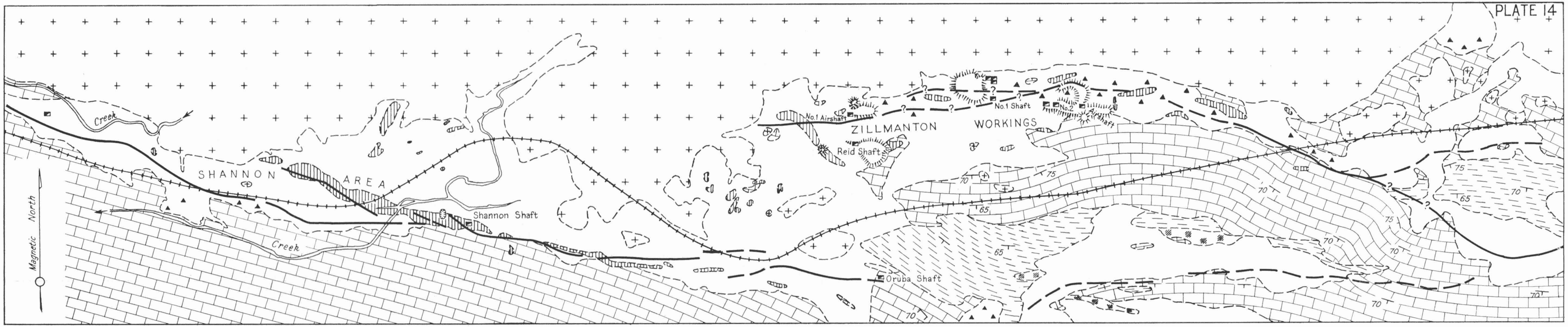


PLATE 13
Distribution of mineralization and location of mines, workings and prospects
(See Appendix 1)
CHILLAGOE DISTRICT
NORTH QUEENSLAND
Scale
5 0 5 10 MILES
Reference
Cu Copper
F Fluorite
Au Gold
Mi Mica
Mo Molybdenum
Pb Lead
Ag Silver
Sn Tin
W Wolfram
Bureau of Mineral Resources, Geology and Geophysics August, 1963
Inset "A"
0 1/4 1/2 3/4 MILE
Pgz granite
Hodgkinson Formation
S - Dh
Inset "B"
0 1/4 1/2 3/4 MILE
Pgz granite
Pf volcanics
Pf volcanics
Cardross Group
Cu, (Au)
Mi
Au
Muldiva
Walsh
Redcap Group
MUNGANA
Creek
Pb, Ag
Dargalong Group
Cu.-Pb-Ag
CHILLAGOE
Calcifer
Crooked
River
True North
W, Mo
See Inset "A"
Wolfram Camp
Emu
Au, F
Fluorspar
W, Mo
Creek
Sn, Pb
See Inset "B"
Bamford Hill
Mo, W
PETFORD
ALMADEN
Koorboora Mines
Sn, (W)
Sunnymount
Muldiva Mines
F
OOTANN
Khartoum
Mo
Tate River
Cu, Pb, W, F, Sn
Creek
F.J.R.



SHANNON - ZILLMANTON AREA

ATHERTON, QUEENSLAND

Showing geology and axes of electromagnetic anomaly

(After W.J. Langron, 1957 and C.D. Branch, 1959)

Scale

500 0 500 1000 1500 Feet

Reference

- *Alluvium, soil*
- Almaden Granite — *Hornblende-biotite granodiorite*
- *Marble*
- *Calc-silicate rock*
- *Chert or silicified quartz siltstone with disseminated pyrite*
- *Lode material : siliceous haematite*
- *Haematite rubble*
- *Axis of electromagnetic anomaly, line broken where medium or weak*
- *Geological boundary*
- 75 *Strike and dip of bedding*
- *Vertical bedding*
- 70 *Prevailing strike and dip of cleavage*
- *Shaft*
- *Open cut*
- *Dump*
- *Railway*
- *Bridge*