1:100 000 GEOLOGICAL MAP COMMENTARY

HATCHES CREEK REGION

NORTHERN TERRITORY

BUREAU OF MINERAL RESOURCES, GEOLOGY & GEOPHYSICS

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AUSTRALIAN GOVERNMENT PUBLISHING SERVICE
CANBERRA 1986

DEPARTMENT OF RESOURCES AND ENERGY
MINISTER: SENATOR THE HON. GARETH EVANS, QC
SECRETARY: A.J. WOODS, AO

BUREAU OF MINERAL RESOURCES, GEOLOGY & GEOPHYSICS
DIRECTOR: R.W.R. RUTLAND

DEPARTMENT OF MINES AND ENERGY, NORTHERN TERRITORY
MINISTER: J.M. ROBERTSON, MLA

NORTHERN TERRITORY GEOLOGICAL SURVEY
CHIEF GEOLOGIST: P. LE MESSURIER

ISSN 0727-1409
ISBN 0 644 05165 5

Published for the Bureau of Mineral Resources, Geology and Geophysics by the Australian Government Publishing Service

Typeset by Canberra Publishing & Printing Co., Fyshwick, A.C.T.
Printed in Australia by Watson Ferguson and Co., Brisbane

INTRODUCTION

The Hatches Creek region map sheet is bounded by latitudes 20°25′ and 21°00′S and longitudes 135°00′ and 135°47′E. It occupies the southwestern part of the Frew River 1:250 000 Sheet area, and incorporates the Hatches, western half of Hanlon, southern most part of Epenarra, and southwesternmost part of Coolibah 1:100 000 Sheet areas. The map sheet is named after the abandoned mining settlement of Hatches Creek in the southwest (Figs. 1 and 2), and covers the northeastern part of the Davenport province — an area of Precambrian rocks forming the southern part of the Tennant Creek Inlier, situated to the north of the Precambrian Arunta Inlier, and lying between the Palaeozoic Wiso Basin to the west and Georgina Basin to the east. The remainder of the Davenport province is covered by the Kurundi region map sheet, Devils Marbles region map sheet, and Elkedra region map sheet (Stewart & Blake, 1984; Wyche & Blake, 1984; Blake & Horsfall, 1984). The Hatches Creek region contains outcrops of the Warramunga Group (in the far north), Hatches Creek Group, and felsic and mafic intrusives, all of which are Proterozoic; flat-lying Cambrian sedimentary rocks of the Georgina Basin; and Cainozoic surficial sediments. It includes the Hatches Creek mineral field, with a recorded production of about 3000 t of tungsten concentrate.

The 1:100 000 scale geological map results from a detailed reconnaissance survey of the Precambrian rocks of the Hatches Creek region carried out by Blake and Wyche from June to October, 1981, as part of the joint Bureau of Mineral Resources (BMR) and Northern Territory Geological Survey (NTGS) Davenport project. Some additional information was obtained in 1982 by I.P. Sweet (in preparation), who studied sedimentological aspects of the Hatches Creek Group, and in 1982 and 1983 by D.H.B. A preliminary report and map of the region has been issued as a BMR Record (Blake & Wyche, 1983). The aeromagnetic map on the back of the geological map was compiled from data obtained by a BMR semi-detailed airborne-magnetometer and gamma-ray-spectrometer survey of the Hatches 1:100 000 Sheet area in 1981 (Table 1). Supplementary gravity measurements were made by BMR along roads and tracks, using station spacings of 200–1000 m, in 1982–83; physical property measurements were made on certain samples collected by the 1981–83 geological mapping party (Hone & others, in preparation).

Habitation and access

The only permanent habitation is at Epenarra homestead in the far north. An unsealed road connects this homestead and the abandoned Hatches Creek mining settlement in the south with the Stuart Highway to the west via Murray Downs homestead in the south and Kurundi homestead in the north (Fig. 1). Tracks joining this unsealed road provide limited access to other parts of the region. Travel by vehicle across country is relatively easy in the north, but is impeded by numerous steep rocky strike ridges elsewhere. Airstrips suitable for light aircraft are located at Epenarra, at the abandoned Kurinelli outstation 30 km southwest of Epenarra, and near the Pioneer mine at Hatches Creek.

Climate

The region has a semi-arid tropical climate. Climatic data for Barrow Creek to the southwest and Tennant Creek to the northwest indicate that the average annual rainfall is about 300 mm, most of which is received from November to March. On average there are about 30 rainy days per year. Maximum temperatures of over 40°C are common in the summer months and minimum temperatures of less than 10°C are common in winter. There are occasional frosts in July. General climatic features are discussed by Slatyer (1962).

Vegetation

Spinifex with sparse low trees and shrubs is the most abundant vegetation (Perry & Lazarides, 1962). Small patches of turpentine bush on rocky ridges and mulga and gidgea in depressions are common locally. Eucalypts line some of the larger watercourses, especially near waterholes. A variety of grasses grow on plains and valley floors.

Topography and drainage

The map area lies mainly within the Davenport geomorphic subdivision of the Northern Plains and Uplands of the Alice Springs area as described by Mabbutt (1962), and is characterised by long and commonly sinuous, narrow to broad steep-sided ridges and valleys (e.g., Fig. 3). It ranges in altitude from less than 300 m on plains in the northeast to more than 500 m on ridges in the southwest. The highest measured altitude is 590 m, at GR NS416916. The main ridges typically have concordant summit levels (bevelled crests). There are also cuestas, hogbacks, mesas, and extensive plains (especially in the north). Flat sandy semi-desert with low sand dunes predominates in the far east. The local relief rarely exceeds 100 m.

The largest drainage system in the map area is that of the northward-draining Frew River in the west; its main tributaries are Lennee, Hatches, and Mia Mia Creeks (Fig. 2). To the east are the drainage systems of the northward-draining Teatree and Hanlon Creeks, the eastward-flowing Poison and Yaddanilla Creeks in the far east, and the southeasterly-draining Gastrolobium Creek in the south. These watercourses flood out and disappear on the plains. According to Mabbutt (1962), the Frew River once flowed into a lake that existed on the Barkly Tableland.

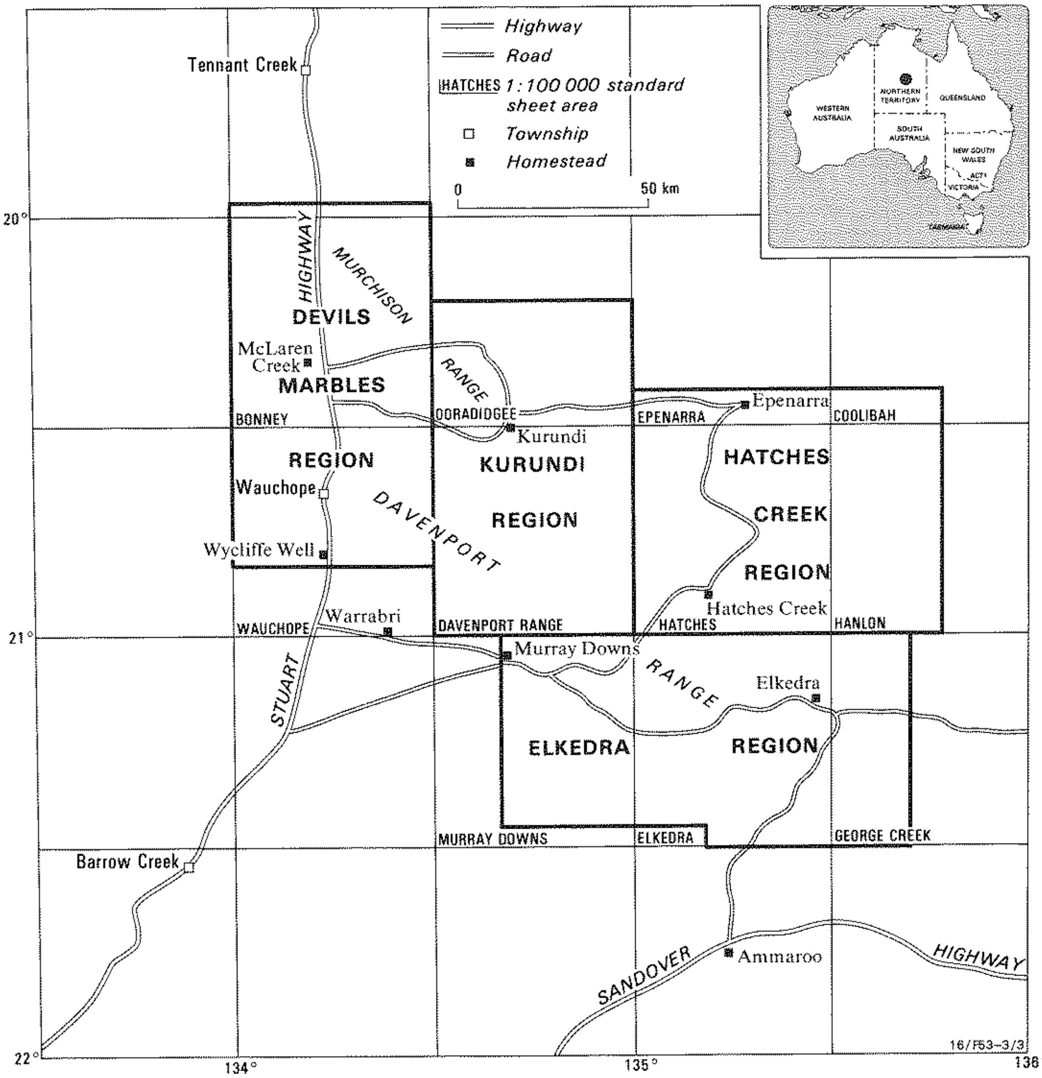

Fig. 1. Geographic setting, Hatches Creek region, showing area covered by 1:100 000 scale geological maps of the Davenport province.

Water supplies

Numerous permanent, semi-permanent, and seasonal waterholes, some several hundred metres long, occur along the main watercourses, and also in many of the smaller creeks in the ranges in the west and south. A few waterbores, in various states of repair, are located on plains in the central and northern parts of the area. For a general account of the water resources see Jones & Quinlan (1962).

Previous investigations

The only previous systematic geological survey of the map area was made by Bureau of Mineral Resources geologists in 1956 as part of a broad reconnaissance survey of the Davenport province. Results of this work were published in a BMR Report (Smith & others, 1961), and in the explanatory notes for the Frew River 1:250 000 Sheet area (Smith, 1964) and three adjoining 1:250 000 Sheet areas — those of Bonney Well (Smith, 1970), Barrow Creek (Smith & Milligan, 1964), and Elkedra (Smith & Milligan, 1966). A detailed investigation of the Hatches Creek mineral field was carried out at the same time by Ryan (1961). The publications contain accounts of previous investigations in the map area to 1962. More recently, brief descriptions of the general geology and mineralisation in the region have been given by Crohn (1976) and Roarty (1977).

The Hatches Creek region has been included in several previous geophysical surveys by BMR (Table

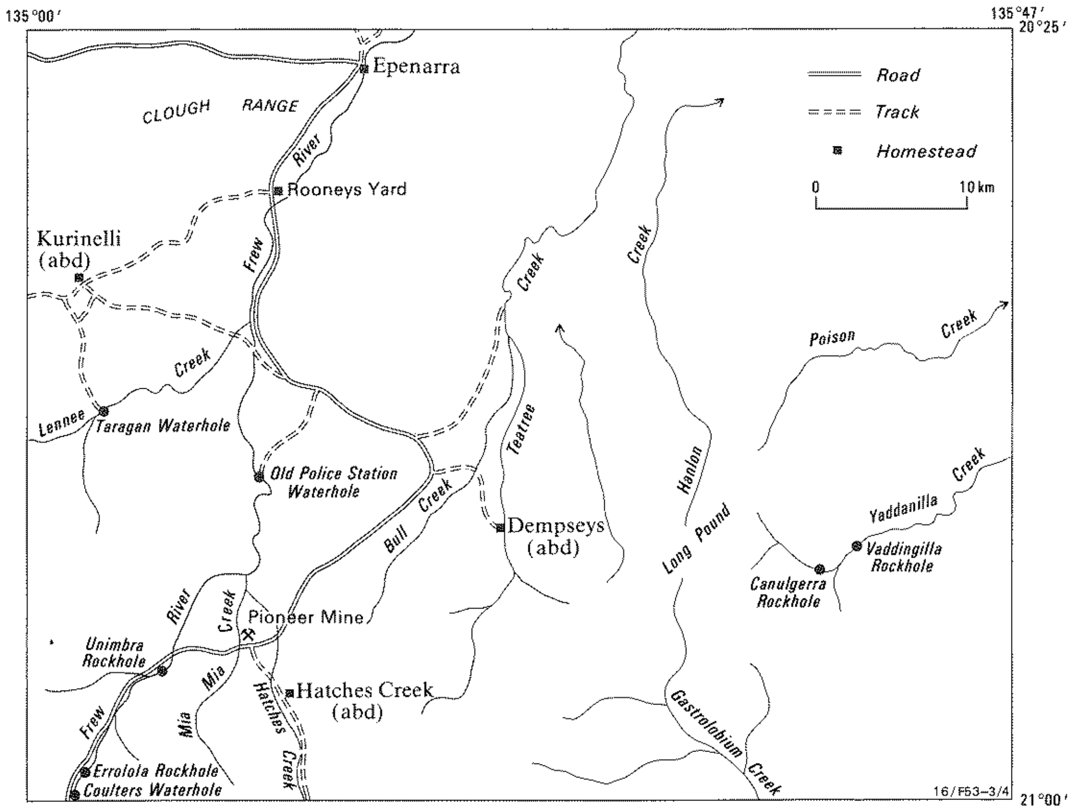

Fig. 2. Locality map.

Fig. 3. Ridges about 100 m high of Errolola Sandstone (foreground) and Coulters Sandstone separated by valley formed on recessive Frew River Formation and Kudinga Basalt, Hatches Creek Group, southwest Hatches Creek region. Looking NNW from GR NS045780 (M2474/10).

TABLE 1. GEOPHYSICAL INVESTIGATIONS (ALL BY BMR)

Year	*Survey*	*Data available as:*
1956	Airborne scintillograph survey	* BMR Record 1957/80 (Livingstone, 1967)
1963–64	Regional airborne magnetometer survey	* BMR Record 1966/142 (Wells & others, 1966) * Frew River 1:250 000-scale map showing total-magnetic-field contours, F53/B1–76 (BMR, 1967)
1965	Regional gravity (helicopter)	* Bouguer anomaly maps at 1:250 000 scale (Frew River Sheet) and 1:1 000 000-scale (Alice Springs Sheet) (revised 1984). Also on Australian National Gravity Database computer tape.
1981	Semi-detailed airborne magnetometer and gamma ray spectrometer	* Magnetic and radiometric contours and profiles (see text, under 'GEOPHYSICS'). Magnetic contours also on reverse of Hatches Creek region geological map
1982–83	Supplementary gravity measurements along roads and tracks	* Bouguer anomaly maps at 1:250 000- scale (Frew River Sheet) and 1:1 000 000-scale (Alice Springs Sheet) (revised 1984). Also on Australian National Gravity Database computer tape.
1982–83	Physical property measurements on rock samples	BMR Report (Hone & others, in preparation)

* Available through Government Printer Copy Service, GPO Box 84, Canberra, ACT 2601; phone (06) 954560.

1). An airborne scintillograph survey over the southwest of the Hatches Creek region in 1956 (Livingstone, 1957) found several anomalies which have subsequently been examined on the ground by local prospectors, but no significant uranium anomalies have been reported (Project Mining Corporation, 1979). A reconnaisance airborne magnetometer survey of the Georgina Basin by BMR in 1963–64 also covered the Hatches Creek region (Wells & others, 1966; BMR, 1967). This survey employed east-west lines 3.2 km apart and 600 m above sea level. Regional gravity was determined in 1965 on a grid of about 11 km.

Map compilation

The Hatches Creek region 1:100 000 scale geological map was compiled using vertical colour aerial photographs at about 1:25 000 scale, taken in September 1980, for the Hatches 1:100 000 sheet, and vertical black and white RC9 Frew River aerial photographs at about 1:80 000 scale, taken in 1963, for the remainder of the region. Field data were plotted on transparent overlays on the aerial photographs and then transferred onto photo-scale compilation sheets by C.L. Knight, BMR draftsman.

Rock nomenclature

Terms used are as defined in the Glossary of Geology (Bates & Jackson, 1980).

Sandstones are classified according to the scheme of Pettijohn & others (1972). Grainsize terms are: 'fine', 0.125 to 0.25 mm; 'medium', 0.25 to 0.5 mm; and 'coarse', 0.5 to 1 mm. Bedding thickness terms are: 'laminated', less than 1 cm; 'thin-bedded', 1 to 50 cm; 'medium-bedded', 50 cm to 2 m; and 'thick-bedded', over 2 m.

The classification recommended by Streckeisen & others (1973) is used for plutonic igneous rocks. Grainsizes for igneous rocks are: 'fine', less than 1 mm; 'medium', 1 to 5 mm; and 'coarse', 5 mm to 3 cm.

Acknowledgements

The figures in this Map Commentary were drawn by J. Convine and N. Kozin.

OUTLINE OF GEOLOGY

The oldest rocks exposed in the Hatches Creek region are tightly folded interbedded greywacke and siltstone of the 1870-Ma-old *Warramunga Group* in the far north. This group was moderately to tightly folded and regionally metamorphosed to greenschist grade at about 1810 Ma, before being overlain unconformably by the *Hatches Creek Group*, which crops out extensively to the south. It is also inferred to be intruded by *unnamed granite* exposed in the northwest. Folds in the Warramunga Group have wavelengths of probably less than 1 km.

The Hatches Creek Group is a sequence at least 10 km thick of shallow-water sedimentary rocks — ridge-forming white, pale-grey, or pale-pink quartz-rich arenite, and recessive friable arenite, siltstone, mudstone, shale, and some carbonates and possible evaporites — and interlayered recessive felsic and mafic volcanic rocks. The sedimentary rocks consist largely of quartz probably derived from outside the Davenport province and feldspar (commonly altered), mica, lithic clasts, and kaolinitic/sericitic material, much of which may be locally derived volcanic detritus. Most ridge-forming arenites consist predominantly of quartz, whereas recessive arenites are generally feldspathic or lithic, and commonly have a relatively abundant clayey or micaceous matrix. Widespread cross-bedding (e.g., Fig. 4); common pebbly beds, ripple marks, convolute bedding and related structures; rare mud cracks and moulds and casts of evaporite minerals; and the occurrence of stromatolites in one formation indicate that most if not all of the sedimentary rocks are shallow-water deposits. The volcanic rocks include both lavas and pyroclastics, and were erupted either subaerially or into shallow water; some were previously mapped as intrusives.

The Hatches Creek Group is subdivided into the Ooradidgee, Wauchope, and Hanlon Subgroups. The oldest of these, the *Ooradidgee Subgroup*, is represented in the map area by six formations of volcanic and sedimentary rocks and two sedimentary members; these units are in part lateral equivalents. The overlying *Wauchope Subgroup* is represented by seven sedimentary and volcanic formations and the succeeding *Hanlon Subgroup* by six almost entirely sedimentary formations. The formations of the two younger subgroups form a mainly layer-cake-type stratigraphy. The Ooradidgee Subgroup is intruded by mostly concordant (sill-like) bodies of *granophyre*, *feldspar porphyry*, and *dolerite/gabbro* which are probably comagmatic with volcanics within the Hatches Creek Group, and also by plutons of *unnamed granite*. There are also some granophyre sills within the basal formation of the Wauchope Subgroup in the southwest.

The rocks of the Hatches Creek Group are folded into several major, upright, open to tight synclines, anticlines, domes, and basins. They are also displaced by numerous faults, some marked by ridge-forming quartz veins, and have been affected by low-grade regional metamorphism. The main folds have wave-lengths of several kilometres, in contrast to those of the Warramunga Group, and somewhat sinuous trends, with variable plunges. Smaller folds are developed locally, mainly in the axial zones of major folds. A pronounced axial plane cleavage is developed in places, especially in fine-grained sedimentary rocks and felsic pyroclastics. Minor recrystallisation effects and the common development of secondary chlorite, epidote, sericite/muscovite, and greenish-brown biotite are indicative of greenschist-facies regional metamorphism. Contact metamorphism, indicated by the presence of hornfels, is commonly apparent within a few metres of igneous intrusions. The folding, regional metamorphism, and much of the faulting predate unnamed granite, possibly emplaced at about 1640 Ma, exposed in the southwest and central north.

Near Hatches Creek the Hatches Creek Group is host to *tungsten* and subordinate copper, bismuth, and molybdenum mineralisation probably related to granite intrusion. The ore minerals occur in quartz veins which postdate the main deformation. There are also several occurrences of gold-bearing quartz veins within the group, closely related spatially to dolerite and gabbro intrusions; these veins may be syntectonic.

The Proterozoic sedimentary and intrusive rocks are overlain by flat-lying unmetamorphosed conglomerate, sandstone, chert, and siltstone of the Middle Cambrian Gum Ridge Formation, which is part of the lower Palaeozoic Georgina Basin succession, and by unconsolidated Cainozoic sediments.

PROTEROZOIC STRATIGRAPHY

Proterozoic stratigraphic details are given in Table 2, overleaf.

WARRAMUNGA GROUP

The Warramunga Group was named by Ivanac (1954) and is defined in Dodson & Gardener (1978). In the Hatches Creek region it is represented by turbiditic rocks, best exposed in low hills southeast of Epenarra homestead. North of the region, near Tennant Creek, it contains felsic volcanics dated by Black (1984, U-Pb zircon method) at about 1870 Ma. The thickness of the Warramunga Group in the region is not known because of a lack of marker beds, scattered and generally poor exposure, and probably complex moderate to tight folding, and because neither the stratigraphic top nor the base have been identified. The rocks do not appear to be recrystallised, but have probably been metamorphosed to lower or middle greenschist facies; however, no diagnostic metamorphic minerals have been recorded. The main folding predates deposition of the Hatches Creek Group, and probably took place around 1810 Ma ago (Black, 1977 and 1984). An unconformity with the overlying Hatches Creek Group is poorly exposed 4.3 km southwest of Epenarra homestead, at GR NT303363, but is well displayed in the Kurundi and Devils Marbles regions to the west (Stewart & Blake, 1984; Wyche & Blake, 1984). The only mineralisation known in the Warramunga Group within the map area is at Woodenjerrie mine (GR NT280370), where small amounts of wolframite were recovered from cross-cutting quartz-hematite veins in 1952–53. Near Tennant Creek the group is host to economically important gold-copper-bismuth deposits (e.g., Large, 1975).

TABLE 2. DETAILS OF PROTEROZOIC STRATIGRAPHY

Unit and thickness (m)	*Map symbol*	*Lithology*	*Relationships*
HATCHES CREEK GROUP			
HANLON SUBGROUP			
Yaddanilla Sandstone (300+)	Ꝑhy	Ridge-forming quartz arenite and feldspathic arenite interlayered with recessive beds (not exposed). Arenites: white to pale grey, medium-bedded, medium-grained, cross-bedded, some bedding planes with casts of mudstone/siltstone pellets.	Conformable on Vaddingilla Formation; top not exposed.
Vaddingilla Formation (800)	Ꝑhv	Recessive thinly interbedded siltstone, shale, and arenite. Arenite: friable, generally reddish-brown, variably feldspathic, micaceous and kaolinitic, fine to medium-grained and rather poorly sorted; some cross-bedding.	Conformable on Canulgerra Sandstone; overlain conformably by Yaddanilla Sandstone.
Canulgerra Sandstone (500)	Ꝑhu	Ridge-forming arenite and recessive interbedded friable feldspathic/lithic arenite and micaceous siltstone. Ridge-forming arenite: quartzose to feldspathic, generally silicified, thin to medium-bedded, mainly medium-grained, commonly cross-bedded and ripple marked.	Conformable on Lennee Creek Formation: overlain conformably by Vaddingilla Formation.
Lennee Creek Formation (1000–1500)	Ꝑhl	Recessive thinly bedded friable arenite, siltstone, and shale; minor thin beds of ridge-forming quartz arenite and recessive calcareous siltstone/mudstone. Friable arenite: iron-stained to bleached; feldspathic/ lithic/ kaolinitic/micaceous; some cross-bedding.	Conformable on Alinjabon Sandstone; overlain conformably by Canulgerra Sandstone
Alinjabon Sandstone (450–750)	Ꝑhi	Ridge-forming, variably feldspathic, quartz arenite and recessive friable arenite, siltstone, shale; minor mafic lava and volcaniclastic arenite at base in southwest. Ridge-forming arenite: white to pale-grey, silicified and locally glassy, thin-bedded, fine to medium-grained; some cross-bedding; rare convolute bedding, quartz pebbles, and mudstone/siltstone pellets. Recessive arenite: friable, feldspathic/lithic, medium to thin-bedded, medium-grained, commonly cross-bedded.	Conformable on Errolola Sandstone; overlain conformably by Lennee Creek Formation.
	Ꝑhi$_v$	Recessive mafic lava and associated micaceous siltstone, shale, and volcaniclastic arenite. Mafic lava: much altered and iron-stained, basaltic to doleritic, non-porphyritic, amygdaloidal in part; some secondary chlorite, biotite, epidote, and actinolite.	Conformable band at base of Alinjabon Sandstone in east of map area.
Errolola Sandstone (500–1200+)	Ꝑhe	Ridge-forming quartz arenite and subordinate variable feldspathic/lithic/kaolinitic arenite: white to pale-grey or pink, generally silicified, mainly medium-bedded, medium-grained, and well sorted; commonly cross-bedded, less commonly ripple-marked; some bedding planes with siltstone pellets or quartz grit; rare beds with sparse pebbles.	Conformable on Kudinga Basalt; overlain conformably by Alinjabon Sandstone.
WAUCHOPE SUBGROUP			
Kudinga Basalt (400–600)	Ꝑhb	Recessive amygdaloidal and scoriaceous to massive basalt; minor interlayered volcaniclastic (basaltic) arenite and epidotic quartz arenite. Basalt: greenish to dark-grey; some flows with feldspar phenocrysts; variably altered, with albite, actinolitic amphibole, biotite, calcite, chlorite, epidote, pyrite, and quartz as common secondary minerals; mainly epidote, chlorite, and quartz in amygdales; flow-margin breccia, with basalt fragments in epidotic quartzite, present near GR NS342864; no pillows found in map area.	Conformable on Frew River Formation and locally on Coulters Sandstone (in SW); overlain conformably by Errolola Sandstone.
	Ꝑhb$_s$	Ridge-forming variably feldspathic arenite; minor interlayered basalt flows. Arenite: silicified; fine to coarse-grained; cross-bedding common; some ripple marks.	One or two conformable bands at or near base of Kudinga Basalt.
Frew River Formation (0–500)	Ꝑhf	Recessive thin-bedded friable kaolinitic arenite and siltstone which are commonly calcareous and dolomitic in upper part and micaceous in lower part of formation; minor silicified, variably feldspathic/lithic quartz arenite, mainly near base.	Conformable on Coulters Sandstone; overlain conformably by Kudinga Basalt.

Unit and thickness (m)	Map symbol	Lithology	Relationships
		Sedimentary features include cross-bedding, ripple marks, grit laminae, bedding planes with siltstone pellets, rare mud-cracks and halite casts, and stromatolites (bulbous forms, algal mats, *Conophyton*).	
Coulters Sandstone (300–1000+)	Ehc	Ridge-forming quartz arenite and subordinate variably feldspathic/lithic/kaolinitic arenite: thick-bedded, especially at base, to thin-bedded; mainly well sorted; abundant cross-bedding, some of which is recumbent-fold type (Allen & Banks, 1972); generally rare ripple marks; scattered pebbles of vein quartz and minor volcanic rocks present locally, mostly near base of formation; some bedding planes with quartz grit and siltstone pellets.	Conformable to possibly disconformable on Newlands Volcanics, Arabulja Volcanics, and Yeeradgi Sandstone; overlain conformably by Frew River Formation and locally (in SW) by Kudinga Basalt.
	Ehc_1	Recessive, friable (kaolinitic/sericitic), feldspathic/ lithic arenite.	Conformable band near top of Coulters Sandstone in east.
Arabulja Volcanics (300)	Ehj	Recessive altered felsic lava: two or more flows; pink to purple and reddish-brown; partly porphyritic — small phenocrysts of largely altered equant feldspar ± minor quartz + pseudomorphed mafic minerals; quartzofeldpsathic groundmass. Flows show platy jointing in lower parts and contorted flow-banding in upper parts.	Conformable on Yeeradgi Sandstone; overlain conformably to possibly disconformably by Coulters Sandstone.
Newlands Volcanics (0–500)	Eha	Recessive porphyritic dacitic ignimbrite: fresh, massive and dark-greyish to (more commonly) much altered, phyllitic to schistose, and shades of purple to reddish-brown or bleached. Fresh specimens contain abundant tabular phenocrysts of feldspar about 3 mm long (now either albite or pseudomorphed) + irregular clots of mafic minerals (greenish-brown biotite and/or chlorite) ± porphyroblastic dark-green hornblende in foliated fine-grained groundmass of quartz + alkali feldspar + biotite/chlorite/muscovite + opaque oxide + epidote.	Conformable on Yeeradgi Sandstone; overlain conformably to possibly disconformably by Coulters Sandstone.
Yeeradgi Sandstone (100–800)	Ehd	Ridge-forming to recessive arenite, subordinate recessive siltstone, mudstone, ashstone, and shale; rare calcareous beds. Arenite: variably feldspathic, lithic (volcaniclastic), kaolinitic, and micaceous; friable to silicified, medium to thin-bedded, medium to fine-grained, commonly cross-bedded; some bedding planes with siltstone/mudstone pellets. Ashstone: pale greenish or buff, very fine-grained, thin-bedded to laminated.	Conformable on Unimbra Sandstone; overlain conformably by Arabulja Volcanics and Newlands Volcanics, possibly disconformably by Coulters Sandstone. Intruded by granophyre.
	Ehd_t	Recessive thin-bedded tuff and tuffaceous arenite: grey, purple or pinkish, variably micaceous, hematitic, and feldspathic/lithic (volcaniclastic), quartz-poor, friable, medium to fine-grained; some cross-bedding and ripple marks.	Conformable layer at top of Yeeradgi Sandstone (northeast of Errolola Rockhole).
Unimbra Sandstone (100–1000+)	Ehs	Ridge-forming, variably feldspathic and lithic(?) arenite and quartz arenite: pale-grey, pink, or white, mainly medium-bedded and medium to coarse-grained; grit and pebbles of vein quartz and subordinate volcanic rocks present in some beds, mainly near base; cross-bedding very common; some ripple marks, bedding planes with mudstone/siltstone pellets; includes 5 m-thick band of brecciated, pale-greenish 'rhyolitic ashstone' at GR NS240874.	Conformable to possibly disconformable on Mia Mia Volcanics and Treasure Volcanics; lower part also interfingers with Treasure Volcanics; overlain conformably by Yeeradgi Sandstone. Intruded by granophyre sills in SW.
	Ehs_v	Relatively recessive felsic lavas of Treasure Volcanics type (in SW); flow-banded rhyolite at GR NT515046.	Conformable lenses within Unimbra Sandstone.

Unit and thickness (m)	Map symbol	Lithology	Relationships
OORADIDGEE SUBGROUP			
Mia Mia Volcanics (2000 +)	Ᵽhm	Recessive felsic massive ignimbritic(?) tuff and subordinate lava containing small phenocrysts of alkali feldspar (mainly microcline) ± quartz ± pseudomorphed mafic minerals; minor thin-bedded to laminated tuff and medium to thin-bedded quartzose to feldspathic arenite. Volcanics: shades of grey, pink, maroon, purple, and green: mainly phyllitic to schistose; commonly contain metamorphic white mica + greenish-brown biotite ± tourmaline.	Base not exposed. Overlain conformably or possibly disconformably by Unimbra Sandstone. Intruded by unnamed leucocratic biotite-muscovite granite and associated veins of pegmatite and greisen.
	Ᵽhm$_s$	Ridge-forming, variably feldspathic/lithic/quartz arenite; minor partly volcaniclastic conglomerate (at GR NS199805) and felsic volcanic bands. Arenites: generally silicified, medium-bedded, and medium-grained; cross-bedding common; some ripple marks.	Conformable lenses in upper part of Mia Mia Volcanics.
Treasure Volcanics (500–3500?)	Ᵽht	Recessive porphyritic dacitic to rhyolitic lava; altered non-porphyritic felsic lava (near Hatches Creek); minor quartzose to feldspathic/lithic (volcaniclastic) arenite and thin-bedded-to-laminated, commonly micaceous tuff. Porphyritic felsic lava: shades of grey, pink, maroon, purple, and reddish-brown; intensely weathered in places, especially in east; contains phenocrysts of plagioclase (now albite but originally more calcic) ± quartz + pseudomorphed mafic minerals, and metamorphic chlorite, white mica, greenish-brown biotite, epidote, and carbonate. Non-porphyritic felsic lava: grey, massive or with small amygdales; recrystallised to fine-grained aggregate of biotite and/or chlorite + muscovite + quartz ± tourmaline.	Conformable on and in places interlayered with Taragan Sandstone; overlain conformably and possibly disconformably by, and also interfingers with, Unimbra Sandstone; intruded by granophyre/feldspar-porphyry and dolerite/gabbro sills.
	Ᵽht$_m$	Recessive basaltic lava: minor interlayered quartzose to volcaniclastic and epidotic arenite. Basalt: dark to pale blueish- or greenish-grey; commonly amygdaloidal/vesicular; some autobrecciated flow margins; consists mainly of largely altered plagioclase + ophitic clinopyroxene ± pseudomorphed olivine ± opaque oxides + secondary epidote, chlorite, actinolite, sericite(?), quartz and calcite; traces of copper minerals at GR NS094976.	Conformable bands in lower part of Treasure Volcanics
	Ᵽht$_s$	Ridge-forming quartz arenite and feldspathic arenite: silicified to friable; well to poorly sorted; fine to coarse-grained; pebbles of vein quartz and felsic volcanics present in places; mainly medium-bedded; commonly cross-bedded; some ripple marks, mud cracks and bedding planes with siltstone/mudstone pellets.	Interlayered conformably with lavas of Treasure Volcanics
Taragan Sandstone (300–1000 +)	Ᵽho	Ridge-forming quartz arenite and felspathic/lithic arenite, commonly pebbly; minor conglomerate (mainly at base), siltstone, altered felsic lava. Arenites: medium to thick-bedded; medium to coarse-grained; cross-bedding common, including some of recumbent-fold type (Allan & Banks, 1972); some ripple marks. Pebbles and less common cobbles and boulders: rounded to angular; mainly of vein quartz; also some of chert, jasper, arenite, quartzite, and rare volcanics.	Conformable on and may overlap Kurinelli Sandstone; overlain conformably by and interfingers with Treasure Volcanics. Intruded by granophyre and dolerite/gabbro sills and unnamed granite.
	Ᵽho$_1$	Recessive, thinly bedded, variably micaceous siltstone, mudstone, and friable arenite; minor silicified arenite and calcareous beds.	Conformable band within Taragan Sandstone
Kurinelli Sandstone (2000 +)	Ᵽhk	Ridge-forming feldspathic, lithic (volcaniclastic/tuffaceous?), and quartzose arenite; subordinate recessive, thin-bedded to laminated, variably micaceous siltstone and friable arenite; rare altered felsic lava. Arenite: white to pale-grey or pinkish, thin-bedded, especially near base, to medium or thick-bedded; mostly	Conformable on and interfingers with Epenarra Volcanics and Rooneys Formation; overlain conformably and possibly overlapped by Taragan

Unit and thickness (m)	Map symbol	Lithology	Relationships
		medium-grained and well sorted; some beds with grit and scattered pebbles of quartz; cross-bedding, including recumbent-fold and convolute types, common; some ripple marks and bedding planes with siltstone/ mudstone pellets.	Sandstone. Intruded by granophyre and dolerite/ gabbro sills and unnamed granite.
	Ɇhk$_v$	Recessive altered andesitic lava and minor tuffaceous siltstone. Lava: maroon to reddish-brown, non-porphyritic; some amygdales; commonly shows platy jointing; may include some sills.	Conformable bands within Kurinelli Sandstone.
Endurance Sandstone Member (0–500)	Ɇhk$_d$	Recessive, thinly interbedded, fine-grained, micaceous greywacke and siltstone, commonly showing graded bedding; minor medium to thin-bedded, variably feldspathic arenite.	Conformable lens within Kurinelli Sandstone. Intruded by dolerite/ gabbro sills.
Warnes Sandstone Member (0–500)	Ɇhk$_w$	Knobbly ridge-forming, variably feldspathic (and lithic?) arenite and quartz arenite: bleached to iron-stained, medium to coarse-grained, poorly sorted, with scattered quartz grit and small pebbles of vein quartz common; friable to patchily silicified; mainly massive (no bedding apparent), but some bedding and cross-bedding present locally.	Conformable lenses within Kurinelli Sandstone. Intruded by granophyre and dolerite/ gabbro sills.
Rooneys Formation (0–1200+)	Ɇhn	Generally recessive thin-bedded to laminated fine-grained feldspathic/lithic arenite and siltstone; minor ridge-forming pinkish feldspathic arenite. Recessive beds: grey to greenish-grey or iron-stained; variably micaceous; some convolute bedding, recumbent-fold cross-bedding, and calcareous beds.	Conformable on Epenarra Volcanics; overlain conformably by Kurinelli Sandstone; also interfingers with both units. Intruded by granophyre and dolerite/ gabbro sills and unnamed granite.
	Ɇhn$_{sh}$	Recessive schistose micaceous metasiltstone and schistose to quartzitic micaceous meta-arenite.	No contacts seen with other Proterozoic units.
Epenarra Volcanics (3000+)	Ɇhr	Generally recessive porphyritic felsic volcanic rocks and volcaniclastic arenite and conglomerate; minor altered amygdaloidal non-porphyritic mafic lava and tuff. Ridge-forming quartz veins common. Felsic volcanics: generally phyllitic to schistose; pale to dark shades of grey, purple, pink, and brown; include ignimbritic tuffs and lavas containing phenocrysts of feldspar ± quartz, volcanic breccia, agglomerate, thinly bedded medium to fine-grained tuff, and lapilli tuff.	Unconformable on Warramunga Group; overlain conformably by, and interfingers with, Rooneys Formation and Kurinelli Sandstone; intruded by granophyre and dolerite sills.
	Ɇhr$_s$	Ridge-forming quartzose to volcaniclastic arenite, pebbly arenite with mainly vein quartz pebbles, and volcaniclastic conglomerate; minor interlayered volcanics.	Conformable bands within Epenarra Volcanics.
WARRAMUNGA GROUP (1000+)	Ɇw	Generally recessive interbedded phyllitic siltstone and medium to fine-grained greywacke.	Overlain unconformably by Epenarra Volcanics.

HATCHES CREEK GROUP

The name Hatches Creek Group was first used by Sullivan (1953) and Hossfeld (1954) and was retained, with its usage slightly modified, by Smith & others (1961), Ryan (1961), and Smith (1964). None of these authors subdivided the group into formally named constituent units. The usage of Smith & others (1961) is followed in this work. However, the Hatches Creek Group is now subdivided into subgroups, formations, and members, definitions of which are given in Blake & others (1985). These units form a generally conformable sequence of shallow-marine to fluvial sedimentary rocks and subaerial to subaqueous volcanics. They are younger than the 1810 Ma deformation of the unconformably underlying Warramunga Group, and are older than 1640 Ma, the approximate Rb-Sr whole-rock isochron age for the Elkedra Granite which intrudes the Hatches Creek Group in the Elkedra region to the south (Blake & others, 1985; Blake & Horsfall, 1984) — the 1640 Ma age is a reassessment by L.P.Black (personal communication, 1983) of an age of 1695 Ma for the granite obtained by Riley (reported in Compston & Arriens, 1968).

The Hatches Creek Group can be correlated with the Tomkinson Creek beds in the north of the Tennant Creek Inlier (Blake 1984). Other possible correlatives include Division 3 rocks of the Arunta Inlier (Stewart & Warren, 1977; Stewart & others, 1984) and Carpentarian units of the McArthur Basin, Pine Creek Inlier, and Mount Isa Inlier (Plumb & others, 1981).

Ooradidgee Subgroup

The six formations of the Ooradidgee Subgroup in the region make up a partly interfingering sequence. The basal formation in the north, the *Epenarra Volcanics*, forms a thick volcanic pile, with subordinate sedimentary beds, laid down on an uneven eroded surface of Warramunga Group rocks. The volcanic rocks of the formation are commonly phyllitic to schistose and are generally deeply weathered. Interlayered arenites (mainly unit Ꝑhr$_{S}$), most common in the upper part of the formation, are similar to adjacent and overlying arenites in the Rooneys Formation and Kurinelli Sandstone. The *Rooneys Formation* crops out in the northern part of the map area to the south of the Epenarra Volcanics . It consists mainly of thinly bedded fine to medium grained sedimentary rocks possibly representing shallow deltaic deposits (Sweet, in preparation), but is also taken to include schistose and quartzitic rocks (unit Ꝑhn$_{sh}$) exposed 12–15 km southeast of Epenarra homestead.

The more extensive *Kurinelli Sandstone* differs from the Rooneys Formation in being generally thicker bedded, coarse-grained, and more quartz-rich. In the south it includes the *Endurance Sandstone Member*, which may represent a tongue of Rooneys Formation, and the *Warnes Sandstone Member*, which consists predominantly of non-bedded poorly sorted quartz arenite forming distinctive knobbly ridges. The general absence of bedding in the Warnes Sandstone Member may be due to slumping or earthquake shaking prior to consolidation, perhaps as a result of penecontemporaneous volcanism. The Kurinelli Sandstone also contains thin bands of much altered igneous rock of probably andesitic composition (Ꝑhk$_{V}$) which may be extrusive or intrusive. The sedimentary rocks of the formation are thought to be shallow-marine, deltaic, and fluvial deposits. At the top of the Kurinelli Sandstone there is an abrupt change from well-sorted arenite to mostly pebbly and locally conglomeratic arenite of the *Taragan Sandstone*. This formation is considered to be a fluvial deposit, possibly laid down by braided streams (Sweet, in preparation). Near Hatches Creek the Taragan Sandstone is taken to include a ridge of generally pebbly arenite separating two sequences of felsic lavas assigned to the Treasure Volcanics. Porphyritic dacitic to rhyolitic lava flows, some probably more than 100 m thick, predominate within the *Treasure Volcanics*, which also include some highly altered non-porphyritic felsic lavas in the vicinity of Hatches Creek, basaltic lavas in the lower part of the formation to the northwest, and

Fig. 4. Cross-bedding in Taragan Sandstone, Ooradidgee Subgroup, Hatches Creek Group, 19 km north of Errolola Rock-hole (GR NS076999) (M2474/25).

numerous arenite bands ranging in thickness from less than 1 m to more than 100 m. The felsic lava flows commonly show platy jointing in their lower parts, parallel to underlying bedding, and contorted flow-banding in their upper parts. Some have auto-brecciated margins and rubbly scoriaceous tops with sandstone-filled fissures several metres deep (Fig. 5). An absence of voluminous fragmental rocks and of pillow lavas is taken to indicate that most of the volcanism was probably subaerial. Many of the interlayered arenites are identical to those in conformably underlying Taragan Sandstone and overlying Unimbra Sandtone, and are interpreted as fluvial and shallow-marine deposits.

The remaining formation of the Ooradidgee Subgroup, the *Mia Mia Volcanics*, is partly a correlative of the Treasure Volcanics. It is confined to the centre of a large structural dome in the southwest, the Mia Mia Dome, and consists of much altered and cleaved felsic pyroclastics and subordinate felsic lavas and interlayered arenites. These rocks were termed the Bottom Series by Hossfeld (1954, and *in* AGGSNA, 1941), who excluded them from the Hatches Creek

Fig. 5. Sandstone filling a fissure in the top of a felsic lava flow, Treasure Volcanics, 10 km north of Errolola Rockhole (GR NS052903) (M2473/18).

include some felsic lavas of Treasure Volcanics type. Variations in thickness (100–1000+ m) may be due in part to deposition on an uneven volcanic surface of considerable relief. The overlying *Yeeradgi Sandstone*, which may be a largely fluvial formation (Sweet, in preparation), is formed partly of detritus derived from nearby contemporaneous volcanoes. It is overlain by felsic lava of the *Arabulja Volcanics* in the far southwest and dacitic ignimbrite of the *Newlands Volcanics* to the east. These two volcanic formations are stratigraphic equivalents, but differ in composition, and were erupted from different volcanic centres. The ignimbrite of the Newlands Volcanics is characterised by abundant tabular feldpsar phenocrysts, except in the poorly exposed and probably non-welded upper part, which consists of very friable fine-grained material. The overlying *Coulters Sandstone* is the middle of the three prominent province-wide ridge-forming units — the youngest is the Errolola Sandstone at the base of the Hanlon Subgroup — and was probably deposited on a broad shallow marine shelf. It is succeeded by the generally poorly exposed *Frew River Formation*, a recessive sedimentary unit containing stromatolitic carbonates and also indications of former evaporites, suggestive of very-shallow-water to intertidal and possibly sabkha environments. The overlying *Kudinga Basalt*, the uppermost formation of the subgroup, is presumed to have covered a broad fluvial plain or shallow marine shelf. It is cut by quartz veins containing malachite and azurite at a small abandoned mine at GR NS377875.

Group. However, arenites in the upper part of the Mia Mia Volcanics are concordant with the overlying Unimbra Sandstone of the Wauchope Subgroup, and, as noted by Smith & others (1961), there is no evidence of an angular unconformity at the top of the unit.

Wauchope Subgroup

The formations of the Wauchope Subgroup, unlike those of the Ooradidgee Subgroup, form a regular, rather than a partly interfingering, sequence. The *Unimbra Sandstone* at the base, which was probably deposited in both shallow-marine and fluvial environments (Sweet, in preparation), is the lowest of the three prominent province-wide ridge-forming units. It is conformable to possibly disconformable on underlying felsic volcanics, and in places interfingers with them. In the far southwest it is taken to

Hanlon Subgroup

The prominent ridge-forming *Errolola Sandstone*, the basal formation of the Hanlon Subgroup, was probably deposited mainly on intertidal flats and in adjoining subtidal environments (Sweet, in preparation). It is succeeded by the *Alinjabon* Sandstone, which consists of two or three bands of ridge-forming arenite separated by recessive bands. The lowest recessive band, at the base of the formation, commonly includes one or more flows of highly altered mafic lava — the youngest volcanic rocks known in the Hatches Creek Group. The Alinjabon Sandstone may have been deposited in a shallow-marine-shelf environment with a possible deltaic influence. The overlying *Lennee Creek Formation*, which crops out mainly in the centres of major synclines, may represent temporary deeper water and lower-energy conditions (Sweet, in preparation). The younger formations of the Hanlon Subgroup — the *Canulgerra Sandstone*, *Vaddingilla Formation*, and *Yaddanilla Sandstone* — may represent a return to shallow-marine-shelf deposition. These three formations are preserved only in the east of the map area.

High-level felsic (granophyre and feldspar porphyry) and mafic (dolerite and gabbro) intrusions, mainly sills, are common within the lower part of the Hatches Creek Group in the western half of the map area. Deeper-level unnamed granite crops out in the southwest, northwest, and central north.

Dolerite, gabbro, and granophyre intrusions near Hatches Creek were termed the *Pedlar Gabbro* by Ryan (1961, and *in* Smith, 1964), who regarded the granophyre as a late-stage differentiate of the gabbro. However, the scarcity of rocks of intermediate composition indicates that the felsic and mafic intrusives were probably derived from separate sources. The name Pedlar Gabbro, therefore, is considered inappropriate for all the high-level intrusions, and is not used in the present study.

Granophyre and feldspar porphyry

Sills of granophyre and feldspar porphyry ranging from a few metres to more than 100 m thick intrude formations of the Ooradidgee Subgroup and the basal formation (Unimbra Sandstone) of the Wauchope Subgroup. The sills are high-level subvolcanic intrusions, and are probably comagmatic with felsic volcanics of the Hatches Creek Group. They are best exposed on footslopes and low mounds, where they typically form small smoothly-rounded boulders with pale thin weathered crusts. Intrusive contacts are sharp, and at their margins the sills commonly show chilling effects, such as spherulitic textures indicative of devitrified glass. Immediately adjacent rocks of the Hatches Creek Group are commonly hornfelsed. Some sills in the far southwest have chilled bulbous lower contacts, indicating intrusion into unconsolidated sediment. In contrast, contacts observed between granophyre and dolerite/gabbro are diffuse, being marked by zones several metres wide of heterogeneous hybrid rocks. Many felsic sills show a prominent platy jointing parallel to their base and top, and some have small miarolitic cavities: few contain any xenoliths. Felsic dykes, possible feeders to either sills or lavas, have been found cutting Hatches Creek Group rocks at a few localities (e.g., at GR NS110987).

Some granophyre is non-porphyritic, but most contains sparse to abundant phenocrysts of albite $\pm$ microcline (rare) $\pm$ quartz (rare) $\pm$ micrographic quartz-feldspar intergrowths $\pm$ biotite (commonly altered) $\pm$ pseudomorphed amphibole or pyroxene $\pm$ opaque minerals, together with irregular fine-grained mafic aggregates (biotite and/or chlorite + opaque minerals) and disseminated sulphide minerals. These are set in a fine to very fine-grained groundmass consisting mainly of micrographic quartz and alkali feldspar. Zircon and apatite are accessory. Secondary minerals which may be present include biotite, chlorite, epidote, sericite/muscovite, hematite, calcite, and rare greenish-brown amphibole. Feldspar porphyry differs from granophyre in not having a micrographic groundmass.

Deeply weathered, phenocryst-rich granophyre near the Cairns gold prospect (GR NT021018) is associated with hematite and magnetite-bearing quartz veins.

Dolerite and gabbro

Dolerite and gabbro form sills, some probably more than 100 m thick, and also cross-cutting sheets and irregular bodies, intruding the Ooradidgee Subgroup. Textures range from fine-grained doleritic (ophitic) to coarse-grained gabbroic. Abrupt internal changes in grainsize and the presence of thin screens of country rock indicate that some sills are multiple intrusions. As the mafic intrusions are relatively readily eroded, they are exposed mainly in gullies, but some form low mounds and piles of boulders in general depressions. They may be comagmatic with basaltic lavas in the Treasure Volcanics and Kudinga Basalt.

Least altered samples of dolerite and gabbro contain primary ophitic clinopyroxene (partly altered to uralitic amphibole) + calcic plagioclase (An_{40-80}) $\pm$ orthopyroxene (rare, generally pseudomorphed) $\pm$ interstitial micrographic quartz and alkali feldspar. Secondary minerals commonly present are epidote, chlorite, biotite, white mica, and actinolite. Quartz veins containing tungsten and copper minerals cut dolerite and gabbro near Hatches Creek (e.g., at the Pioneer mine, GR NS185921), and auriferous quartz veins are spatially associated with dolerite and gabbro at the Crystal mine in the south (at GR NS219953) and near Kurinelli Outstation in the northwest.

Unnamed granite

Unnamed granite crops out in the southwest, northwest, and central north of the map area.

Pink leucocratic granite in the southwest intrudes the Mia Mia Volcanics. It is medium to coarse-grained, even-grained, and non-xenolithic, and consists of about equal amounts of quartz, sodic plagioclase, and perthitic microcline, subordinate muscovite, and minor biotite. Veins and pods of quartz-feldspar pegmatite and greisen cut adjacent country rocks.

Isolated outcrops of intensively weathered, medium to coarse-grained porphyritic granite and minor aplitic granite occur in the northwest. No contacts with other Proterozoic rocks are exposed here.

To the east, a large poorly exposed granite body intrudes the Rooneys Formation, Kurinelli Sandstone, and Taragan Sandstone. The granite ranges from fine to coarse-grained, porphyritic to even-grained, and biotite to biotite + muscovite-bearing. It is commonly xenolithic, and in places is sheared. Samples examined under the microscope contain about equal amounts of quartz, sodic plagioclase, and microcline (some as phenocrysts), subordinate biotite ± muscovite, and minor amounts of allanite, apatite, calcite, chlorite, epidote, opaque oxide, sphene, and zircon.

The granites intruding Hatches Creek Group rocks, and possibly also the granite in the northwest, may be similar in age to the Elkedra Granite (Blake & others, 1985), which was intruded into previously folded Hatches Creek Group rocks in the south of the Elkedra region map area (Blake & Horsfall, 1984): a Rb-Sr isochron age of 1695 Ma for this granite obtained by Riley (reported in Compston & Arriens, 1968) has been amended to approximately 1640 Ma by L.P. Black (personal communication, 1983). Hurley & others (1961) determined a K-Ar age of 1480 Ma on biotite from the granite intruding the Mia Mia Volcanics in the southwest of the Hatches Creek region.

PHANEROZOIC STRATIGRAPHY

MIDDLE CAMBRIAN

Gum Ridge Formation

Rocks assigned to the Gum Ridge formation of Öpik (in Ivanac, 1954) and Smith (1964) form low flat-topped hills and ridge-cappings, mainly in the northern and central parts of the map area. The formation is mostly sub-horizontal, and its contact with underlying Proterozoic rocks is a major unconformity. The main rock types are conglomerate, generally poorly sorted sandstone, thin-banded chert, which is commonly brecciated, and siltstone. Fossils appear to be very rare, but some hyolithid-bearing chert is exposed near GR NT270100. Conglomerate, which predominates in southern outcrops, probably represents alluvial fan and terrace deposits: it consists of angular to rounded pebble, cobble, and boulder-size clasts of locally derived Hatches Creek Group rocks, mainly silicified arenites, in a sparse to abundant, poorly sorted, sandstone matrix.

CAINOZOIC

Eight Cainozoic units have been distinguished on the Hatches Creek region map.

Ferricrete and lateritic gravel (Tl) form cappings up to 3 m thick on Proterozoic and Cambrian rocks. These cappings represent remnants of the upper parts of probably Tertiary weathering profiles, and consist of cemented or friable highly ferruginous material in which no original parent rock structures or textures are visible. *Silcrete* (Ts), which also probably formed during Tertiary weathering, is widespread as small patches (mostly too small to show at 1:100 000 scale) on hills and ridges. It is made up of angular clasts, mainly of quartz, in a very fine-grained to amorphous siliceous matrix.

Calcrete (Czk), represented by inorganic limestone that probably formed by evaporation of groundwater during the Cainozoic, is exposed as low mounds on the Teatree Creek floodplain near GR NT430230. Residual *vein quartz rubble* (Czq) flanks ridge-forming quartz veins. Poorly consolidated to unconsolidated *gravel and sand*(Czc), which may be mainly Tertiary rather than Quaternary, form dissected fans flanking ridges of Proterozoic rocks.

Sand, silt, clay, and gravel deposited on the flood plains of the main watercourses are assigned to unit *Qa*, claypan deposits are mapped as unit *Ql*, and the mixed fluvial, colluvial, and minor aeolian sediments which cover most of the plains in the map area comprise unit *Qc*.

STRUCTURE

The main structural features are shown in the Proterozoic Geology and Structure map on the 1:100 000 map sheet.

The poorly exposed Warramunga Group in the north is moderately to tightly folded, as is indicated by variations in dip and strike of bedding in outcrops southeast of Epenarra homestead. The folds appear to have wavelengths of less than 1 km and axial angles of around 90°. The widespread Hatches Creek Group to the south forms large upright synclines, anticlines, and domes outlined by ridge-forming resistant arenites and valley-forming recessive sedimentary and volcanic rocks. Typical folds are several kilometres across and tens of kilometres long. They are concentric in style except in some fold hinges, where the development of an axial plane cleavage is indicative of additional shortening (Stewart, in preparation).

Numerous faults, some marked by upstanding quartz veins, displace the Proterozoic rocks. Most of the faults probably formed as the Hatches Creek Group was being folded. They appear to be steep or vertical at the surface, but some, especially strike faults, may change to shallow-dipping thrusts at depth. Only a few faults have demonstrable throws of more than a kilometre.

Cambrian and younger sediments are flat-lying, and have not been affected by either folding or, apparently, faulting.

Four major Proterozoic structural units are recognised in the Hatches Creek region, following Stewart (in preparation) and Stewart & Blake (1984). These are the Ooradidgee Block in the far north, the Edmirringee Block in the northwest, the Taragan Block to the south, and the Fold and Thrust Belt in the south and east. The *Ooradidgee Block* contains exposures of granite, Warramunga Group, and, along its southern border, Epenarra Volcanics of the Hatches Creek Group. The Epenarra Volcanics, which generally have steep southerly dips, post-date the tight, relatively small-scale folding of the Warramunga Group. The southern margin of the Ooradidgee Block is marked by a zone of intense quartz-veining and shearing. The *Edmirringee Block* consists of Hatches Creek Group rocks — Epenarra Volcanics, Kurinelli Sandstone, and Rooneys Formation — forming broad folds with general northeasterly trends. The *Taragan Block* extends for about 65 km from northeast to southwest, is up to 25 km wide, and contains generally gently dipping to subhorizontal Hatches Creek Group rocks. It is bounded on its northwestern and southeastern sides by major faults which are considered to be mainly strike-slip faults, although steeply dipping beds along the southeastern boundary indicate that some vertical movement may also have taken place. The Taragan Block appears to end against a poorly exposed granite body to the northeast, and it terminates in a thrust fault in the adjoining Kurundi region to the southwest. Lateral offsets indicate that the block moved 1–2 km southwest relative to adjacent structural units. The presence of later folds superimposed on earlier folds in front of the Taragan Block in the Kurundi region indicates that the block moved after the main folding of the Hatches Creek Group had taken place (Stewart, in preparation). The remainder of the Hatches Creek region is part of Stewart's *Fold and Thrust Belt*. In the west of this belt the Hatches Creek Group forms major tight to isoclinal folds and the Mia Mia Dome (within which the Mia Mia Volcanics are exposed). Small folds, with wavelengths of less than 1 km, occur on the flanks of the dome. Elsewhere in the Fold and Thrust Belt the Hatches Creek Group has been folded into broader and more open structures, and in the far east it forms the western flank of a very large syncline or structural basin. Fold plunges in the belt range from gentle to steep. Axial planes are mostly close to vertical and are generally arcuate. Strike faults, some possibly representing thrusts, may account for abnormal local thicknesses of some formations, such as the Coulters Sandstone south of the abandoned Dempseys homestead.

Variations in fold trends within the region are attributed by Stewart (in preparation) to the presence of relatively rigid masses, especially thick volcanic piles, within the Hatches Creek Group. The more rigid masses acted as buttresses around which well-bedded rocks were folded inhomogeneously to fill the available intervening space.

REGIONAL METAMORPHISM

All Precambrian rocks in the map area, except perhaps some granite, have been affected by low-grade regional metamorphism.

Greywacke and siltstone of the *Warramunga Group* have well-preserved clastic textures, do not appear to have been significantly recrystallised, and are not known to contain any minerals or mineral assemblages diagnostic of a specific metamorphic facies. However, they are tightly folded and generally cleaved, and predate the Hatches Creek Group, hence they have probably been regionally metamorphosed to greenschist facies, like most of the Hatches Creek Group in the region (see below). Alternatively, they may have been regionally metamorphosed to only prehnite-pumpellyite facies, as indicated on the Metamorphic Map of Australia (Vallance & others 1983).

In the *Hatches Creek Group* several features indicate regional metamorphism to greenschist facies. Megascopic and microscopic textures are generally well preserved in sedimentary rocks, but some fine-grained metamorphic white mica and biotite (greenish-brown) are commonly present. Felsic tuffs are commonly cleaved and typically contain metamorphic muscovite/sericite and biotite. Felsic lavas generally have at least some megascopic igneous textures preserved and characteristically contain euhedral phenocrysts of plagioclase which is now albite but was originally of more calcic composition, together with quartz showing variable undulose extinction and ferromagnesian minerals replaced by chlorite and/or greenish-brown biotite and opaque minerals. The groundmass of felsic lavas is partly recrystallised and generally contains some metamorphic muscovite and/or biotite. In the basaltic lavas megascopic and some microscopic primary igneous features are preserved, and igneous pyroxene remnants are present locally; albite, actinolitic amphibole, epidote, chlorite, and biotite occur as secondary and amygdale minerals. In interlayered granophyre sills microscopic igneous textures are preserved, but phenocrysts of originally more calcic plagioclase are now albite, and primary ferromagnesian minerals are pseudomorphed by chlorite or green-brown biotite aggregates. In dolerite and gabbro intrusions ophitic textures are commonly evident, and some plagioclase laths show igneous zoning, but primary pyroxene is generally partly or completely replaced by secondary green amphibole, and most of the plagioclase now present is albite.

The presence of anhedral to subhedral dark-greenish-brown hornblende of metamorphic origin in dacitic feldspar porphyry of the Newlands Volcanics southeast of Hatches Creek indicates that the regional metamorphism may locally have reached upper greenschist or lower amphibolite facies.

Because of the prevailing greenschist-facies regional metamorphism, the felsic volcanics of the Hatches Creek Group and the associated granophyre intrusions cannot be isotopically dated satisfactorily by either the Rb-Sr or K-Ar methods. Any Rb-Sr ages obtained may date the regional metamorphism, but are likely to be uninterpretable, judging from the experience of Black (1981) in the Tennant Creek area and Page (1978) in the Mount Isa region. K-Ar dating may give only a minimum age for metamorphism.

CONTACT METAMORPHISM

Granophyre, gabbro, and granite intrusions commonly have contact metamorphic aureoles ranging in width from less than a metre to perhaps more than 100 m. In these aureoles quartz arenite and feldspathic arenite are recrystallised to quartzitic hornfels, some of which has micrographic textures.

Felsic lavas of the Treasure Volcanics are most altered/metamorphosed in the Hatches Creek mining area, possibly as a result of contact metamorphism related to underlying granite: the lavas here now consist mainly of fine-grained granular aggregates of quartz, muscovite, biotite, and commonly tourmaline which in places is porphyroblastic.

IGNEOUS ROCK GEOCHEMISTRY

Major and trace element analyses are available for 44 felsic and 18 mafic igneous rocks from the Hatches Creek region. The felsic rocks (63–77% SiO_2) comprise 12 from the Treasure Volcanics, 3 (2 highly altered) from the Mia Mia Volcanics, 1 from the Arabulja Volcanics, 4 from the Newlands Volcanics, 22 granophyre samples, and 2 granite samples — one from the Mia Mia Dome (GR NS185804) and one from the northeast (GR NT472270). The mafic rocks (45–56% SiO_2) comprise 3 from the Treasure Volcanics, 4 from the Kudinga Basalt, and 11 dolerite/gabbro samples. Silica values for the igneous rocks show a marked bimodal distribution, indicative of an extensional crustal regime during the magmatism.

The felsic volcanics and granophyre samples plot together on variation diagrams for all elements, indicating that they form a comagmatic suite. This suite has pronounced linear trends for TiO_2, Al_2O_3, P_2O_5, Th, Zr, Nb, and Y, but plots of Fe_2O_3, FeO, MgO, CaO, Na_2O, K_2O, Rb, and Sr against SiO_2 are less well confined, because of alteration effects attributable to weathering, low-grade metamorphism, and/or metasomatism. Notwithstanding the alteration effects, the suite is clearly potassic, most samples containing between 3.5 and 5.5% K_2O and having K_2O/Na_2O values greater than 1.5. Other general geochemical features are: Al_2O_3 contents of 11–13.5%, 0.1–0.25% P_2O_5, 2–30 ppm Th, 4–7 ppm U, 280–350 ppm Zr, 5–70 ppm Y, less than 20 ppm Cu, 3–10 ppm Sn, and up to 7 ppm W. One sample of Mia Mia Volcanics is anomalously rich in W (15 ppm) and another is enriched in Sn (20 ppm).

The two analysed granite samples plot with the Hatches Creek Group volcanics for most elements. However, the granite in the Mia Mia Dome is relatively rich in Sn (20 ppm) and W (12 ppm) and is very low in Zr, La, and Ce; in contrast, the granite in the northeast contains 118 ppm La and 209 ppm Ce, about twice as much as the average Hatches Creek Group felsic volcanic rock.

Although all the analysed mafic igneous rocks are somewhat altered, they show linear trends, indicative of fractionation, on plots of reputedly stable incompatible oxides (TiO_2, P_2O_5) and elements (Zr, Y) against M', where M' = 100 Mg/Mg + 0.85 (Fe^{2+} + Fe^{3+}) (after Cox, 1980). The plots show that the mafic lavas and intrusions are all similar in composition, except that lavas of the Kudinga Basalt are slightly richer in Zr. Low contents of TiO_2 (<1.5%), P_2O_5 (<0.25%), Zr (<200 ppm), and Y (<40 ppm) for the Davenport mafic rocks are comparable to those of most Mount Isa mafic rocks, which are considered to be continental tholeiites (Bultitude & Wyborn, 1982).

GEOPHYSICS (by I.G.H.)

Geophysical investigations are listed in Table 1.

The 1981 semi-detailed airborne-magnetometer and gamma-ray-spectrometer survey by BMR of the Hatches 1:100 000 Sheet area employed north-south flight-lines nominally 400 m apart and 100 m above ground level. The results are available from the Government Printer Copy Service as: (1) contours and stacked profiles of the total magnetic field and total-count gamma-ray-spectrometer channel; (2) stacked profiles of the total-count (TC), potassium (K), uranium (U), and thorium (Th) gamma-ray-spectrometer channels; and (3) stacked profiles of U/K, Th/K, U/Th, U x U/Th, TC x U/Th, and radio-altimeter and flight-path plots.

The geophysical data delineate geophysically distinctive stratigraphic horizons, and granite contact zones which may be loci of undiscovered mineralisation. They have also identified fracture systems that may have been involved in the formation of mineral deposits.

RESULTS AND INTERPRETATION

Gravity

Densities of samples of Hatches Creek rock units are summarised in Table 3 (for details, see Hone & others, in preparation).

TABLE 3. SUMMARY OF ROCK DENSITIES, HATCHES CREEK REGION

Rock type	*No. of samples*	*Density (t/m^3)* Range	Mean
Granite intruding Hatches Creek Group	5	2.63–2.68	2.65
Granite intruding Warramunga Group	7	2.68–2.73	2.70
Granophyre	6	2.65–2.70	2.69
Mafic sills	22	2.80–3.12	2.98
Mafic volcanics	59	2.78–3.33	2.94
Felsic volcanics	54	2.58–2.94	2.74
Sandstone	37	2.56–2.95	2.67
Other sedimentary rocks	9	2.57–3.03	2.80

* For details, see Hone & others (in preparation).

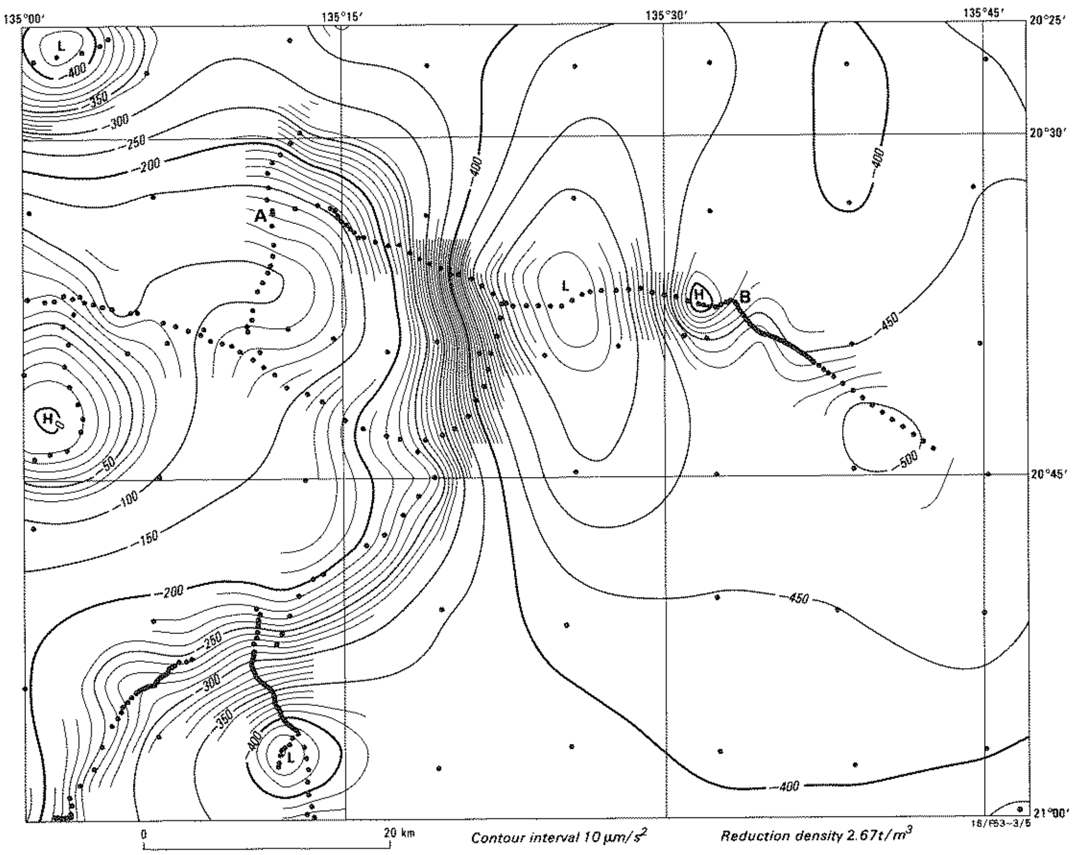

Fig. 6. Hatches Creek region, contours of Bouguer gravity. Contour interval, 10 $\mu m.s^{-2}$, reduction density 2.67 t/m^3.

Gravity values are higher in the central-western part of the region, over the Ooradidgee Subgroup, than in the southeast, over the Hanlon and Wauchope Subgroups.

Five main Bouguer gravity features can be recognised (Fig. 6):

1. An extensive yet intense low just east and north of the centre of the map area, attributed to a steep-sided granite body measuring about 27 km from north to south, about 17 km from east to west, and about 15 km thick. An interpreted profile, based on a forward model along line A–B in Figure 6 across the low, is given in Figure 7.
2. A gravity low in the southwest. This is probably due to another granite, a small part of which is exposed in the eastern part of the Mia Mia Dome.
3. A less intense gravity low in the far northwest, which is probably due to granite intrusive into the Warramunga Group.
4. A gravity high in the west, which may be due to either thick bodies of mafic rocks or a rise in dense basement.
5. A broad gravity low in the east. This is interpreted as being due to a substantial thickness of Hanlon Subgroup sedimentary rocks

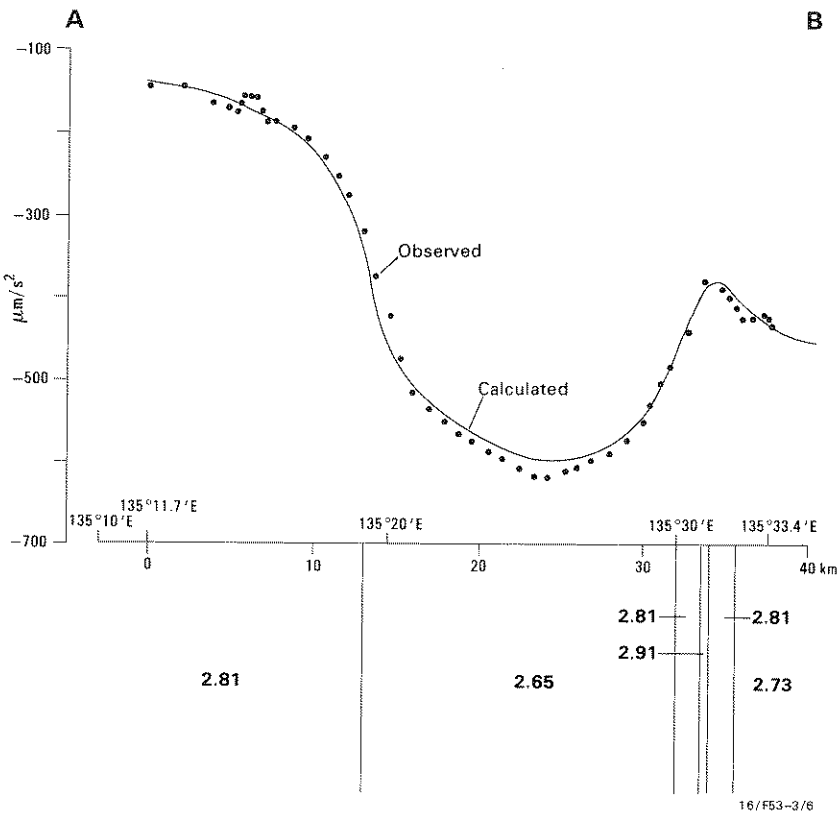

Fig. 7. Gravity profile and interpreted model along line AB in Figure 6, northeast Hatches Creek region.

Magnetics

Total-magnetic-field contours at 10 nT intervals are printed on the back of the geological map, and are also shown in synoptic form in Figure 8 for comparison with the total-count gamma spectrometer contours shown at the same scale in Figure 9. The contours indicate the presence of long, continuous, stratigraphically conformable magnetic sources that clearly outline geological structures. Several major faults, especially those bounding the Taragan Block, correspond with breaks in the contour pattern.

The results of laboratory magnetic-susceptibility and remanence measurements on representative samples are summarised in Table 4, together with Koenigsberger ratios (ratios of remanent to induced magnetisations, assuming an inducing field of 52 000 nT).

The sedimentary rocks of the Hatches Creek Group are non-magnetic. Some felsic volcanic samples are magnetic, in particular some from the Newlands Volcanics and Treasure Volcanics, as also are most samples of mafic intrusives and granophyre,

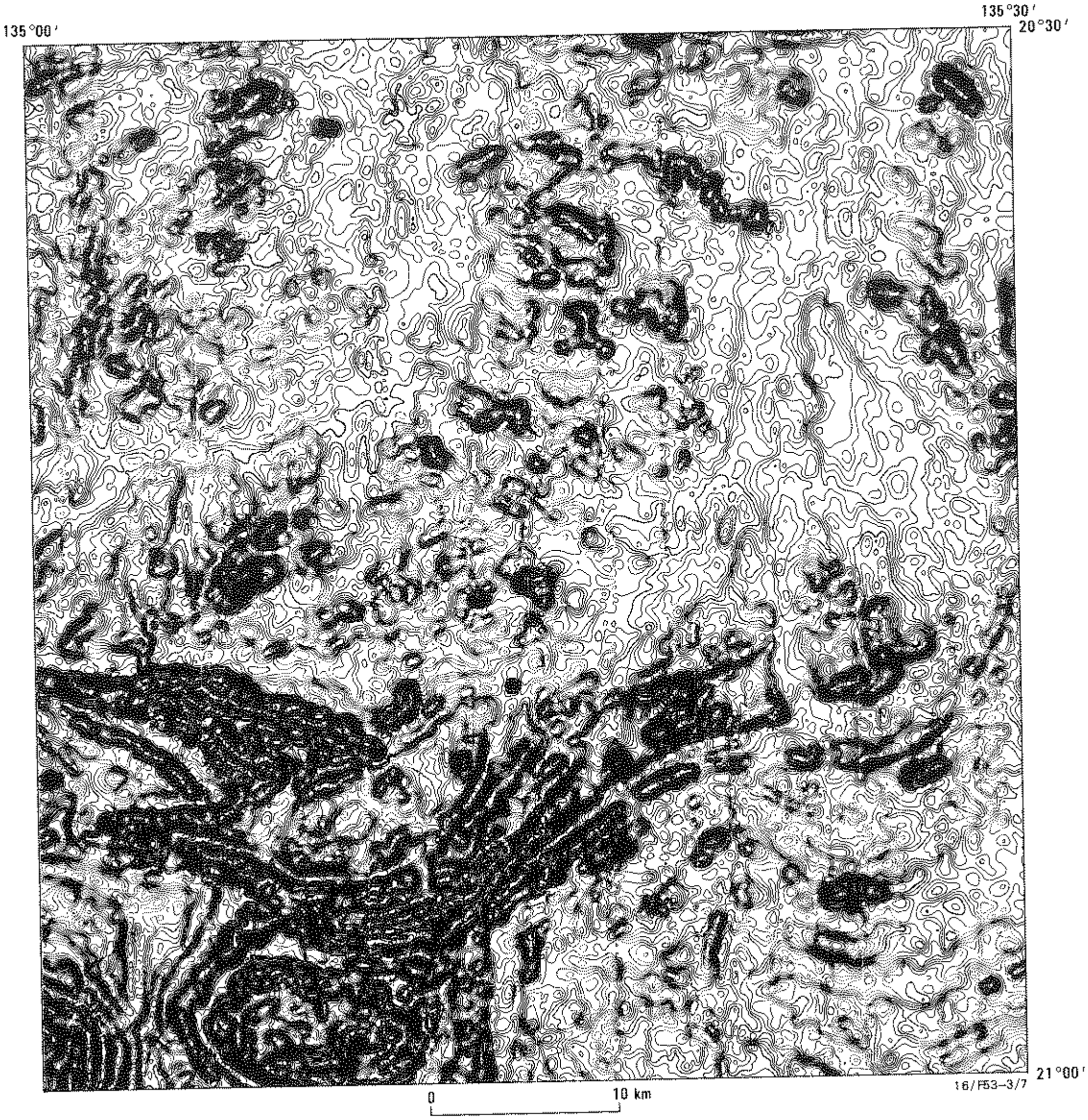

Fig. 8. Hatches 1:100 000 Sheet area: total-magnetic-field contours.

and especially basalt. The granites are non-magnetic. The youngest magnetic rock in the Hatches Creek Group is basalt at the base of the Alinjabon Sandstone. The Kudinga Basalt is less magnetic than the basalt of the Treasure Volcanics, which in turn is less magnetic than the basalt of the Alinjabon Sandstone.

The Warramunga Group has a wide range of magnetic properties and, unlike the Hatches Creek Group, includes some highly magnetic sedimentary rocks.

Table 5 gives the typical maximum magnetic anomalies recorded for the various rock units from the airborne data. The strongest magnetic anomalies arise from dolerite and gabbro sills, and from the Kudinga Basalt. However, not all the dolerite and gabbro are strongly magnetic. Moderate magnetic anomalies arise from sources in felsic volcanics of the Epenarra, Treasure, Mia Mia, and Newlands Volcanics, basalt of the Alinjabon Sandstone, and granophyre sills. These anomalies are typically of very long strike length. Moderately strong magnetic anomalies of short strike extent arise from restricted igneous sources in the Kurinelli Sandstone and Taragan Sandstone. Arenites and granite are almost non-magnetic, and the granite intrusions do not appear to have magnetic contact aureoles.

Radiometrics

Total-count gamma-ray spectrometric contours obtained from the 1981 airborne survey are shown in reduced, condensed form in Figure 9. In the south, where the Proterozoic rocks are well exposed, highs and lows of long strike length correlate with the

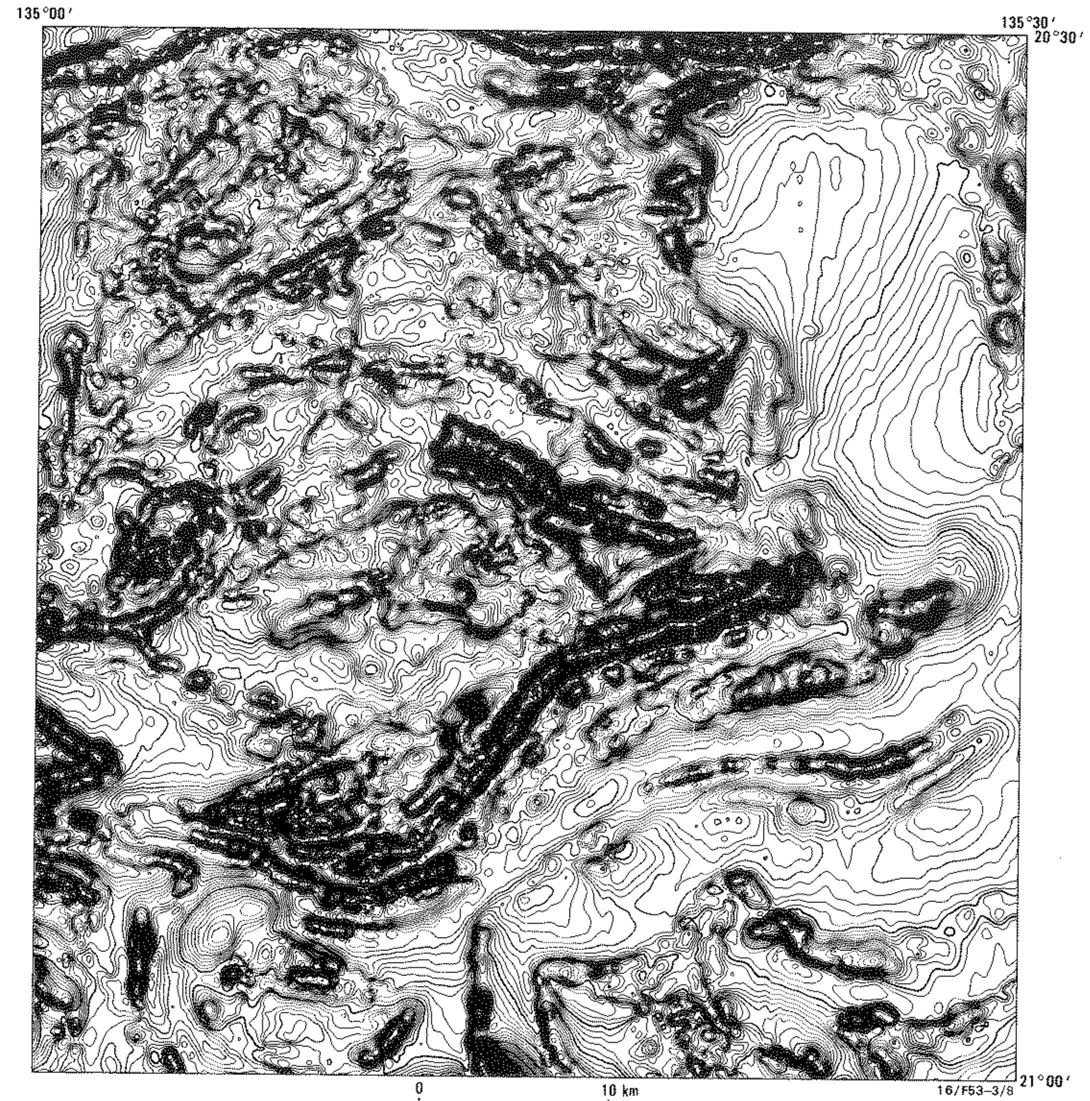

Fig. 9. Hatches 1:100 000 Sheet area: radiometric contours, total-count channel.

mapped rock units. Highs occur over the Mia Mia and Treasure Volcanics, and lows over the Coulters and Errolola Sandstones. Local highs occur over the Frew River Formation and Newlands Volcanics. In the less well exposed northern parts, anomalies are less elongate, and the local highs appear to be due mainly to scattered exposures of felsic volcanics and laterite. The radioactivities of the rock units, deduced from amplitudes of total-count gamma spectrometric anomalies, are summarised qualitatively in Table 6. The highest-amplitude anomalies are over felsic volcanics and granophyre sills. The granites also appear to be relatively radioactive, but this is difficult to determine from the airborne data because of limited exposure. The Taragan, Coulters, and Errolola Sandstones are distinguished by very low radioactivity in places, whereas the Kurinelli and Yeeradgi Sandstones are weakly radioactive in places, probably where they include some felsic volcanics and tuffaceous sedimentary rocks. The mafic volcanics and intrusives are slightly radioactive in places.

The spectral radiometric data can provide useful additional information when displayed on an image processing system. Moore (1983), for example, has shown that rocks of the Treasure Volcanics in the east are, relative to those in the west, enriched in uranium and thorium, and depleted in potassium, probably because of more intensive weathering and the development of laterite; also, the Coulters Sandstone around the Mia Mia Dome is particularly deficient in uranium, and the Taragan Sandstone near the centre of the Hatches Sheet area has anomalously low potassium.

TABLE 4. SUMMARY OF MAGNETIC SUSCEPTIBILITIES, REMANENCES, AND KOENIGSBERGER RATIOS

Unit	*Rock type*	*Number of samples*	*Susceptibility (μSI)*			*Remanence (mA.m⁻¹)*			*Koenigsberger ratio*		
			Range	*Median*	*Mean*	*Range*	*Median*	*Mean*	*Range*	*Median*	*Mean*
—	laterite	2	810–1000	910	910	2–100	51	51	0.05–2.96	1.50	1.50
Felsic intrusives	granophyre	6	2570–23 510	8160	11 120	70–6500	1850	2378	0.66–21.37	2.96	6.00
	granite intruding Hatches Creek Group	5	120–1180	220	400	0.2–150	2	34	0.03–3.04	0.19	0.95
	granite intruding Warramunga Group	7	150–850	330	380	1–85	20	26	0.08–4.95	1.44	1.71
Mafic intrusives	dolerite, gabbro	23	490–84 160	2510	13 490	0.14–300 000	850	20 506	0.02–262	7.21	35.11
Canulgerra Sandstone	quartz arenite	1	—	0	0	—	5	5	—	—	—
Alinjabon Sandstone	quartz arenite	3	150–200	200	180	0.6–12	0.8	4	0.01–1.15	0.10	0.45
	basalt	7	300–49 420	2810	14 890	50–10 000	355	2003	0.79–7.69	4.16	3.98
	dolerite, basalt	3	850–15 300	13 080	9740	5–1500	65	523	0.09–2.36	1.87	1.44
Errolola Sandstone	quartz arenite	4	0–1300	70	370	1–7	3	4	0.1–1.92	1.22	1.08
Kudinga Basalt	basalt	30	140–29 100	810	2390	0.5–2400	3	188	0.01–25.64	0.10	1.26
Coulters Sandstone	quartz arenite	6	0–40	0	10	0.5–70	10	18	—	45	45
Arabulja Volcanics	felsic volcanics	3	10–6000	2600	2870	60–150	100	103	0.24–283.02	0.92	94.73
Newlands Volcanics	felsic porphyry	12	400–47 490	5340	9940	20–4500	175	994	0.18–10.43	1.72	3.04
Yeeradgi Sandstone	arenite	2	10–840	740	740	—	6	6	1.05–11.0	6.03	6.03
	siltstone, claystone	7	220–840	380	470	0.8–45	9	19	0.07–4.52	0.56	1.09
Unimbra Sandstone	arenite	4	30–330	140	160	1–550	1	138	0.06–55.0	1.22	14.13
Mia Mia Volcanics	felsic volcanics	3	50–240	80	120	1–4	3	3	0.10–1.50	0.96	0.85
	quartz arenite	1	—	240	240	—	550	550	—	55.0	55.0
Treasure Volcanics	felsic volcanics	19	10–22 000	380	2440	1–57 500	50	3201	0.07–578	—	—
	basalt	8	390–8230	1330	2690	1–2200	65	596	0.03–19.41	0.82	4.35
Taragan Sandstone	arenite	6	0–90	20	30	0–15	2	4	0.08–1.92	1.28	1.09
Kurinelli Sandstone	arenite	4	0–1030	600	560	0–250	18	71	0.02–5.86	2.24	2.71
Rooneys Formation	siltstone	1	—	200	200	—	1	1	—	0.12	0.12
Epenarra Volcanics	felsic volcanics	9	140–4750	360	940	0.8–1200	30	227	0.11–27	1.90	5.24
	siltstone, arenite	5	170–370	300	280	0.5–350	15	80	0.03–48	2.00	10.92
Warramunga Group	sedimentary rocks, porphyry	14	20–149 110	15 400	24 820	0.3–11 200	400	1797	0.03–9.22	0.69	1.48

TABLE 5. MAGNETIC ROCK UNITS: TYPICAL MAXIMUM ANOMALIES ENCOUNTERED IN THE AIRBORNE DATA

Unit	*Maximum anomaly (nT)*
Alinjabon Sandstone	190 (mafic volcanics)
Kudinga Basalt	690, 210, 210, 120
Newlands Volcanics	100, 140, 240
Mia Mia Volcanics	270
Treasure Volcanics	170, 190, 90, 90, 80 (mafic volcanics)
Taragan Sandstone	120 (short strike extent, from mafic volcanics?)
Kurinelli Sandstone	130 (short strike extent, from mafic volcanics)
Epenarra Volcanics	370
Dolerite and gabbro sills	680
Granophyre	60

TABLE 6. SUMMARY OF APPARENT RADIOACTIVITIES OF ROCK UNITS IN THE HATCHES 1:100 000 SHEET AREA

Unit	*Radioactivity*
Lennee Creek Formation	Low
Alinjabon Sandstone	Low
Errolola Sandstone	Distinctively low, generates lows of long strike length
Kudinga Basalt	Weak
Frew River Formation	Mainly weak; moderate over a limited strike length
Coulters Sandstone	Distinctively low
Yeeradgi Sandstone	Weak
Newlands Volcanics	Moderate to weak
Arabulja Volcanics	Moderate
Unimbra Sandstone	Moderate (felsic lava) to low (arenite)
Mia Mia Volcanics	Moderate (felsic volcanics) to low (arenite)
Treasure Volcanics	Moderate (felsic lava) to low (mafic volcanics and arenite)
Taragan Sandstone	Noticeably low
Kurinelli Sandstone	Weak
Rooneys Formation	Low
Epenarra Volcanics	Moderate
Dolerite and gabbro sills	Low to locally weak
Granophyre	Moderate to weak
Granite	Moderate to weak

MINERAL RESOURCES

Tungsten, gold, copper, and bismuth have been produced from the Hatches Creek region. The most intensely mineralised part of the area is near the abandoned mining settlement of Hatches Creek, in the southwest — the Hatches Creek mineral field (mapped in detail by Ryan, 1961), from which almost all of the recorded production of tungsten, and all of that of copper and bismuth, has come. Most of the gold produced has been obtained from small mines near Kurinelli Outstation in the northwest (Roarty, 1977).

Mining began near Hatches Creek in 1913, and was carried out sporadically until late 1957, by which time about 3000 t of tungsten concentrate (about 65% WO_3), 5.7 t bismuth concentrate, and 70 t copper concentrate had been produced (Ryan, 1961). The tungsten production includes a small amount of eluvial concentrate.

The mineralisation near Hatches Creek occurs in quartz veins. These are generally steeply dipping, mainly between 15 and 45 cm wide, and of various orientations. Ore minerals present (Ryan, 1961) include the tungsten minerals wolframite, scheelite, tungstite, and probably cuprotungstite; the bismuth minerals bismutite, bismuthinite, and native bismuth; the copper minerals chalcopyrite, chalcocite, covellite, bornite, malachite, azurite, chrysocolla, atacamite, brochantite, and tetrahedrite; molybdenite; very sparse cassiterite; and traces of gold. Quartz and subordinate mica are the main gangue. The mineralised veins cut Kurinelli Sandstone, Taragan Sandstone, and Treasure Volcanics of the Ooradidgee Subgroup and also dolerite and gabbro. They appear to postdate the folding of the Hatches Creek Group rocks, and are thought to be related to a postulated underlying granite, perhaps part of the granite intruding the Mia Mia Volcanics to the south (at GR NS185805).

A few small tungsten mines and prospects are present to the north, where wolframite-bearing quartz veins cut the Treasure Volcanics, Kurinelli Sandstone, and Warramunga Group. These veins are well away from any exposed granite.

Gold in the Kurinelli area, and also at the Crystal gold mine near Hatches Creek (at GR NS219953), occurs in quartz veins cutting gabbro and dolerite intrusions and associated screens and xenolithic blocks of thinly bedded siltstone and fine-grained arenite of the Rooneys Formation (near Kurinelli) and Endurance Sandstone Member of the Kurinelli Sandstone (at the Crystal mine). The total recorded production from the Kurinelli area is about 13.6 kg gold (Roarty, 1977), made up of about 12.4 kg reef gold and 1.2 kg alluvial/eluvial gold. The auriferous quartz veins may be related to the main folding and metamorphic event affecting the Hatches Creek Group. The close association with dolerite and gabbro indicates that the gold may have been derived from a mafic igneous source.

A few small copper deposits have been worked near Hatches Creek, where some tungsten-bearing quartz veins contain appreciable copper values.

There is also a small abandoned copper mine to the east (at GR NS376875), situated in amygdaloidal Kudinga Basalt. Traces of secondary copper minerals have been noted in basaltic lava of the Treasure Volcanics (at GR NS095976), and chalcopyrite is present as an accessory mineral in some dolerite and gabbro bodies.

ECONOMIC POTENTIAL

The Hatches Creek field may become economic as a result of a rise in metal prices combined with more efficient mining methods and metallurgical processes. Inferred ore reserves, as determined by Ryan (1961), are around 1000 t of tungsten concentrate. Because the region has been extensively prospected over many years, and the mineralised quartz veins generally form prominent topographic features, it is unlikely that any significant new deposits of Hatches Creek type will be found outcropping in the map area. However, blind mineralisation may conceivably exist, related to either outcroppings or concealed granites.

The most prospective target for base-metal deposits may be the Frew River Formation in the Wauchope Subgroup of the Hatches Creek Group. The formation contains carbonates, is locally stromatolitic, and was probably deposited in very-shallow-marine, lacustrine, or sabkha environments; the carbonates in it are similar to those associated with the McArthur River lead-zinc deposits, and are possibly of comparable age. Hence the formation can be considered a potential host for syngenetic stratiform mineralisation. Although the Frew River Formation is not known to contain any base-metal mineral occurrences, this may be partly because it is a recessive unit largely concealed by surficial Cainozoic sediments.

A stream-sediment geochemical orientation survey undertaken by BMR in 1982 (Hoatson & Cruikshank, 1985) indicates that there is little potential for a significant W ± Cu ± Bi ± Mo deposit northeast of the Hatches Creek tungsten mines, nor for stratiform exhalative-type scheelite mineralisation in the quartz-rich sedimentary rocks of the Hatches Creek Group. Detrital cassiterite and scheelite found in coarse sieve fractions in the eastern part of the Mia Mia Dome are probably derived from the outcrop of unnamed granite or from adjacent Mia Mia Volcanics and are unlikely to occur in economic concentrations.

NOTES ON MINES AND PROSPECTS

Black Diamond mine, W (GR NS195905)
Reference: Ryan (1961).
Surface workings: shafts, pits, costeans; maximum depth worked about 60 m.
Country rocks: arenite of Warnes Sandstone Member, Kurinelli Sandstone.
Lodes: quartz veins striking about 060° and dipping 60–80°S.
Ore and gangue: wolframite and quartz; very minor scheelite, bismutite, malachite, iron oxides; some mica.
Production: 87.2 t concentrate, 1939–58.

Bonanza mine, W (GR NS192903)
Reference: Ryan (1961).
Surface workings: shaft, pits; worked to depth of at least 30 m.
Country rock: arenite, Kurinelli Sandstone.
Lodes: quartz veins up to 45 cm wide striking about 060° and dipping 60–75°S.
Ore and gangue: wolframite, quartz; minor scheelite; some copper and bismuth minerals.
Production: 56.92 t concentrate, 1938–54.

BXB mine, W (GR NS206858)
Reference: Ryan (1961)
Surface workings: shafts, pits, costeans; worked to depth of about 18 m.
Country rocks: altered felsic volcanics (mainly lavas) and minor interlayered quartz arenite, Treasure Volcanics.
Lodes: two sets of north to northeast-trending steeply-dipping quartz veins up to 40 cm wide.
Ore and gangue: wolframite and quartz; minor scheelite, copper and bismuth carbonates, biotite, kaolinite, and iron oxides.
Production: 19.2 t concentrate recorded to 1957.

Cairns prospect, Au (GR NT021018)
Reference: Roarty (1977).
Surface workings: costeans.
Country rocks: altered porphyritic granophyre; arenite and siltstone, Kurinelli Sandstone.
Lodes: quartz and quartz-hematite-magnetite veins.
Ore and gangue: gold, quartz, iron oxides.

Copper Show mine, W, Cu (GR NS168852)
Reference: Ryan (1961).
Surface workings: shafts, pits, costeans; worked to depth of about 27 m.
Country rocks: altered felsic volcanics and some thin arenite lenses, Treasure Volcanics.
Lodes: two main quartz veins striking 100° to 140° and dipping 40–80°N; average width about 60 cm.
Ore and gangue: wolframite, scheelite, tungstite, cuprotungstite, malachite, azurite, chalcocite, bornite, bismutite(?), limonite, fuchsite(?), muscovite, quartz.
Production: about 22 t tungsten concentrate 1938–56 and 44 t copper concentrate 1950–55.

Crystal mine, Au (GR NS219953)
Reference: Ryan (1961).
Surface workings: two main shafts, pits.

Country rocks: altered gabbro and dolerite; blocks/screens of fine-grained arenite, Kurinelli Sandstone.
Lodes: quartz veins; main vein trends 025° and dips 45–50°E.
Ore and gangue: gold, quartz, limonite.
Production: none recorded.

Dempseys Choice, Au (GR NT040206)
Reference: Roarty (1977).
Surface workings: shaft, pits, costeans.
Country rocks: gabbro, dolerite.
Lodes: quartz veins.
Ore and gangue: gold, quartz.
Production: about 1200 g Au, 1933.

Endurance mine, W, Bi (GR NS190914)
Reference: Ryan (1961).
Surface workings: shafts to depth of 12 m, pits, costeans.
Country rocks: altered gabbro (Pedlar Gabbro of Ryan, 1961); arenite and siltstone, Kurinelli Sandstone, exposed nearby to north.
Lodes: quartz reef up to 35 mm wide striking about 060° and dipping 55–70°SE.
Ore and gangue: scheelite, wolframite, bismuthinite, bismuth and copper carbonates; quartz and subordinate epidote, mica, and sericite.
Production: 7.5 t mixed wolframite-scheelite-bismuth concentrates, 1952–58.

Euro mine, W (GR NS190859)
Reference: Ryan (1961).
Surface workings: shaft, pits, costeans.
Country rock: arenite, Taragan Sandstone.
Lodes: northeast-trending quartz veins (on the Kangaroo Line).
Ore and gangue: wolframite, quartz, mica.
Production: 1.35 t concentrate, 1948–57.

Frenchmans Point mine, W (GR NS205877)
Reference: Ryan (1961).
Surface workings: pits, costeans.
Country rocks: quartzose arenite, Taragan Sandstone.
Lodes: steeply dipping quartz veins up to 15 cm wide striking east to north.
Ore and gangue: wolframite, quartz.
Production: 5.7 t concentrate, mainly in 1942–44.

Green Diamond group of mines, W, Cu (GR NS196902)
Reference: Ryan (1961).
Surface workings: shaft (maximum depth 41 m), pits, costeans.
Country rock: arenite, Warnes Sandstone Member of the Kurinelli Sandstone.
Lodes: quartz veins up to 45 cm thick dipping 35–60°S, strike approximately parallel to bedding in country rock.
Ore and gangue: wolframite, scheelite, tungstite, azurite, malachite, bismutite, bismuthinite, cuprite, native copper, iron oxides, pyrite, chalcopyrite, quartz; subordinate muscovite, kaolin.
Production: 58.3 t tungsten concentrate 1937–58. Some tungsten and copper concentrates produced in 1969 (Cu ore sent to Mount Isa).

Hen and Chickens mine, W (GR NS205861)
Reference: Ryan (1961).
Surface workings: shafts, pits, costeans; worked to depth of about 25 m.
Country rocks: altered felsic lava and interlayered arenite, Treasure Volcanics.
Lodes: three quartz veins striking between 100° and 120° and dipping south; one quartz vein striking 180° and dipping 60–80°W.
Ore and gangue: mainly wolframite and quartz; rare scheelite, minor malachite, chalcocite, covellite, chalcopyrite, and possibly native bismuth; some iron oxides and mica.
Production: 24 t concentrate before 1940; 444 t concentrate 1940–58.

Hit or Miss group of mines, W (GR NS195855)
Reference: Ryan (1961).
Surface workings: several shafts, pits, costeans; worked to depth of 62 m.
Country rocks: altered felsic lava and minor interlayered arenite, Treasure Volcanics.
Lodes: numerous steeply dipping quartz veins, mostly striking between north and northwest.
Ore and gangue: wolframite and quartz, with minor molybdenite and mica; also, in lodes trending east-northeast, abundant copper minerals — azurite, malachite, chrysocolla, atacamite, brochantite, chalcocite, and bornite.
Production: probably more than 400 t concentrate to 1958.

Kangaroo group of mines, W (GR NS188857)
Reference: Ryan (1961).
Surface workings: shafts, pits, costeans; worked to depth of 41 m.
Country rocks: interlayered arenite and altered felsic lava, Treasure Volcanics, and, in north, quartz arenite, Taragan Sandstone.
Lodes: northeast-trending quartz veins of the Kangaroo Line, and several other quartz veins of various trends: veins mainly steeply dipping and up to 1 wide.
Ore and gangue: wolframite, quartz, mica; minor molybdenite and copper minerals.
Production: probably at least 100 t concentrate.

Kurinelli mine, Au (GR NT036180)
Reference: Roarty (1977).
Surface workings: shaft, pits, costeans.
Country rock: dolerite; thin-bedded to laminated micaceous siltstone and fine-grained arenite, Rooneys Formation.

Lodes: quartz veins.
Ore and gangue: gold, quartz.
Production: about 8.215 g Au, 1935–77; 0.5 kg alluvial gold, 1926.

Masters Gully mine, W (GR NS198862)
Reference: Ryan (1961).
Surface workings: shafts, pits, costeans; worked to depth of 46 m.
Country rocks: altered felsic lava and interlayered arenite, Treasure Volcanics, and, in north, quartz arenite, Taragan Sandstone.
Lodes: three main quartz veins with easterly and northerly trends and steep dips.
Ore and gangue: wolframite, traces of copper, bismuth, and molybdenum minerals; quartz, some mica.
Production: 95.1 t concentrate 1937–58.

Pioneer mine, W (GR NS185920)
Reference: Jensen (1955), Ryan (1961).
Surface workings: shafts, costeans, pits; main shaft with poppet head; worked to depth of 63 m.
Country rocks: gabbro and dolerite (Pedlar Gabbro of Ryan, 1961); screens of arenite and siltstone, Kurinelli Sandstone.
Lodes: quartz veins up to about 1 m wide striking about 060° and dipping 40–70°S.
Ore and gangue: wolframite and scheelite, with bismutite, chalcocite, azurite, malachite, and limonite in oxidised zone, and native bismuth, bismuthinite, tetrahedrite, pyrite, and chalcopyrite. Quartz, the main gangue, is accompanied by mica, feldspar, and less commonly epidote and tourmaline.
Production: 442 t concentrate 1935–58, assaying 66–67% WO_3; average grade mined, about 2.2% WO_3. Also worked in late 1960s.

Ricketty Kate mine, W (GR NS200910)
Reference: Ryan (1961).
Surface workings: shallow shaft, pits, costeans; maximum depth worked about 3 m.
Country rock: arenite, Kurinelli Sandstone.
Lodes: northeast-striking quartz veins up to 30 cm wide dipping 45–85°S.
Ore and gangue: wolframite and small amounts of copper and bismuth minerals, with quartz and minor mica.
Production: 9 t concentrate recorded to 1952.

Silver Granites mine, W (GR NS193853)
Reference: Ryan (1961).
Surface workings: shafts, pits, costeans; worked to depth of about 28 m.
Country rocks: altered felsic lava, Treasure Volcanics.
Lodes: several steeply dipping quartz veins striking northeast to east-northeast, one vein striking north-northeast.
Ore and gangue: wolframite, malachite, bornite, chalcocite, molybdenite, and native bismuth(?), with quartz and some mica.
Production: 19 t concentrate recorded 1938–57.

Treasure group of mines, W — Treasure (Fig. 10; GR NS197868), Hidden Treasure (GR NS198866), Next Treasure (GR NS195866).
Reference: Ryan (1961).

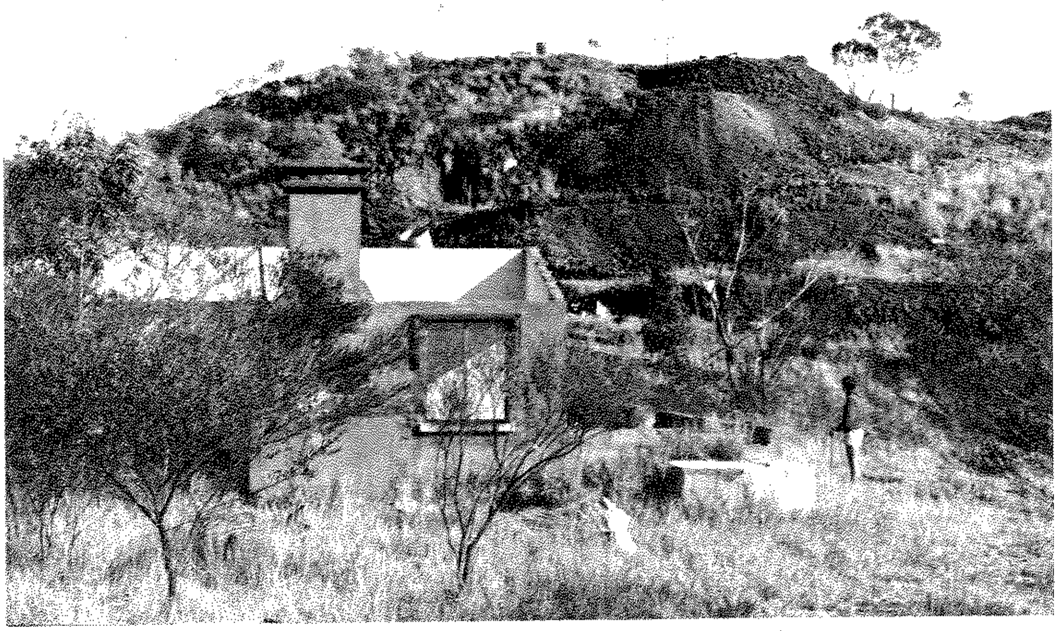

Fig.10. Treasure tungsten mine, Hatches Creek, August 1984 (M2660/18).

Surface workings: shafts, pits, costeans; worked to depth of about 55 m.
Country rocks: altered lava and some interlayered arenite. Treasure Volcanics, underlain to N and overlain to S by ridge-forming quartzose and pebbly arenite, Taragan Sandstone. Most lodes are in volcanics.
Lodes: north-trending quartz veins, generally less than 30 cm wide, with vertical to steep westerly dips.
Ore and gangue: wolframite and quartz; traces of copper, bismuth, and lead minerals; minor biotite; no scheelite.
Production: 329 t concentrate 1936–58.

White Diamond mine, W (GR NS200860)
Reference: Ryan (1961).
Surface workings: shaft, pits, costeans; worked to depth of 15 m.
Country rocks: altered felsic lava and interlayered arenite, Treasure Volcanics.
Lodes: two main quartz veins, up to 40 cm wide, with easterly and northerly trends and steep dips.
Ore and gangue: wolframite, quartz; minor malachite, azurite, chalcocite, molybdenite, muscovite, biotite; traces of bismuth.
Production: 34.53 t concentrate 1942–58, possibly similar production 1936–41.

Woodenjerrie mine, W (GR NT279369)
Surface workings: shallow shafts, pits, costeans.
Country rocks: medium to thin-bedded greywacke and siltstone, Warramunga Group.
Lodes: quartz veins.
Ore and gangue: wolframite, quartz, hematite, pyrite.
Production: minor; worked 1952–53.

Mine, W, Cu (GR NS170948)
Surface workings: shaft, pit, costeans.
Country rocks: highly fractured altered felsic lava, Treasure Volcanics.
Lodes: quartz veins.
Ore and gangue: wolframite(?), malachite, quartz.
Production: not known, minor.

Mine, W (GR NS210944)
Surface workings: pits.
Country rock: fine-grained feldspathic quartz arenite, Kurinelli Sandstone.
Lode: quartz vein.
Ore and gangue: wolframite(?), quartz.
Production: none.

Prospect, Cu (GR NS180873)
Surface workings: pits, costeans.
Country rocks: quartz arenite, Kurinelli Sandstone, and chloritic dolerite dyke up to 3 m thick.
Lodes: irregular quartz veins.
Ore and gangue: malachite, quartz.
Production: none known.

Mine, Cu (GR NS376875)
Surface workings: shaft, pits.
Country rock: altered basaltic lava, Kudinga Basalt.
Lodes: quartz veins.
Ore and gangue: malachite, quartz, iron oxide, calcite.
Production: minor, unknown.

Prospects, Au (GR NT054202, NT064198, NT060184)
Surface workings: pits, costeans.
Country rocks: dolerite, gabbro, arenite and siltstone, Rooneys Formation.
Lodes: quartz veins.
Gangue: quartz; some secondary copper minerals at GR NT064198.

Prospects, Au? (GR NT030146, NT027138)
Surface workings: pit, costeans.
Country rocks: altered dolerite; fine-grained feldspathic arenite, Rooneys Formation.
Lodes: quartz veins.
Gangue: quartz.

GEOLOGICAL HISTORY

The earliest event recorded in the map area was the deposition of muddy sand and silt represented by the Warramunga Group, probably by turbidity currents in deep water, about 1870 Ma ago (Black, 1984). Some time after lithification, the Warramunga Group was folded and subjected to low-grade regional metamorphism, probably at around 1810 Ma (Black, 1977, 1981). The unnamed granite in the northwest may have been emplaced at about this time, or at a later date. Uplift associated with the tectonism was followed by a period of erosion.

Subsequent regional downwarping, possibly due to crustal thinning, resulted in the area becoming part of an extensive, ensialic depositional basin. Renewed sedimentation was accompanied by felsic and basaltic volcanism and pene- contemporaneous high-level, subvolcanic intrusive activity, represented by the Hatches Creek Group and associated granophyre, feldspar porphyry, dolerite, and gabbro. Sedimentation and the accumulation of volcanic products kept pace with subsidence in the basin, so that shallow-marine to fluvial and locally subaerial depositional environments prevailed throughout Hatches Creek Group time (see Sweet, in preparation).

The earliest volcanism in the map area was largely felsic in character; it took place in the north, probably from several volcanic centres, and is represented by the Epenarra Volcanics of the Ooradidgee Subgroup. Penecontemporaneous shallow-marine and fluvial sedimentation resulted in the deposition of the Rooneys Formation, Kurinelli Sandstone, and Taragan Sandstone to the south of the Epenarra Volcanics. In places the sediments interfingered with and overlapped the volcanics. These sediments and the younger sediments of the Hatches Creek Group were mainly derived from source areas of Warramunga Group and Arunta rocks to the west (Sweet, in preparation), but at some stratigraphic levels they included considerable amounts of locally derived volcanic detritus. A later phase of volcanism from possibly several separate centres in the south is represented by the felsic and subordinate mafic lavas and associated pyroclastics of the Treasure Volcanics and the mainly felsic pyroclastics of the Mia Mia Volcanics. This volcanism, which is considered to have been partly subaerial, was accompanied by shallow-water clastic sedimentation, resulting in sands being interlayered with and overlapping lava flows and pyroclastic deposits on the flanks of volcanic piles. Most of the granophyre and feldspar porphyry intrusions in the area may have been emplaced during this phase of volcanism.

At the end of Treasure Volcanics time there was a general lull in volcanic activity, and, as subsidence in the basin continued, a thick shallow-marine to fluvial quartz-rich sand blanket was laid down over the entire area. This sand blanket is represented by the Unimbra Sandstone of the Wauchope Subgroup. Subsequent eruptions from a new group of volcanic centres led to the Unimbra sands being overlain by volcaniclastic sediments of the Yeeradgi Sandstone, felsic lava of the Arabulja Volcanics, and dacitic ignimbrite of the Newlands Volcanics. When this volcanism ceased, the area became covered by another thick, quartz-rich sand blanket, now the Coulters Sandstone. This sand was succeeded by mainly finer-grained clastic sediments and carbonates of the Frew River Formation. The carbonates included some stromatolitic bioherms and were evidently laid down in very shallow-marine, supratidal, or sabkha environments. A period of basaltic volcanism followed, during which Kudinga Basalt lava flowed onto a broad plain or shallow shelf underlain by the Frew River Formation. Feldspathic sands were deposited during intervals between eruptions early in Kudinga Basalt time. Some of the dolerite and gabbro intrusions in the area may be genetically and temporally related to this volcanism. After the basaltic eruptions had ceased, a third extensive thick blanket of quartz-rich sand was deposited, partly on intertidal flats. This sand forms the Errolola Sandstone at the base of the Hanlon Subgroup. Shallow-marine and possibly deltaic sedimentation followed, with the deposition of sands and subordinate silts and clays of the Alinjabon Sandstone, accompanied at first by minor mafic volcanism, the last recorded volcanism in the area. Water depth may have increased during deposition of mainly fine-grained sediments of the overlying Lennee Creek Formation. Shallow-marine and partly intertidal conditions probably prevailed during the deposition of the succeeding Canulgerra Sandstone, Vaddingilla Formation, and Yaddanilla Sandstone in the east, the youngest exposed units of the Hatches Creek Group.

Some time after the deposition of the Yaddanilla Sandstone the Hatches Creek Group was folded, faulted, and regionally metamorphosed to mainly greenschist facies, possibly as a result of large-scale gravity-type sliding, and was intruded by granite. Granite emplacement probably took place at about 1640 Ma, after the main folding, but conceivably could have been at least partly responsible for gravity-sliding tectonism. The tungsten-bismuth-copper-molybdenum mineralisation in the area, mainly near Hatches Creek, may be attributed to late-stage hydrothermal solutions emanating from crystallising granite. The gold mineralisation, on the other hand, may be related to the folding and regional metamorphism, when gold, scavenged by solutions permeating gabbro and dolerite, and adjacent country rocks of the Ooradidgee Subgroup, was deposited together with silica in tension cracks, as auriferous quartz veins.

As a result of the tectonism and granite intrusion, the region was elevated well above sea level and was subaerially eroded. It may have remained land for the remainder of the Precambrian, gradually being worn down to form a mature landscape of low relief, not very different from that at the present time. Most of the region was inundated during the Cambrian, when shallow-marine sediments of the Georgina Basin sequence were deposited unconformably on the Precambrian rocks, but it has probably been part of a large landmass for most of the Phanerozoic, and it has been subjected to continued weathering and erosion, with some fluvial and aeolian deposition, throughout the Cainozoic. The region appears to have been a tectonically stable part of the north Australian craton since about 1640 Ma ago.

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