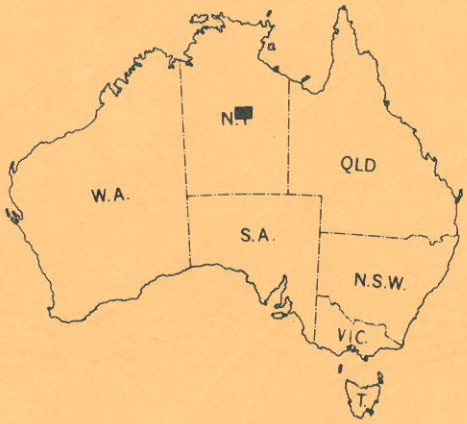
1:250 000 GEOLOGICAL SERIES—EXPLANATORY NOTES

TENNANT CREEK

NORTHERN TERRITORY



SHEET SE/53-14 INTERNATIONAL INDEX

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

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COMPILED BY R. G. DODSON & J. E. F. GARDENER

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Explanatory Notes on the Tennant Creek Geological Sheet

Compiled by R. G. Dodson & J. E. F. Gardener.

The Tennant Creek 1:250 000 Sheet area lies in central Australia between latitudes 19° and 20°S and longitudes 133°30′ and 135°E.

The township of Tennant Creek is on the Stuart Highway which runs north to Katherine and Darwin and south to Alice Springs and Adelaide. Access from the east is by the Barkly Highway which joins the Stuart Highway about 23 km north of Tennant Creek. Apart from Tennant Creek, the Sheet area contains small settlements at the Nobles Nob, Peko, Ivanhoe, Warrego, and Gecko mines and the Threeways Roadhouse at the junction of the Stuart and Barkly Highways. Two pastoral properties, Phillip Creek and Tennant Creek, lie within the area.

The climate is hot in summer, and mild in winter. The yearly average rainfall is about 365 mm, and is confined mainly to the summer months; the pattern of rainfall is unreliable. Mean daily temperature maxima range from about 24°C in winter to about 37°C in summer and mean daily minima from about 11°C to about 24°C. Temperatures of up to 43°C are common in summer, and rare frosts have been recorded in winter.

Vegetation of the area is governed by the semi-arid climate. Soft spinifex (*Triodia pungens*) is abundant over most parts of the area, and scattered ghost gums (*Eucalyptus papuana*) and snappy gums (*E. brevifolia*) are conspicuous. Mulga (*Acacia aneura*) forms thick scrub on the low-lying clay flats, and numerous acacia species are present in the more sandy areas.

Aerial photographs at scales of 1:46 000 and 1:85 000 cover the Sheet area. The photographs, photo mosaics, and the 1:250 000 topographic sheet are available from the Division of National Mapping, Department of National Development, Canberra.

Previous investigations

Woolnough (1936) compiled the first geological report on the Tennant Creek goldfield. Ivanac (1954) carried out a comprehensive study of the regional geology of the area and in particular of the mines of the Tennant Creek goldfield. Geochemical surveys were made of selected parts of the area (McMillan & Debnam, 1961), and in 1973 a review of previous geochemical investigations, together with detailed geochemical studies of the rocks and lodes of the area, was started (Haldane & Smith, in prep.).

The geology of the Tennant Creek 1-mile Sheet area was described by Crohn & Oldershaw (1965), and that of the adjoining Mount Woodcock 1-mile Sheet area was described by Dunnet & Harding (1967). Numerous, mostly unpublished, geological and geophysical reports have been prepared by Bureau of Mineral Resources (BMR) officers, company staff (particularly Geopeko Ltd and Australian Development Ltd), the Geological Survey of the Northern Territory, postgraduate students, and CSIRO. Hays (1958), Crohn (1961), Faulks (1965), and Rose & Willis (in prep.) have described the hydrology of the basins in the area.

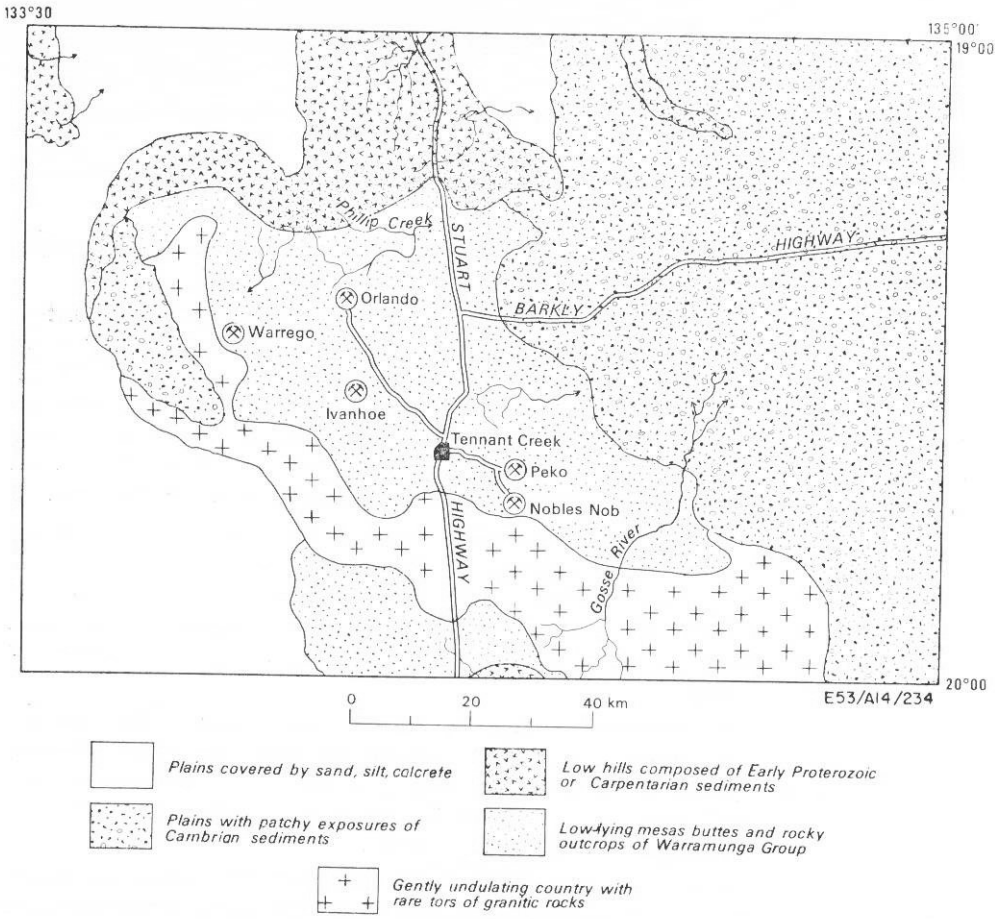


Fig. 1. Physiography.

Mendum & Tonkin (in prep.) carried out a geological survey of the area in 1970-71. The geological content of the Explanatory Notes is largely based on their work, updated and corrected where necessary.

Acknowledgements

Officers of the Geological Survey of the Northern Territory who assisted with the compilation of these notes are P. W. Crohn, M. R. Daly, J. Howard, and Mrs. J. E. Lau. The assistance of Mr. H. F. Eggington, Water Resources Branch, Department of the Northern Territory, in providing information on the Tennant Creek town water supply is also acknowledged.

PHYSIOGRAPHY

The drainage of the Sheet area is developed on an uplifted peneplain which lies at an average height of about 300 m above sea level. The general relief of the area is about 60 m, but reaches a maximum of about 100 m in the Mount Samuel area, 7 km southwest of Tennant Creek. The few streams in the Sheet area are seasonal, and only a few waterholes contain water by late winter. All drainage terminates in the low-lying parts of the Sheet area.

The physiography of the Sheeet area is closely related to the underlying rock types (Fig. 1). The Warramunga sediments form mesas and buttes in the central part of the area; in other parts they weather to low rocky outcrops. The volcanic bands in the Warramunga Group crop out as low hills, and chert beds in the group form low ridges. Quartz veins, which commonly occupy major faults, form sharp ridges. Rounded residual boulders are common on the granites. The Tomkinson Creek Beds quartzite forms steep-sided ridges in the Short and Whittington Ranges in the north. Extensive black soil plains are developed on Cambrian Anthony Lagoon Beds in the northeast.

Calcrete is widespread in areas occupied by Cambrian rocks in the southwest; laterite has been formed locally in valleys of the Short Range, and in places the weathered surface of the Tomkinson Creek Beds sediments is patchily covered by an indurated siliceous layer.

STRATIGRAPHY

?ARCHAEAN

One small outcrop and several subcropping bodies of hematite quartzite, about 30 km west-southwest of Tennant Creek, are tentatively assigned to the Archaean because of their high metamorphic grade compared with Early Proterozoic Warramunga Group rocks. Schist and gneiss intersected in drill holes and described by Whittle (1966) are believed to be related to the quartzite.

PROTEROZOIC

Warramunga Group

The Warramunga Group sedimentary and volcanic rocks were named the Warramunga Series by Owen (1942); it was re-named the Warramunga Group by Ivanac (1954) and this nomenclature was retained by Crohn & Oldershaw (1965) and Dunnet & Harding (1967).

The Warramunga Group forms sparse outcrops in the central part of the Sheet area, but is overlain by younger sediments to the north. Crohn & Oldershaw (1965) stressed the difficulty of subdividing the Warramunga Group because of the complexity of structures, the scarcity and isolation of outcrops, and the scarcity of marker beds. They tentatively divided the group into three units $\mathrm{P}lw_1$-$\mathrm{P}lw_3$, consisting essentially of shale/greywacke ($\mathrm{P}lw_1$), sandstone/shale/siltstone ($\mathrm{P}lw_3$), and greywacke/shale with an interbedded hematite shale band ($\mathrm{P}lw_2$). The hematite shale was considered to be a marker bed. Dunnet & Harding (1967) also noted the difficulty of subdividing the Warramunga Group, particularly as they considered that the Group is characterized by lateral lithological change. Within the Mount Woodcock 1-mile Sheet area Dunnet & Harding mapped three separate sequences of Warramunga Group rocks; within these sequences the major subdivisions were based on the relative proportions of greywacke, shale, and volcanic rocks.

Mendum and Tonkin (in prep.) attempted a more complex subdivision of the main sedimentary sequence, dividing the sucession into ten units, including seven units $\mathrm{P}w_1$-$\mathrm{P}w_7$, based on the proportions of siltstone, greywacke, and shale and, locally, the presence of hematite shale, conglomerate, and volcanolithic material. Other units within the Warramunga Group recognized by Mendum and Tonkin are as shown in Table 1.

The *Bernborough Formation* consists of acid lava, tuff, and greywacke, all interbedded with shale and siltstone. The *Whippet Sandstone Member* consists of massive to blocky and flaggy sandstone and, locally, grit and pebble bands.

TABLE 1. STRATIGRAPHY OF THE TENNANT CREEK 1:250 000 SHEET AREA

	Age		*Rock unit*	*Thickness (m)*	*Lithology*	*Stratigraphic relations*	*Topographic expression*
CAINOZOIC			Alluvium Cza			Superficial	
			Black Soil Czb			Superficial	Claypans
			Sand Czs		Sand, soil, colluvium	Superficial	
			Calcrete Czt	1	Dolomite fragments in calcareous matrix	Superficial	
			Laterite Czl		Pisolitic laterite, ferruginous soil	Superficial	
			Silcrete Ts	3-8	Silcrete, conglomerate	Superficial	
MESOZOIC	?Cretaceous		Sandstone K	4	Sandstone, siltstone, conglomerate	Caps rocks of the Tomkinson Creek Beds, overlain by laterite and silcrete	Valley infillings, mostly in Short and Whittington Ranges
PALAEOZOIC	Middle Cambrian		Anthony Lagoon Beds €my		Chert, sandstone	Conformable on €mg	Scattered rubble and scree in NE
	Early Middle Cambrian		Gum Ridge Formation €mg	25	Chert, chert breccia, limestone	?Unconformable on €lh	Low hills of angular chert rubble
	Early Cambrian		Helen Springs Volcanics €lh	15	Weathered vesicular basalt, tuff	Disconformable on Warramunga Group	Highly weathered and lateritized rubble
PROTEROZOIC	?Adelaidean		Rising Sun Conglomerate Pur		Basal conglomerate, quartzite, sandstone	Unconformable on Warramunga Group	Low hills
	Early Proterozoic or Carpentarian	HATCHES CREEK GROUP	Orthoquartzite Plh		Quartzite, sandstone, interbeds of vesicular basalt and acid lava	Disconformable on Warramunga Group; tentatively correlated with Tomkinson Creek Beds	Low rocky hills
			Diorite/dolerite		Diorite and dolerite, mostly highly weathered	Intrude Warramunga Group rocks and Tomkinson Creek Beds	Exposures commonly with coverings of calcrete

TABLE 1. STRATIGRAPHY OF THE TENNANT CREEK 1:250 000 SHEET AREA—*(cont.)*

Age		*Rock unit*	*Thickness (m)*	*Lithology*	*Stratigraphic relations*	*Topographic expression*
PROTEROZOIC	Early Proterozoic or Carpentarian	TOMKINSON CREEK BEDS				
		Attack Creek Formation Pta	800	Siltstone, limestone, minor mudstone, sandstone	Conformable but sharp contact with Pts	Low hills
		Short Range Sandstone Pts	200-880	Orthoquartzite, minor conglomerate	Conformable on Ptm	Forms narrow ridges
		Morphett Creek Formation Ptm	2500-4200	Sandstone, siltstone, shale, conglomerate	Conformable on Ptw	Exposed on hill slopes
		Whittington Range Volcanics Ptw	200-400	Vesicular basalt, minor rhyolite, sandstone and siltstone	Directly overlies Pth	Forms small highly weathered outcrops in Whittington Range
		Hayward Creek Formation Pth	3000-6000	Quartz sandstone, feldspathic sandstone, basalt, pebble beds	Conformable on Ptb	Constitutes large part of Whittington Range
		Blanche Creek Member Ptb	up to 150	Basal conglomerate, poorly sorted pebbly sandstone	In places, unconformably overlies Warramunga Group rocks	Small rocky outcrops on E side of Whittington Range
	Early Proterozoic	Granite		Types range from fine-grained adamellite to porphyritic coarse-grained potash granite	Intrudes Warramunga Group rocks. Relations with the Tomkinson Creek Beds unknown	Scattered exposures, mostly as heaps of boulders
		Porphyries Pp, Pfp		Quartz porphyry and quartz-feldspar porphyry	A variety of forms, mostly marginal to granite. Intrude Warramunga Group rocks	Similar to granite
		Lamprophyre		Biotite lamprophyre, amphibole and pyroxene lamprophyre	Intrude Warramunga Group rocks	Mostly altered to limonitic clay
		WARRAMUNGA GROUP				
		$P w_6$	?	Greywacke, siltstone, minor shale, hematite shale	Conformable on $P w_2$; may overlie $P w_5$	
		$P w_5$	1000-2100	Greywacke, shale, basal pebble beds	May be a shallow-water equivalent of $P w_2$ or a correlate of Pww. Overlies $P w_1$	
		$P w_4$	up to 1450	Greywacke sandstone, minor siltstone, chert and pebble beds	Youngest unit of group. Overlies $P w_3$	

TABLE 1. STRATIGRAPHY OF THE TENNANT CREEK 1:250 000 SHEET AREA—*(cont.)*

Age		*Rock unit*	*Thickness (m)*	*Lithology*	*Stratigraphic relations*	*Topographic expression*
PROTEROZOIC	Early Proterozoic	WARRAMUNGA GROUP Ƥ w_3	300 in Whippet area, 3000 in Last Hope area	Shale, greywacke, minor grit bands	Conformable on Ƥ w_2 and locally overlies Ƥ wo	Outcrops mostly rubble-covered hills. Extensive areas occupied by Warramunga Group rocks have no characteristic surface expression
		Warrego Volcanics Ƥ wo		Acid volcanics, tuff, minor shale, hematite shale	Overlies Ƥ w_7. Upper part grades into Ƥ w_3	
		Ƥ w_7	?	Greywacke, siltstone, conglomerate, minor tuff	Base not exposed. May be lateral equivalent of Ƥ w_2. Upper part transitional into Ƥ wo	
		Gecko Volcanics Ƥ wg	Up to 300	Tuff, minor acid volcanics and greywacke	Conformable with Ƥ w_2	
		Ƥ w_2	*780-1200	Shale, greywacke, siltstone, hematite shale	May be equivalent to Ƥ w_3 which is sparsely exposed. May overlie Ƥ w_7	
		Bernborough Formation Ƥ wb	Up to 800	Acid lava, tuff, tuffaceous greywacke, minor shale and siltstone	Overlies rest of Ƥ ww	
		Whippet Sandstone Member Ƥ ww	120-180	Sandstone, rare pebble beds	Conformable on Ƥ w_1	
		Ƥ w_1		Greywacke, siltstone, shale, minor tuff and acid volcanics	Oldest exposed Warramunga Group rocks	
?ARCHAEAN		A		Ferruginous quartzite (garnet gneiss intersected in drill hole)		Low isolated outcrops

* Crohn & Oldershaw (1965) estimated Ƥ w_2 to be up to 780 m thick, Dunnet & Harding (1967) up to 1200 m thick.

The *Warrego Volcanics* are composed mainly of purple banded rhyolite, grey ignimbrite, pink ashstone, and tuff; they include also banded hematite shale, siltstone, greywacke, and shale. They crop out between the Orlando mine and the Warrego mine, from which their name is derived. The Warrego Beds overlie greywacke and shale of Unit $\in w_7$, and grade upward into Unit $\in w_8$. They are intruded by porphyry.

The *Gecko Volcanics* consist of grey-green and purple tuff, quartz porphyry and quartz-feldspar porphyry, and greywacke; they are exposed south and southwest of the Gecko mine, from which their name was taken. The Gecko Beds are conformable with the surrounding shale of Unit $\in w_2$, within which they form a series of small lenses.

The Warramunga Group is considered to be a eugeosynclinal sequence as it is composed of greywacke, shale, siltstone, and volcanics. Mendum and Tonkin believe that the Warramunga Group is not more than 3000 m thick at any one locality, but a composite section may be drawn to give a total thickness of 6000 m.

Age of the Warramunga Group

The Warramunga Group is considered to be Early Proterozoic i.e. older than 1800 m.y. It is intruded by granites that have yielded K-Ar ages ranging from 1510 to 1720 m.y. (Hurley et al., 1961; Walpole & Smith, 1961). Rb-Sr whole-rock determinations for other northern and central Australian granites yield ages that are 75 to 300 m.y. (average 170 m.y.) greater than the corresponding K-Ar ages (Compston & Arriens, 1968). Assuming that the same correction should be applied for the granites that intrude the Warramunga Group, it is evident that at least the oldest granites would range down into the Early Proterozoic; the Warramunga Group itself would be appreciably older. Recent work by Black (1977) confirms an Early Proterozoic age.

Granite

On the basis of slight mineral and textural differences, twenty types of granite were differentiated in the Sheet area by Mendum and Tonkin.

The outcropping granites lie in a northwesterly-trending zone extending from the southeastern corner of the Sheet area to near the sandstone ridge 23 km west-northwest of Warrego mine. Outcrops range from small isolated tors composed of large exfoliated boulders to weathered low hills composed of fine-grained granite. However, granite outcrops are somewhat rare, even within this zone; most occurrences are blanketed by superficial deposits.

Granites intrude sediments of the Warramunga Group, but their relations to the Tomkinson Creek Beds and the Rising Sun Conglomerate are not known.

Most of the copper/gold deposits lie relatively close to potash-rich granite, indicating a possible genetic relationship.

Porphyries

Two types of porphyry were recognized by Mendum and Tonkin: *quartz-feldspar porphyry* in which quartz and feldspar phenocrysts lie in a hematitic fine-grained matrix, and *quartz porphyry* in which the phenocrysts consist of quartz only.

Quartz-feldspar porphyry is associated with the granite between Gosse River and the Warrego-Last Hope mines area. It occurs as sills, dykes, pipes, bosses, and irregular masses. The quartz porphyry forms numerous outcrops associated

with granite in a zone extending from the southeast corner of the Sheet area to the hills 20 km west-northwest of the Warrego mine. In many places the quartz porphyry is marginal to granite or quartz-feldspar porphyry, and crosscuts bedding traces of the Warramunga Group. It also forms dykes in the Warramunga Group.

Diorite and dolerite

Sills and dykes of diorite and, less commonly, dolerite, intrude the lower part of the Tomkinson Creek Beds and the upper part of the Warramunga Group. Diorite and dolerite dykes also intrude granite near the Gecko and Orlando mines.

The diorite and dolerite typically crop out as soft brown limonitic material which generally retains vestiges of igneous texture.

Lamprophyre

Small lamprophyre dykes and sills intrude sediments of the Warramunga Group near the margins of granite.

The lamprophyres are deeply weathered; at the surface they are typically capped by dolomitic calcrete. Most of the lamprophyres are the biotite-rich (minette) variety but Crohn and Oldershaw described an example of the amphibole, pyroxene-bearing variety, camptonite.

EARLY PROTEROZOIC to EARLY CARPENTARIAN

Tomkinson Creek Beds

The name Tomkinson Creek Beds was first used in an unpublished report by Randal, Brown, & Doutch (1966) and was published by Dunnet & Harding (1967); the sequence was previously called the Ashburton Sandstone (Noakes & Traves, 1954).

The *Hayward Creek Formation* constitutes a large part of the Whittington Range where it is about 3000 m thick, and the Short Range where it is about 6000 m thick. It also crops out in the northwest corner of the Sheet area. The bulk of the formation consists of quartz sandstone and feldspathic sandstone, with basalt interbeds. The basal 500 m includes a few pebbly beds. Cross-beds and ripple marks are characteristic of the base of the formation.

The *Blanche Creek Member* is the lowermost unit of the Tomkinson Creek Beds. It crops out along the eastern side of the Whittington Range as far as Gibson Creek, and also along the southern margin of the Short Range.

The *Whittington Range Volcanics* form small outcrops in the central southern part of the Whittington Range. Fresh rock obtained from diamond-drill core consists of coarse-grained weathered basalt overlain by micaceous quartz sandstone and red-brown micaceous siltstone. The sediments are capped by highly altered vesicular and non-vesicular basalt and a few spherulitic rhyolite flows.

Because it is easily weathered, outcrops of the *Morphett Creek Formation* are preserved only in the central southern part of the Whittington Range and the north side of the Short Range. The formation ranges from 2500 to 4800 m in thickness. The lower part consists of fissile to flaggy feldspathic sandstone which is overlain by shale and siltstone, interbedded with minor sandstone and conglomerate.

The *Short Range Sandstone* crops out on the western side of the Whittington Range. It is 200 to 800 m thick, and consists of pink, light grey, cream, and purple blocky orthoquartzite.

The uppermost unit of the group, the *Attack Creek Formation*, crops out immediately west of the prominent north-south ridge formed by the Short Range

Sandstone. Within the Sheet area the formation is at least 800 m thick, and consists of a basal calcareous siltstone, overlain by dark grey, partly silicified limestone which grades into black calcareous manganese-rich mudstone and black chert. The uppermost beds are feldspathic quartz sandstone and silicified orthoquartzite.

Hatches Creek Group

Mendum and Tonkin consider that the Hatches Creek Group, which crops out in the extreme south of the Sheet area, can be correlated with the Tomkinson Creek Beds which crop out in the northern part of the area. Both directly overlie Warramunga Group rocks, and are lithologically similar. In the Elkedra Sheet area to the southeast, a definite upper limit in age for the Hatches Creek Group is set by the intrusive Elkedra Granite, which has a Rb-Sr age of 1695 m.y. (Compston & Arriens, 1968). An imprecise lower limit is set by the underlying Warramunga Group. On this basis, the Hatches Creek Group could range in age between Early Proterozoic (probably near the end of Early Proterozoic) and Early Carpentarian.

?ADELAIDEAN

The *Rising Sun Conglomerate* crops out about 0.5 km south of Nobles Nob mine. The unit consists of conglomerate, quartzite, grit and, in the upper part, sandstone and siltstone. Mendum and Tonkin believe that boulders in the conglomerate were derived from Hatches Creek Group and/or Tomkinson Creek Beds quartzites.

CAMBRIAN

Exposures of the *Helen Springs Volcanics* are generally weathered and lateritized, making recognition difficult. They form small outcrops east-northeast of Tennant Creek township, at Kelly West Trig. station in the south, west of the Warrego mine, and on each side of the Gosse River. Locally the unit includes a few metres of quartz sandstone which is overlain by extensively lateritized volcanics described by Ivanac (1954) as vesicular basalt, tuff, and agglomerate. Crohn & Oldershaw (1965) believed the unit to be about 15 m thick.

The *Gum Ridge Formation* crops out extensively over much of the Sheet area. The age of the formation has been established as early Middle Cambrian from fossils. Most surface exposures consist of angular chert rubble with rare fragments of silicified siltstone or limestone. Outcrops include minor sandstone and mudstone beds. The limestone is granular or saccharoidal, and in outcrop is characterized by a polygonal mud-crack pattern.

The *Anthony Lagoon Beds* occur as scattered rubble and scree only in the northeastern corner of the Sheet area. The unit was described by Randal, Brown, & Doutch (1966).

Substantially greater thicknesses of so far undifferentiated Cambrian-Ordovician sequences occur in the western part of the Sheet area where they form part of the Wiso Basin Succession.

MESOZOIC

Sediments which unconformably overlie the Tomkinson Creek Beds are believed to be Cretaceous because of their similarity to rocks in the adjacent Helen Springs Sheet area, where they were identified by Randal, Brown, & Doutch (1966) as Cretaceous. At the junction of Blanche and Attack Creeks about 4 m of massive flat-bedded friable feldspathic sandstone is believed to be of similar age. Farther west, siltstone, claystone, and sandstone may also be Cretaceous.

CAINOZOIC

Several small basins filled by unconsolidated to moderately consolidated Tertiary sediments occur in the eastern part of the Sheet area. They are referred to more specifically in the section on Groundwater.

Pisolitic *laterite* is present as remnants of a previously more extensive cover. Locally the laterite has been eroded and re-deposited in nearby depressions. On the western margin of the Short Range nodular laterite forms layers up to 15 m thick, and thin layers of laterite form extensive infillings of valleys.

Calcrete as loose fragments less than 1 m thick is scattered about the surface, particularly on black soil plains within a northwest-trending belt in the southwest corner of the Sheet area. It is typically cream to light brown, and consists of about 60 percent of subangular dolomite fragments in a light brown calcareous matrix. *Black soil areas* (claypans), most of which contain calcrete, occur mainly in the northeast corner of the Sheet area. ?Tertiary *silcrete* cappings, ranging from 3 to 8 m in thickness, are fairly widespread in the northern part of the Sheet area.

STRUCTURE

Three phases of folding, f_2, f_3, and f_4, were recognized in the Warramunga Group rocks by Mendum and Tonkin. An additional phase f_1 was postulated by Dunnet & Harding (1967) by constructing a model of the Warramunga Group rocks before phase f_2 folding (Mendum and Tonkin estimated that before f_2 folding the enveloping surface had a dip of about 25° northwest). The overlying Tomkinson Creek Beds rocks show the effect of two phases of folding, presumed to be f_2 and f_3, recognized in the Warramunga Group; the unconformity surface between the Warramunga Group and the Hatches Creek Group shows signs of decollement.

Faults are common in the Sheet area (Fig. 2). The main phase of faulting is believed to antedate the f_2 folding, but numerous faults show evidence of repeated movements. Many of the fractures are infilled with quartz or jasper or, less commonly, dolomite or talc. Some of the veins contain pyrite and, less commonly, copper and bismuth minerals and gold.

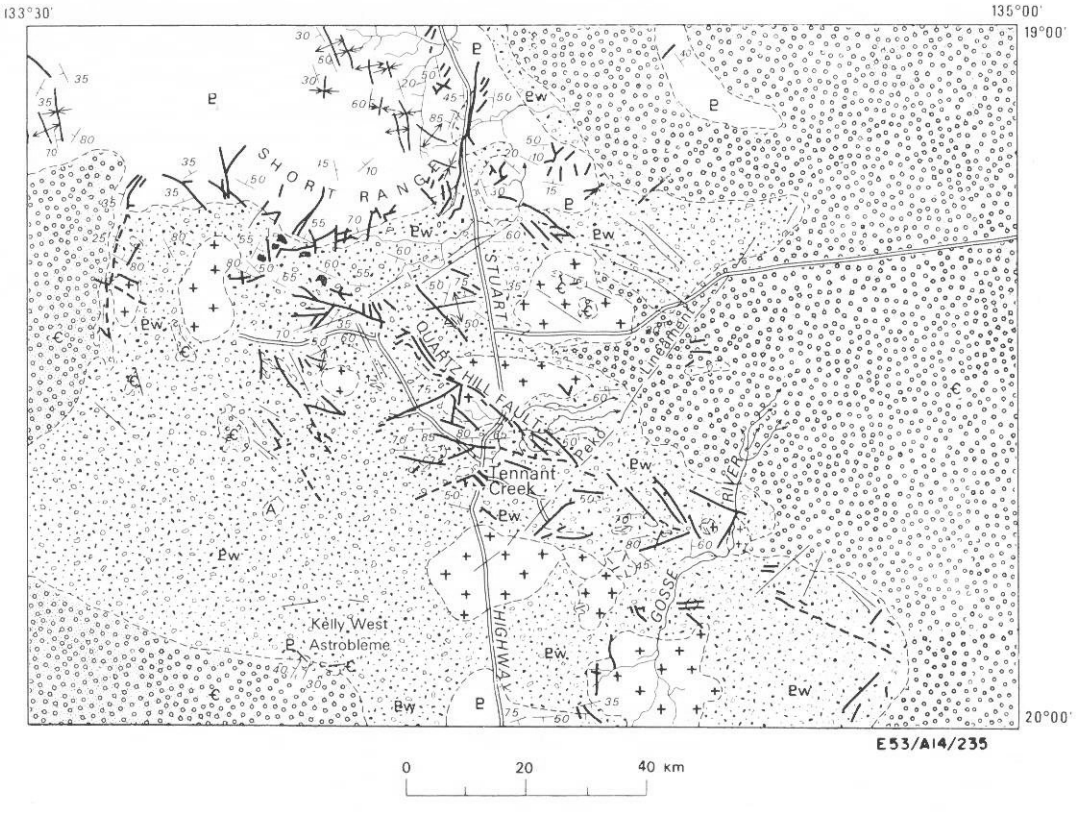
The major faults trend northwest. However, several northerly-trending strike and oblique slip faults were recognized in the Sheet area. Part of the Stuart Highway north of Gibson Creek follows the trace of a large oblique slip fault; in the southern part of this fault the eastern block has been displaced southwards about 5 km relative to the western block. The Peko Lineament, trending northeast from the Cabbage Gum Basin through Peko mine, is a prominent photo-geological feature but little structural information can be deduced from its surface expression.

Kelly West astrobleme

What appears to be an astrobleme was discovered about 40 km south-southwest of Tennant Creek township (Tonkin, 1973). The surface expression of the structure consists of an approximately circular outcrop, about 2 km in diameter, composed of quartzite of the Hatches Creek Group. A few rather poor shatter cones have been found in the quartzite.

ECONOMIC GEOLOGY

Although more than 120 mines of various sizes have been exploited in the Tennant Creek Field (Ivanac 1954), by 1976 only six were being mined—Peko, Orlando, Juno, Warrego, and Gecko, all operated by Peko Mines Ltd, and the Nobles Nob mine operated by Australian Development Ltd. Ivanhoe mine (Peko



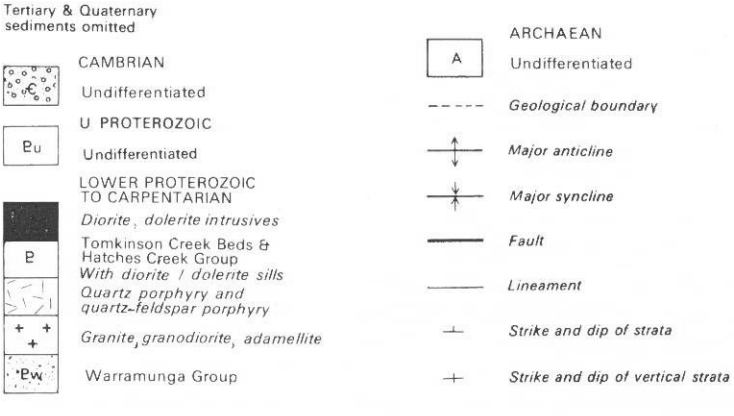


Fig. 2. Structural elements.

Mines Ltd) ceased production in 1972. A small orebody is being developed at Golden Forty by Australian Development Ltd. Despite the known presence of lead and zinc at one of the mines and small amounts of uranium in another, production in 1976 was confined to the mining of gold, copper, and bismuth.

Following is a summary of the geology of the mines operated by Peko Mines Ltd. All are in Warramunga Group rocks (reserves are for 1975).

The *Peko* mine is developed on a steeply westerly-pitching irregularly shaped pipe-like body. The pipe contains seven individual orebodies, and is cut by a steeply dipping normal fault. On the footwall side of the pipe, between 240 and 400 m below the surface, two more orebodies and several pods of ore have been found. Copper is the principal metal in the Peko lodes; gold and bismuth are also present. The calculated reserves of Peko mine were: 200 000 tonnes ore containing 2.6 percent copper, 4.0 g/tonne gold, and 0.26 percent bismuth.

The *Orlando* mine is situated on an easterly-trending shear. Seven narrow orebodies are known in the shear zone—four gold, two copper, and one enriched in lead and zinc. Only the gold and copper ore has been mined. Reserves calculated for Orlando are 120 000 tonnes ore containing 5 percent copper and 3.8 g/tonne gold.

The *Juno* mine is small and is characterized by high gold and bismuth grades. The ore is in two lodes in a wedge-shaped body of magnetite-chlorite rock. The country rocks are greywacke and shale. Reserves are 50 000 tonnes ore containing 0.3 percent copper, 25 g/tonne gold, and 0.30 percent bismuth.

The *Warrego* mine is the largest known deposit in the Tennant Creek Field. The orebody pitches southeast and dips steeply northeast, cross-cutting interbedded greywacke and siltstone. The ore is mostly copper-rich; high gold and bismuth values occur in some parts of the lode. Reserves are 5 400 000 tonnes ore containing 2.1 percent copper, 6.6 g/tonne gold, and 0.30 percent bismuth.

At the *Gecko* mine copper-gold-bismuth ore forms small lodes within a subvertical east-trending breccia zone. Reserves are: 1 900 000 tonnes ore containing 4.0 percent copper, 0.6 g/tonne gold, and 0.10 percent bismuth.

Production from the Peko Mines Ltd mines until 28.1.75 was as follows:

Mine	*Tonnes*	*Au(g/t)*	*Ag(g/t)*	*Cu(%)*	*Bi(%)*
Peko	3 085 000	3.4	14	4.14	0.2
Orlando (primary ore)	280 000	18		0.8	
(secondary ore)	30 000	5		5	
Juno	378 400	65.2			0.6
Warrego	863 400	2.4		2.21	0.11
Ivanhoe (closed 1972)	315 000	2.9		3.13	
Gecko (no production recorded before 28.1.75).					

At the *Nobles Nob* mine, operated by Australian Development Ltd, 32 585 kg of gold had been produced from about 1 270 000 tonnes of ore up to the end of 1975. This mine was worked by underground methods until 1969, but is now operated as an open cut. Most of the ore consists of brecciated quartz-hematite and associated hematite-impregnated sericitic mudstone.

In addition, some 120 other mines and prospects on the field have recorded some gold production, including 20 with a production of more than 30 kg. Subeconomic uranium mineralization has been recorded from diamond-drill hole intersections at the North Star mine 35 km north-northwest of Tennant Creek.

Ore genesis

All known economic mineral deposits in the field are associated with lodes composed mainly of quartz-hematite but which contain enough magnetite to be magnetic. The lodes are emplaced in shears within Warramunga Group rocks. The lodes have been previously described by Ivanac (1954), Edwards (1955),

Juno mine closed in 1977.

Crohn & Oldershaw (1965), Elliston (1963, 1966), Whittle (1966), and Dunnet & Harding (1967). Ivanac suggested that granites were the source of the mineralization, stressing the close proximity of deposits to the margins of granite masses. Elliston considers that 'porphyroids' (porphyries), formed by accretion in a colloidal suspension, were the source rocks, the mineralizing solutions being expelled from a thixotropic gel during compaction. Whittle and Dunnet & Harding consider the most likely source of the mineralization to have been basic rocks of the dolerite/diorite suite. Mendum and Tonkin believe that, in a high-temperature, high-pressure environment, gold and other metals could have been leached from sedimentary rocks of the Warramunga Group by solutions rich in chloride ions, and could have been redeposited as the mineralized solutions ascended to structurally favourable locations, such as shear zones, in regions of lower temperature and pressure.

GROUNDWATER

Because only limited supplies of generally saline groundwater are available from the Warramunga Group, the town water supply for Tennant Creek is drawn from a group of small, shallow, sedimentary basins of probable Tertiary or younger age.

The Cabbage Gum Basin, 18 km south of Tennant Creek, contains up to about 30 m of poorly sorted sedimentary rocks (clay, siltstone, sandstone, and grit) resting on a basement of Warramunga Group and acid igneous rocks. Potable water is contained in two aquifers. One aquifer is characterized by vugs in the superficial sediments, and by high transmissibilities and low storage coefficients. The other aquifer is the leached zone, up to 30.5 m thick, of a deep weathering profile formed in the underlying acid igneous rocks. It is essentially granular, contains kaolin, and is characterized by low transmissibilities and storage coefficients. Withdrawal of water by pumping is confined to the upper sedimentary aquifer, both because of its higher transmissibility, and to lessen the possibility of intrusion of saline water from outside the basin.

Kelly Well Basin, 13 km south of Cabbage Gum Basin, contains similar poorly sorted sedimentary rocks. The main aquifer is a vuggy silicified siltstone between 17 m and 33.5 m below the surface. In the central part of the basin the sediments show a lateral continuity which is absent in the Cabbage Gum Basin.

Kelly Well West Basin, about 10 km west of the Kelly Well Basin, also contains sedimentary rocks in an ancient valley system with vuggy siltstone and weathered granite as the maior aquifers. Recharge to this basin is by underflow from the Cabbage Gum and Kelly Well Basins, and by direct infiltration.

During 1975 the average weekly requirement for the town was 13.6×10^6 litres and it was drawn mainly from Kelly Well Basin.

Bore yields in the Warramunga Group are variable but generally low (maximum 2 l/s). Salinities are also variable, ranging from low or moderate to as high as 30 000 mg/l in groundwater in Peko Mine (Davies & Ride, 1970).

At the Warrego Mine in the central western portion of the Sheet area, potable water is obtained from a small basin in weathered granite, but the major requirements for the treatment plant are met from production bores in calcareous rocks of the Wiso Basin sequence, some 25 km west of the mine.

GEOPHYSICS

AGGSNA surveys, 1935-1937

In a report dated August 1934 Dr W. G. Woolnough, Commonwealth Geological Adviser, suggested the use of the magnetic method to assist exploration

in the Tennant Creek field because of the association of gold with ironstone lodes. The first survey was made in 1935 by the Aerial, Geological and Geophysical Survey of Northern Australia (AGGSNA). Intense magnetic anomalies were found over ironstone bodies, and a number of significant anomalies, considered to be due to ironstone bodies, were found in areas where there was no surface evidence of ironstone. Following the encouraging results of the 1935 survey, further surveys were made in 1936 and 1937. Two progress reports on the work were published (Rayner & Nye, 1936; Richardson, Rayner & Nye, 1937). A third progress report (Richardson & Rayner, 1937) was written but not published, and a fourth and final report was planned, but not written, as AGGSNA was disbanded at about that time. The main results of the 1935-1937 surveys and the material which was to be included in the third and fourth reports were published later in a unified report (Daly, 1957).

The AGGSNA surveys resulted in the discovery of many concealed ironstone bodies; most have been drilled and found to have generally low gold and copper values associated with them. Investigation of a magnetic anomaly on the Peko mine led to the discovery of an orebody 120 m below the surface. In general the iron oxide in the ironstone is hematite near the surface and magnetite at depth. Many of the hematite-rich ironstones near the surface contain significant amounts of magnetite.

Airborne surveys, 1956, 1960

Airborne surveys were carried out by BMR to assist the development of the Tennant Creek Mineral Field through delineation and interpretation of regional anomalies and detection of anomalies due to subsurface ironstone bodies. In 1956 an airborne magnetic and radiometric survey was made over an area which included all the known workings in the Field. The data were published in 1957-58 in a series of maps at 1:63 360 scale (BMR Maps G110/25-29). In 1960 the survey area was extended to cover the whole of the Tennant Creek 1:250 000 Sheet area (Spence, 1962). The data from the 1956 and 1960 surveys were combined and published in 1962 in a series of four maps at 1:126 720 scale (BMR Maps G237/11-14) and as one map at 1:250 000 scale (BMR Map E53/B1-68). The contour interval used for the magnetic data was 50 nT.

In 1968 the magnetic data from part of the 1960 airborne survey area were recontoured at an interval of 10 nT (Shelley, 1974), and published in BMR Maps E53/B1-5658, 5758, 5858, 5859. The area recontoured is south of 19°45′S and east of 134°35′E. The recontoured data better define many anomalies recognizable only in the original contouring as inflexions and embayments. Additional anomalies with amplitudes of less than 50 nT were delineated. The recontoured data have not been interpreted.

Aeromagnetic results

The aeromagnetic results show a pattern of regional anomalies with east-southeast and north-northwest trends, as well as numerous local anomalies due to ironstone bodies. The magnetic anomalies of only the largest ironstone bodies, such as Peko, Golden Forty, Eldorado, and Warrego, are obvious in the aeromagnetic map. The regional magnetic anomalies are due to disseminated magnetite in rocks of the Warramunga Group. Outcropping basic igneous rocks such as those in the northwest quarter of the Sheet area are the sources of some of the magnetic anomalies; other anomalies are believed to be caused by non-outcropping basic rocks. Areas where granitic rocks crop out or are at shallow depth have low, flat magnetic responses.

A magnetic high in the southeastern corner of the Sheet area is within an area shown as undivided granite and adamellite overlain by Cainozoic sand, soil, colluvium, and gravel. The recontoured data (Shelley, 1974) show the high as a number of individual anomalies with steep gradients indicating near-surface sources which may be Precambrian rocks. The gravity data indicate the possible presence of such rocks.

Detailed aeromagnetic surveys, 1964-1967

Eleven areas of particular interest, totalling about 750 km^2, were selected for detailed aeromagnetic surveying. The selection was made by BMR and the Northern Territory Mines Branch on the basis of the 1956 and 1960 aeromagnetic data. The aims of the surveys were to assist geological interpretation, and to locate areas of interest for detailed investigation. The surveys were made in 1964, 1966, and 1967 (Milsom & Finney, 1965; Finney, 1967; Shelley & Browne-Cooper, 1967). The contour interval used in the presentation of results was 10 nT.

The detailed aeromagnetic surveys delineated a number of magnetic features that are not apparent in the earlier aeromagnetic maps. Some correlation is possible between observed geology and magnetic contours, and, in some areas, non-outcropping rock types can be identified from their magnetic characteristics. A number of anomalies were found which warranted further investigation by ground geophysical surveys.

Ground surveys

Most exploration effort following the availability of the aeromagnetic data concentrated on following up and drilling the most intense of the anomalies which were caused by ironstone bodies. Orlando, Ivanhoe, and Warrego were found in this way. Most of the exploration was done by companies, but some was done by the Northern Territory Mines Branch and BMR.

In 1957 and 1958 BMR made detailed ground magnetic surveys over areas selected from the 1956 aeromagnetic results, primarily to obtain data for use in the interpretation of these results. Quantitative interpretations were made of the anomalies located, and drill holes were recommended (O'Connor, Goodchild, & Daly, 1959; O'Connor & Daly, 1962; Daly, 1959a).

A minor survey was made in 1958 in the Olive Wood area at the request of Peko Mines N.L. (O'Connor & Daly, 1958). Minor surveys were made in 1961 in a number of areas at the request of Australian Development N.L. (Douglas, 1962). In 1963 a minor survey was made in the Red Bluff area for Australian Development N.L., and another in the Quart Bowl area for the Northern Territory Mines Branch (Douglas, 1964a, 1964b). Daly (1959b) interpreted magnetic anomalies in the New Hope area obtained by National Lead Ltd.

In 1967, 1969, 1971, and 1972 ground geophysical surveys were made to locate and investigate anomalies detected during the detailed aeromagnetic surveys (Haigh, 1969; Williams et al., 1977; Hone, 1974a, 1974b). A minor survey (Haigh, 1970) was also made in the Burnt Shirt area for the Northern Territory Mines Branch.

Quantitative interpretations were made of the anomalies investigated during these ground surveys. Drill holes were recommended to test the anomalies, and most of these have been drilled by the Mines Branch, Department of the Northern Territory. Low gold and copper values are associated with the bodies drilled.

Gravity surveys

The Australia-wide reconnaissance helicopter gravity survey by BMR covered the Tennant Creek Sheet area in 1965 (Flavelle, 1965). The data were published in 1967 in BMR Map E53/82-14. More detailed surveys were made in 1972 (Hone, 1974b) and 1973 (Bullock, 1977) mainly in the southwestern part of the Sheet area.

The station density of the reconnaissance gravity survey is about 1 per 125 km^2, and only a generalized interpretation of the results is possible. Granite masses produce gravity lows relative to the values over rocks of the Warramunga and Hatches Creek Groups, and the Tomkinson Creek Beds. The gravity data indicate the presence of unexposed Precambrian rocks in the northern and southern parts of the Sheet area, and the possible presence of unexposed granite masses in the northern quarter of the Sheet area.

The gravity low in the southeast of the Sheet area extends south into the Bonney Well Sheet area where granite has been mapped. The gravity high in the southwest of the Sheet area has been investigated in more detail (Hone, 1974b; Bullock, 1977), and consists of a number of smaller highs interpreted to be due to basic intrusive bodies. The gravity high in the southeastern corner of the Sheet area probably indicates concealed Precambrian rocks.

Radiometric surveys

The radiometric data from the 1956 and 1960 airborne surveys (Spence, 1962) are in the published maps showing the aeromagnetic data and are presented as anomalies due to point sources, and as changes in intensity of radioactivity.

In 1970 a detailed airborne gamma-ray spectrometer survey was made (Shelley, 1975) over an area of 350 km^2 in the central part of the Tennant Creek Sheet area to determine the radiometric response of the various rock types, and the distribution of uranium in the area. The area flown was chosen to cover a large number of mines and prospects and a large number of radiometric point sources located in the 1956 airborne magnetic and radiometric survey. The data have been published in BMR Map E53/B1-58 as stacked profiles together with flight-line locations and generalized geology. The data have not been interpreted.

Electrical and electromagnetic surveys

In 1958 BMR made a geophysical survey in the Cabbage Gum Basin (Wiebenga & Dyson, 1964) at the request of the Northern Territory Administration to assist in the search for a water supply for Tennant Creek. Resistivity was the main method used. The data were interpreted to obtain resistivities and thicknesses of decomposed or weathered granite and sediments (Warramunga Group rocks). The magnetic method was used because magnetic anomalies were considered to indicate unweathered Warramunga rocks and, therefore, areas unlikely to contain suitable water. Weathered Warramunga rocks and Tertiary or younger sediments were assumed to have better aquifer properties.

In 1971 BMR made induced polarization logs of 13 drill holes in the Tennant Creek area. The results showed anomalous responses in magnetic and/or sulphide-bearing zones. An applied potential or mise-a-la-masse survey was also made but met with little success because of low near-surface resistivities (Gillespie, 1972).

A test transient electromagnetic survey was made in 1972 (Spies, 1974). The results indicate that the responses were from near-surface conductive layers (the oxidized zone). No anomalies were obtained from ironstone bodies, indicating that these bodies do not have appreciable conductivity contrast with the host-rock.

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APPENDIX:

ROCK UNITS OF THE WARRAMUNGA GROUP AND THE TOMKINSON CREEK BEDS, TENNANT CREEK AREA, NORTHERN TERRITORY

Compiled by J. R. Mendum, P. C. Tonkin, & D. E. Gardner

This note formalises certain Proterozoic stratigraphic terminology from the Tennant Creek Block in the Northern Territory. Specifically, it defines eight additional units: two, the Warrego Volcanics and Gecko Volcanics of the Early Proterozoic Warramunga Group; and six, the Hayward Creek Formation and Blanche Creek Member, the Whittington Range Volcanics, the Morphett Creek Formation, the Short Range Sandstone, and the Attack Creek Formation of the Proterozoic Tomkinson Creek Beds. The name Warramunga Group, previously used in publications (e.g. Ivanac, 1954) is also defined to validate its use. The Tomkinson Creek Beds were defined by Randal & Brown (1969).

The defined units are described fully in an unpublished report (Mendum & Tonkin, in prep.).

WARRAMUNGA GROUP

The Warramunga Group, named by Ivanac (1954) was originally described as the Warramunga Series by Owen (1942). Dunnet & Harding (1967) described it as consisting of the Bernborough Formation, the Whippet Sandstone Member, and several unnamed rock units.

The term Warramunga Group is well established and is therefore retained—it is defined to validate its use.

Proposed name: Warramunga Group.

Derivation of name: After the name of the local Aboriginal tribe.

Distribution: Sediments and interbedded volcanics of the Warramunga Group underlie much of the central part of the Sheet area. Outcrops of the Group extend as far north as Hayward Creek and south into adjoining Bonney Well Sheet area. The major development of the Group lies in a roughly ovoid zone between Gosse River in the southeast and the Last Hope mine in the northwest.

Lithology: The Warramunga Group is composed mainly of interbedded sediment and volcanic lenses. Mendum and Tonkin have divided the group into seven unnamed units ($\exists w_1$-$\exists w_7$), the Whippet Sandstone Member, the Bernborough Formation, the Gecko Volcanics, and the Warrego Volcanics. Units $\exists w_1$-$\exists w_7$ consist of tuffaceous greywacke, siltstone, shale, and minor sandstone; a distinctive hematite-rich shale is present in the central part of the sequence. The Whippet Sandstone Member consists of quartz sandstone, feldspathic sandstone, and rare pebble beds; the Bernborough Formation consists of acid lava, tuff, greywacke, and minor shale. The Gecko Volcanics and the Warrego Volcanics are described separately.

Type Section: No type section was measured for the unit because of the lack of continuity of outcrops. The Group is folded into a large westerly-plunging anticlinorium with abundant intermediate and small-scale folds.

The older part of the unit is best exposed towards the western extremity of outcrop, the middle part within an oval-shaped area between Gosse River in the southeast and the Last Hope Mine in the northwest, and the younger beds crop out in the north, along the foot of Short Range.

Thickness: It is doubtful if the Warramunga Group exceeds a thickness of 3000 m at any place but a composite section may be drawn to give a maximum thickness of 6000 m.

Age: The Warramunga Group was intruded by granite dated at 1797 m.y. (Black 1977), and is therefore probably Early Proterozoic.

Relations: The Warramunga Group is assumed to rest unconformably on Archaean to Early Proterozoic gneiss intersected in drill holes southwest of Tennant Creek township. The Group is overlain unconformably by the Tomkinson Creek Beds; this contact is best exposed in the range west of the Last Hope Mine.

GECKO VOLCANICS

Proposed name: Gecko Volcanics.

Derivation of name: Gecko Mine in Tennant Creek 1:250 000 Sheet area, grid reference 402850.

Distribution: A series of small lenses with a total area less than 3 km^2 within an unnamed shale-siltstone unit. The lenses stretch in a rough line from 3 km west to 9 km southeast of the Gecko Mine, alongside the track from Quartz Hill to the Marion Ross and Orlando Mines. At Mount Argo (grid reference 406846) the Gecko Volcanics form two distinct beds which are folded into a northwest-plunging antiform.

Lithology: Grey-green and purple tuff; quartz and feldspar porphyry; and greywacke derived mostly from volcanic rocks.

Type Section: The southwestern limb of the Mount Argo antiform (grid reference 407845) is nominated as the type section locality. What is believed to be the lower part of the unit consists of well-jointed, blocky, purple to grey, vesicular quartz-feldspar porphyritic lava and tuff. The uppermost part consists of sheared quartz-feldspar and feldspar porphyry.

Thickness: The maximum thickness is 300 m.

Age: The Warramunga Group of which the Gecko Volcanics is a constituent Formation is probably Early Proterozoic.

Relations: Conformable with the underlying and overlying shale of the unnamed $\text{P}w_2$ unit.

WARREGO VOLCANICS

Proposed name: Warrego Volcanics.

Derivation of name: Warrego Mine in Tennant Creek 1:250 000 Sheet area; grid reference 376849.

Distribution: Crops out in an area of 21 km^2 between the Orlando and Warrego Mines. The largest single area of outcrop is 11 km east-northeast of the Warrego Mine, where the volcanics define the westerly-plunging Great Western Syncline. Numerous faults complicate the areal distribution of the unit. The Warrego Volcanics are also exposed in a fault block 8.5 km southeast of the Warrego Mine. Farther west the upper part of the volcanics is exposed in an anticline.

Lithology: Purple banded rhyolite, grey ignimbrite, pink ashstone and tuff, and grey banded hematite shale, interbedded with siltstone, greywacke, shale, and minor chert.

Type Section: No type section was measured for the unit; exposure is poor and the lithology shows marked lateral variation. The outcrop on the northern limb of the Great Western Syncline, where the whole sequence is present, is regarded as the type area.

The basal beds are exposed on the southern margin of flat-topped hills in a crescent-shaped outcrop area south of Black Angel Trig.; in two areas within the Great Western Syncline, one along its southern margin 8 to 14 km east-northeast of the Warrego Mine and the other 5 km northwest of the Great Western Trig.; and in the sides of the Warrego No. 2 Dam. They consist of volcanic rocks—pyroclastics (one or more of ashstone, agglomerate, and tuffaceous siltstone) and in addition dark purple to cream and pink rhyolitic lava on the southern limb of the syncline—interbedded with sedimentary rocks—fine to coarse-grained greywacke, and in addition grey, finely banded hematite shale along the southern limb where it forms the basal bed, and purple cleaved shale, pink claystone, and chert 5 km northwest of Great Western Trig.

Beds higher in the sequence are exposed in the western part of the Great Western Syncline; 6 km and 8.5 km southeast of the Warrego Mine; 1 km south and 700 m southeast of Black Angel Trig.; at the copper smelter 11 km east of the Warrego Mine, and at localities 0.5 km southwest and 3.5 km northeast of the smelter. They include volcanic rocks—minor agglomerate, tuff (in part feldspathic, shaly, silicified, flaggy to blocky, fissile, cleaved, fine to coarse-grained; white, red-grey, grey-purple, pink, fawn), greywacke (in part feldspathic; fine-grained), siltstone, cherty siltstone, shale, hematite shale, chert (in part finely banded), chert breccia.

Beds near the top of the sequence in the western part of the Great Western Syncline consist of flaggy to blocky tuff and leached white tuffaceous siltstone interbedded with pink and cream cherty ashstone. The topmost beds, along with northern limb of the syncline, consist of cream, pink, and purple ashstone overlain by blocky tuff and greywacke.

Thickness: Ranges from 550 m in the type area to about 200 m at a locality 7 km southeast of the Warrego Mine.

Age: The Warramunga Group of which the Warrego Volcanics is a constituent Formation is probably Early Proterozoic.

Relations: Conformably overlies the unnamed unit $\text{P}w_7$ and is conformably overlain by the unnamed unit $\text{P}w_3$. The lower contact is sharply defined around the southern limb of the Great Western Syncline where the basal bed of the volcanics—banded hematite shale—overlies claystone and tuffaceous siltstone of unit $\text{P}w_7$. In the sides of Warrego No. 2 Dam pink, blocky to flaggy, compact, finely banded silicified ashstone overlies purple to white flaggy siltstone of unit $\text{P}w_7$.

The upper contact grades into unit $\text{P}w_3$ and is marked by the highest tuff, ashstone, or lava in the sequence; it is exposed around the northern limb of the Great Western Syncline and at a locality 0.5 km southwest of the Black Angel Mine.

TOMKINSON CREEK BEDS

Hayward Creek Formation

Proposed name: Hayward Creek Formation.

Derivation of name: From Hayward Creek, lat. 19°10′S long. 134°09′E in the Tennant Creek 1:250 000 Sheet area.

Distribution: The Hayward Creek Formation constitutes a large part of the Whittington Range and the Short Range area, and it also crops out in the northwest corner of the Tennant Creek 1:250 000 Sheet area. There is an isolated outcrop 8 km southwest of No. 11 Bore, and others northeast and northwest of Meerie Waterhole.

Type section: The type section is from grid reference 410883 to 408883. Here, the pebbly lithic sandstone and conglomerate of the Blanche Creek Member passes upward into medium-grained clean quartz sandstone (orthoquartzite) about 1000 m thick. The basal part of the quartz sandstone contains terrestrial cross-bedding on a small scale, and shows a few symmetrical ripple marks. In the lower half of the sandstone there are a few pebbly beds, 15 to 30 cm thick, of subrounded white quartz and pink and grey silicified orthoquartzite, 3-4 cm across, in an orthoquartzite matrix; red jasper pebbles form about 1 per cent of the rock. In the upper half the grainsize decreases; pebbles are less abundant and smaller, and the sandstone is fine to medium-grained. The topmost 2000 m at the type-section locality consists of cream to red, silicified, clean quartz sandstone and feldspathic sandstone. It is thin to thick-bedded, flaggy to massive, and is commonly cross-bedded.

Lithology: The formation consists of clean quartz sandstone (orthoquartzite), and feldspathic sandstone. The basal 500 m includes a few pebbly beds; in part it is cross-bedded and ripple-marked. The Blanche Creek Member, of pebbly sandstone and conglomerate, forms the base of the formation.

Thickness: The Hayward Creek Formation ranges in thickness from about 3000 m in the southern part of Whittington Range to about 6000 m in the Short Range.

Age: The Tomkinson Creek Beds appear to be correlatives of the Hatches Creek Group which crops out in the extreme south of the Sheet area—they are lithologically similar and both directly overlie Warramunga Group rocks. An upper limit in age for the Hatches Creek Group was set by the age of an intrusive granite which has a Rb-Sr age of 1695 m.y. (Compston & Arriens, 1968); a lower limit is set by the underlying Warramunga Group. On this basis the Hatches Creek Group and therefore the Tomkinson Creek Beds are within the age range from Proterozoic to Early Carpentarian.

Stratigraphic relations: The formation overlies the Early Proterozoic Warramunga Group, locally with slight angular unconformity, and is overlain conformably by the Whittington Range Volcanics.

Blanche Creek Member

Proposed name: Blanche Creek Member.

Derivation of name: From Blanche Creek in the Tennant Creek 1:250 000 Sheet area, lat. 19°02′S, long. 134°09′E.

Name of host formation: Hayward Creek Formation.

Distribution: The Blanche Creek Member crops out in scattered outcrops along the eastern side of the Whittington Range as far south as Hayward Creek. It is also found along the southern edge of the Short Range.

Type section: The type section is near grid reference 411885. At this locality the formation consists of poorly sorted sandstone and conglomerate. Pebbles 1 to 6 cm across account for up to 20 per cent of the rock. The member characteristically shows high-angle cross-bedding.

Lithology: It is a poorly sorted lithic sandstone and conglomerate, consisting of 20-30 percent sub-rounded pebbles in a lithic sandstone matrix. The pebbles are predominantly of white quartz; about 10 per cent are of black chert, red jasper, and igneous rocks (mostly quartz porphyries) and rarely dark red siltstone and shale fragments.

Thickness: The member is up to 150 m thick.

Age: By assumed correlation of Tomkinson Creek Beds with Hatches Creek Group, Proterozoic to Early Carpentarian.

Stratigraphic relations: The Blanche Creek Member overlies the Lower Proterozoic Warramunga Group in many parts of the area, locally with slight angular unconformity. It is the basal member of the Hayward Creek Formation and passes up conformably into this formation.

WHITTINGTON RANGE VOLCANICS

Proposed name: Whittington Range Volcanics.

Derivation of name: From Whittington Range in the north of the Tennant Creek 1:250 000 Sheet area.

Distribution: The Whittington Range Volcanics form six small outcrops in the central-southern part of the range and two in the eastern part of the Short Range about 7.5 km northwest of Phillip Creek station. The volcanics typically form low mesa-like outcrops capped with Tertiary silcrete. Elsewhere, evidence of the volcanics is found amongst the angular rubble on the valley floor. This consists mostly of quartz sandstone fragments, but also includes pebbles and angular fragments of vein quartz, blue-green rhyolite, epidotised basalt, and red jasper.

Type section: The type section is near grid reference 407892. The stratigraphic section of this locality starts with 10 m of interbedded quartz sandstone and basalt, overlain by 35 m of coarse-grained basalt, and 12 m of micaceous quartz sandstone with some brown micaceous siltstone. This is overlain by 290 m of vesicular and fine-grained basalt, much of it epidotised, with some interbedded flows of white and blue-green spherulitic rhyolite. The basalt is veined with jasper and quartz, and vesicles are filled with chlorite, pumpellyite, calcite, quartz, epidote, jasper, and albite.

Lithology: The rock is highly weathered. Rock from diamond-drill core consists of coarse-grained weathered basalt (12 m) overlain by micaceous quartz sandstone and red-brown micaceous siltstone (6 m). These sediments are capped by volcanic rocks 30 to 100 m thick; they consist predominantly of highly altered vesicular and non-vesicular basalt, with some interbedded flows of white and blue-green spherulitic ?rhyolite.

Thickness: The formation is 200 to 400 m thick.

Age: By assumed correlation of Tomkinson Creek Beds with Hatches Creek Group, Proterozoic to Early Carpentarian.

Stratigraphic relations: The formation conformably overlies the Hayward Creek Formation, and is conformably overlain by the Morphett Creek Formation.

MORPHETT CREEK FORMATION

Proposed name: Morphett Creek Formation.

Derivation of name: From Morphett Creek in the Helen Springs 1:250 000 Sheet area, lat. 18°53′S, long. 134°05′E.

Distribution: The formation has only limited outcrop in the central part of Whittington Range, and in some areas on the north side of Short Range.

Type section: The type section is between grid references 407893 and 403891, in the Tennant Creek 1:250 000 Sheet area. A generalised section has at its base 16 m of ferruginous quartz sandstone with jasperoidal cement. This is overlain by 60 m of flaggy to blocky feldspathic quartz sandstone, with ripple marks, mud-clasts and cross-bedding. On this rests a lens of boulder conglomerate up to 14 m thick; boulders are of orthoquartzite, quartz, and pebbly sandstone. The sandstone and conglomerate are succeeded by 220 m of interbedded red and white shale and micaceous siltstone, some quartz siltstone, and laminated feldspathic quartz siltstone. Minor ironstone and calcareous beds are intercalated in this sequence at intervals of about 15 to 25 m.

Lithology: The lower part of the formation consists of fissile to flaggy, and locally massive and thick-bedded, feldspathic sandstone, with thin conglomerate locally above it and several bands of rounded quartz pebbles near the base. Ripple marks, cross-beds and shale clasts are common. This is overlain by flaggy to laminated shale and siltstone, with minor interbedded quartz siltstone and feldspathic quartz sandstone. The lower 100 to 150 m of the feldspathic sandstone is ferruginous and has a jasperoidal cementing material. The rock is deep brown and is readily recognised on aerial photographs as a dark layer immediately overlying the Whittington Range Volcanics. The siltstone and shale are soft and poorly exposed.

Thickness: The formation ranges from 2500 to 4800 m in thickness.

Age: By assumed correlation of Tomkinson Creek Beds with Hatches Creek Group, Proterozoic to Early Carpentarian.

Stratigraphic relations: The Morphett Creek Formation conformably overlies the Whittington Range Volcanics, and is in turn conformably overlain by the Short Range Sandstone. There is a distinct break in lithology at the top of the formation, where it passes abruptly from shale and siltstone into the resistant Short Range Sandstone.

SHORT RANGE SANDSTONE

Proposed name: Short Range Sandstone.

Derivation of name: From the Short Range in the Tennant Creek 1:250 000 Sheet area, lat. 19°12′S, long. 134°05′30″E.

Distribution: In the Tennant Creek Sheet area the formation crops out only on the western side of the Whittington Range. It is easily discerned on aerial photographs as a thin prominent ridge running south from grid reference 398898 to 403877, and as ridges and small hills up to 7 km west of this ridge.

Type section: Near grid reference 401894, where a southern tributary of Attack Creek cuts through the sandstone. The generalised section contains pink, light grey, cream, and purple, massive to blocky orthoquartzite. It is silicified, compact, and resistant to weathering. It is characterised in its lower half by very long, low-angle, medium to large-scale cross-beds about 1 m thick. Ripple marks are common throughout. The upper half of the formation is characterised by numerous shale clasts, abundant ripple marks, and small to medium-scale cross-beds.

Lithology: The Short Range Sandstone consists of pink, light grey, cream, and purple, massive to blocky orthoquartzite. It is cross-bedded and ripple-marked; the quartz grains, 0.3 to 0.4 mm across, are well-sorted and rounded.

Thickness: The formation is 200 to 800 m thick; generally it thickens northwards.

Age: By assumed correlation of Tomkinson Creek Beds with Hatches Creek Group, Proterozoic to Early Carpentarian.

Stratigraphic relations: The Short Range Sandstone conformably overlies the Morphett Creek Formation and is conformably overlain by the Attack Creek Formation. Boundaries with these formations are very distinct.

ATTACK CREEK FORMATION

Proposed name: Attack Creek Formation.

Derivation of name: From Attack Creek in the Tennant Creek 1:250 000 Sheet area, lat. 19°03′30″S, long. 134°03′E.

Distribution: The formation crops out in a small area immediately west of the prominent north-south ridge formed by the Short Range Sandstone.

Type Section: The type section is between grid refs 401893 and 398892. The section here commences with a basal 80 m of cream calcareous siltstone, medium to thick-bedded. There follows 300 m of dark grey, flaggy limestone, in part silicified. Thin calcareous siltstone or shale interbeds (1 cm or less) separate 8-10 cm flags of limestone. Some limestone beds contain shaly clasts, siliceous nodules, and oolitic concentrations. The limestone grades into 20 m of concretionary ironstone, calcareous black (manganiferous) mudstone, and brown and black mottled chert. This is overlain by 200 m of cream to rusty brown feldspathic quartz sandstone and pink to cream, silicified orthoquartzite, followed by a sequence 120 m thick of softer rocks, largely eroded, believed to be friable sandstone or siltstone. The upper part of the formation consists of 100 m of massive, thick-bedded, cream orthoquartzite with 1 to 2 percent of well-rounded pink orthoquartzite pebbles scattered throughout the sandstone matrix; there are voids left by weathered-out shale clasts.

Lithology: The formation consists of a basal calcareous siltstone overlain by dark grey, partly silicified, flaggy limestone with thin interbeds and shale clasts. The limestone grades into black, calcareous, manganese-rich mudstone and black chert. This is succeeded by feldspathic quartz sandstone and silicified orthoquartzite. The uppermost beds are thick-bedded cream orthoquartzite with 1 to 2 percent of well-rounded pink orthoquartzite pebbles; they contain voids left by weathered-out shale clasts. The top of the formation has been partly removed by erosion.

Thickness: Within the Tennant Creek Sheet area the formation is at least 800 m thick.

Age: By assumed correlation of Tomkinson Creek Beds with Hatches Creek Group, Proterozoic to Early Carpentarian.

Stratigraphic relations: The formation has a conformable but sharp contact with the underlying Short Range Sandstone. The formation is situated in the core of a syncline, and its upper part is truncated by the present-day erosion surface.

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