GEOLOGY AND MINERAL RESOURCES OF THE WODGINA DISTRICT

by J. G. Blockley

ABSTRACT

The Wodgina district, located about 80 miles (129 km) south of Port Hedland in the Pilbara Goldfield, includes a typical Archaean "greenstone" belt preserved in a synclinal keel in granitic rocks. The "greenstones" comprise metamorphosed basalt, tuff, ferruginous chert, clastic sediments, felsite and untramafic rock. These rocks were intruded by an older gneissic granite and a younger porphyritic granite. Pegmatite veins, generated from the porphyritic granite, have been past sources of tin, tantalum and beryllium minerals. They also contain significant, but so far un-mined deposits of lithium. A small amount of copper ore was produced from mineralised shears and from a disseminated deposit near a felsite sill. The district has untested deposits of iron ore, and layered ultramafic rocks of the type elsewhere associated with nickel mineralisation.

INTRODUCTION

Since tin was discovered at Wodgina in about 1902, the Wodgina district has been an important source of pegmatite minerals, yielding cassiterite, tantalo-columbite and beryl as well as a little copper. It also has significant deposits of lithium minerals, some iron ore and potential for nickel.

Although there have been many published descriptions of the economically and scientifically interesting pegmatites, there is no geological map of the whole field showing the locations of the various deposits or mining centres. This, together with the lack of lease surveys, has resulted in several of the centres being either not marked, or placed incorrectly, on plans.

The present report is an attempt to correct this gap in the records by presenting a 1 : 100,000 scale geological map of the district, showing as many of the mines as could be located, together with a brief description of its geology and mineral resources (Plate 20). This mapping was done in 1969 during a survey of the tin deposits of the Pilbara Goldfield.

LOCATION, ACCESS AND FACILITIES

The Wodgina district, as the term is commonly used, includes the mining centres of Wodgina, Stannum, Mill's Find, Numbana and Mount Francisco. It covers a tract of country extending from lat. 21° 20′ S, long. 118° 40′ E to Lat. 21° 28′ S, long. 118° 33′ E, and includes two prominent ranges of 'greenstone' hills which rise to heights of about 600 feet (180 m) above the surrounding granitic plains. The area forms part of the Marble Bar 1 : 250,000 Sheet area (Noldart and Wyatt, 1962).

Wodgina, the main centre in the district, is 75 miles (121 km), by graded road, south of Port Hedland. The other centres in the district are connected to Wodgina by tracks. The greater part of the district is in the Yandeyarra Aboriginal Reserve, and non-aborigines require a permit from the Department of Native Affairs for entry.

When mapped by the writer in 1969, the only mining activity in the district was a little prospecting. During past mining operations, water was obtained from wells sunk close to the workings or treatment plants. Supplies were always considered inadequate, and any future operators will probably have to seek water in the alluvium and jointed granite along the Turner River.

PREVIOUS WORK

The first, and most complete account of the geology of the Wodgina district is that by Maitland (1906). His report includes geological maps of the Wodgina and Stannum centres and descriptions of the mines working at that time. Montgomery (1907), Woodward (1910), Blatchford (1913), and Cleland (1913) all described tin and tantalite deposits in the district. Finucane and Telford; (1939), Miles, and others (1945), and Ellis (1950) gave accounts of the tantalite workings in the district; the first of these also included a geological map of the Wodgina centre. Simpson (1912, 1919, 1928) recorded the occurrence of uranium and thorium minerals in the pegmatites, and the compilation of the State's mineral occurrences by the same author (Simpson, 1948, 1951, 1952) summarised information on the tin, tantalum, lithium and beryllium deposits of the district. Low (1963) published some details of a copper deposit at Mount Francisco.

GENERAL GEOLOGY

The rock assemblage of the Wodgina and Mount Francisco ranges is typical of an Archaean 'greenstone belt', and includes metamorphosed basalt ferruginous chert, clastic metasedimentary rocks, and acid and ultramafic intrusives. These rocks are preserved as roof pendants along a synclinal keel in a large area of granitic rocks, consisting of an older gneissic granite and younger porphyritic granite. Near its contact with the metamorphic rocks, the porphyritic granite grades into a marginal phase which is even-grained or pegmatitic in texture. Prominent pegmatite veins, in most places closely associated with the marginal granite, cut the metamorphic rocks and were the source of the tin, tantalite and beryl mined from the district.

The main structural feature in the Wodgina district is a syncline trending north-northeast which passes through the middle of the Wodgina range and extends with interruptions by granite intrusion to Mount Francisco. Upon this syncline are superimposed many complex drag folds, particularly in the chert bands, and northwesterly-trending cross folds. The interpretation of the overall structure is further complicated by the lenticular shape of many of the rock units, and by a number of cross faults. A major north-northeasterly fault can be traced, by means of quartz reefs and its displacement of rock units, from south of Mount Francisco to the central part of the Wodgina range. Farther north, its course is marked by topographic lineaments such as straight creek beds, but displacement and quartz filling are no longer seen.

The disposition of the thicker basalts and clastic sedimentary rocks along the axis of the syncline suggests that the present structure follows a former depositional trough (perhaps controlled by the major fault) in which the lavas and sediments accumulated.

Younger rock units in the district are duricrust, pisolite and ferruginous sandstone of probable Tertiary age, and recent residual soil, outwash and alluvium.

ARCHAEAN METAMORPHIC ROCKS

The following brief descriptions of the metamorphic rocks are based on field observations and the examinations of a few thin sections.

Ferruginous chert

Recrystallised ferruginous chert, with interbedded slate and rare iron formation is the most abundant of the metamorphic rocks. It forms the higher ridges in the district and its outcrop has controlled the topography, which reflects the geological structure. In thin section, it consists of finely crystalline quartz, grunerite and iron oxides with accessory apatite. In some exposures, the chert grades upwards into a cream coloured rock composed of fine-grained quartz and zoisite, but in general, attempts to subdivide the ferruginous chert stratigraphically were unsuccessful.

Metabasalt

Metabasalt is well exposed at Wodgina, Stannum and in a broad valley north of the Comet mine. The unit as mapped also includes some metamorphosed tuff, agglomerate and dolerite. Although these basic rocks are now recrystallised to quartz-epidote-plagioclase amphibolites, primary structures such as amygdales, pillows and agglomeratic bands are well preserved, and attest to their volcanic origin. All of the metabasalt units are lenticular, and are thickest in the keel of the main syncline.

Amphibole schist

The most poorly exposed of the metamorphic rocks is the amphibole schist. It is commonly, though not always, found associated with the metabasalt, and in places, grades laterally into this rock. The schist is made up of well foliated actinolitic amphibole, plagioclase and quartz. No direct evidence of the original identity of this rock was seen, but its basic composition and close association with the metabasalt suggests that it is a metamorphosed basic tuff.

Ultramafic rock

Ultramafic rock is well exposed in the hills north of the Wodgina centre, along the west side of the Wodgina range, and at Mount Francisco. It also forms a number of small remnants in the granite, particularly between Round Hummock and Mount Francisco. In most outcrops, this rock is conformable with the other metamorphics, but in some places, transgression and rafting were noted, and a few cross-cutting dykes were also seen.

Ultramafic rock is particularly well exposed in the Wodgina district, forming ridges 200 to 300 feet high (60 to 90 m), with very little soil cover. Many exposures have a coarse layering, clear on air-photographs, but less so on the ground. This layering is parallel to the attidude of the surrounding metamorphic rocks, and is folded. It seems to be primary, and not due to metamorphism.

In the area north of the mines at Wodgina, the ultramafic rock shows not only the coarse layering, but also a fine banding, of the order of one or two centimetres thickness. In this area, many outcrops of the rock have a spotted texture due to clots of more iron-rich material about one centimetre in diameter. The origin of these structures is not known at present, but their close analogy with features described from the Tumbiana Pisolite (Trendall, 1965) and elsewhere, suggests that in this locality the ultramafic rock may be tuffaceous.

The ultramafic rock consists of fine-grained tremolite, chlorite, talc and magnetite. In some specimens, the outlines of primary olivine grains can be discerned, but in all thin sections examined, the original rock-forming minerals were completely recrystallised.

Metasediments

Metamorphosed clastic sedimentary rocks crop out on the eastern side of the Wodgina range, near the Stannum centre. The most conspicuous rock type amongst these is a deformed conglomerate with pebbles of chert and quartz stretched out at right angles to the fold axes, parallel to the "a" lineation direction. Other rock types present are chlorite and biotite schist (with pebble bands) and quartzite.

Felsite

Lenticular sills of felsite are exposed at Stannum, in the valley north of the Comet mine, and near Wodgina. The rock is very fine grained, with local spheroidal textures, is cream to white, and is cleaved. The sills were intruded close to, or along the contact of chert and metabasalt or amphibole schist. In most places they are conformable, though a discordant contact was noted near the Stannum tin mine.

The felsite consists of small phenocrysts of altered plagioclase and irregular patches of amphibole and chlorite set in a fine-grained matrix of granulated quartz and feldspar. Fresh microcline is developed in pressure shadows alongside the phenocrysts.

GRANITIC ROCKS

Gneissic granite

Gneissic granite, composed of quartz, microcline, plagioclase, green biotite (partly replaced by chlorite) and actinolite, crops out on the western and southern sides of the Wodgina range, and underlies much of the sand-plain between Wodgina and the Yule River. It ranges from well banded gneiss to foliated granite. Remnants of greenstone, aligned parallel to the foliation, are common. In many places the gneiss contains concordant bands of porphyritic granite with phenocrysts set parallel to the gneissic trend, and is cut by dykes of massive, even-grained granite. Concordant pegmatites are common in the more gneissic parts.

Porphyritic granite

The porphyritic granite intrudes the gneissic granite, with much interfingering at the contact. It occupies most of the southern part of the Wodgina district, and extends considerably beyond it (Blockley, 1970). Although aligned phenocrysts and broad compositional banding were noted in a few places, the rock is generally massive, forming tors and rounded domes in contrast to the more subdued outcrops of the gneiss. It is made up of phenocrysts of microcline set in a matrix of quartz, oligoclase, microcline and brown or green biotite.

The marginal phase of the porphyritic granite varies from even, medium-grained granite to pegmatite. It contains muscovite rather than biotite, and in some outcrops carries pink spessartite garnet. In many places it is foliated parallel to the attitude of the adjacent metamorphic rocks. Its composition is generally more acid than the porphyritic granite, but varies considerably due to assimilation of the intruded metamorphic rocks.

Pegmatites

The rare-metal pegmatites form clearly intrusive veins within the metamorphic rocks, or rarely, as at Numbana, in the granite. Most veins have a north-northeasterly strike, parallel to that of the host rocks, but many dip only gently, and cut the bedding direction of their host rocks. The greater number of pegmatites have irregular shapes and were probably intruded into tension gashes. However, some, like the Tantalite lode at Wodgina, follow well-defined faults.

The pegmatites consist mainly of inter-grown quartz and albite, but lenses or veins of blue quartz, pure albite, or quartz-albite-muscovite are common. Microcline, green muscovite, blue-green tourmaline, lepidolite and spessartite are other common constituents of the pegmatites. Some pegmatite veins have a more or less zonal arrangement of the mineral assemblages, but in others this is not so. Simple pegmatites also occur, and consist usually of either quartz-albite or blue quartz. Some of the tin-bearing pegmatites at Wodgina have a late-stage phase of blue tourmaline and muscovite, which may occur along the edge of the veins, or as detached veins on parallel shears. Wall-rock alteration about pegmatites cutting basic and ultramafic rocks has produced a selvage of biotite.

MINERAL DEPOSITS

Tin deposits

About 470 tons (478 tonnes) of tin concentrate were mined from the Wodgina district. It was won from pegmatites, and from eluvium in small gullies in their immediate vicinity. Because of the wide scattering of the tin-bearing pegmatites, and the unfavourable topography, no concentrations of alluvial cassiterite suitable for large-scale placer mining were formed.

The Mount Cassiterite tin mine at Wodgina had the largest production in the district. The cassiterite was won from a pegmatite lode striking about 080°, dipping southerly, worked in patches from three adits over a total length of 450 feet (135 m) to a depth of 250 feet (75 m) below its highest point. The width of the lode ranged from 12 inches (30 cm) to 14 feet (4·3 m), and averaged 5 feet (1·5 m) on the No. 3 level. Cassiterite occurred in the pegmatite, in marginal veins of blue tourmaline, and in the biotite selvage to the main vein. Pieces of up to 80 pounds (35 kgm) in weight were recorded. The ore milled averaged about 3 pounds of tin concentrate to the ton (1·4 kgm per tonne).

Smaller tin mines were located on a number of pegmatites cropping out on the ridge east of the Mount Casserite mine, and all the gullies in that area were hand-worked for alluvial tinstone.

At West Wodgina, Stannum, Mill's Find and Mount Francisco, cassiterite was mined from quartz-albite pegmatites in which it is found in small, but very rich patches. In many of these veins, the tinstone is associated with lepidolite. One pegmatite worked at West Wodgina yielded 9 hundred-weights of tin concentrate from 20 tons (460 kgm from 20·3 tonnes) of ore. Three samples of the faces worked at the Bright Star mine at Mount Francisco assayed 1·71, 0·47 and 0·77 per cent tin respectively, and a sample from the dump at Mill's Find assayed 0·50 per cent tin.

Tantalum deposits

The production of tantalite and tantalo-columbite from the Wodgina district is recorded as 178 tons (181 tonnes), of which 110 tons (112 tonnes) came from the Tantalite lode on M.C. 107 at Wodgina. The main tantalum mineral produced was mangano-tantalite, but mangano-columbite, tanteuxenite and microlite have also been recorded.

The Tantalite lode is a pegmatite vein striking north, dipping 40° east, and extending for about 2,200 feet (670 m) along strike. It has a true width of from 10 to 30 feet (3·0 to 9·1 m). It consists of a granitic textured core, with marginal and cross-cutting veins of almost pure albite. The tantalite is invariably found in the albite-rich parts. Mining was restricted to depths of 30 feet (9·1 m) or less. The ore treated on the lease averaged about 3 pounds of concentrate to the ton (1·4 kgm per tonne), but this included some eluvial ground and only the richer parts of the lode.

At Wodgina, tantalite was also mined from pegmatite veins north west of the main lode, and from the Terra Nova mine south of Mount Tinstone.

Tantalite and tantalo-columbite has also been mined from near Stannum, Mount Francisco and Numbana. Most of the production was from eluvium, though some may have been won by knapping and hand-cleaning the better grade pegmatite lodes.

Beryllium

Beryl was first identified at Wodgina by E. S. Simpson in 1927, and first mined in 1943, since when 1,177 tons (1,198 tonnes) containing about 136 tons (138 tonnes) of BeO have been produced. Much of the beryl is of the variety rosterite, having a high content of caesium. The ore is white or grey, lacks distinctive cleavage and crystal form and is readily mistaken for quartz.

The greatest production of beryl came from the north end of the Tantalite lode at Wodgina where it occurred in bunches and masses associated with albite. One mass was reported to have been 38 feet (11·6 m) long, 24 feet (7·3 m) high and 18 feet (5·5 m) wide, lying more or less horizontally. Beryl was also mined from two pegmatites on the east side of the range below Mount Tinstone, and from near M.C. 310, northwesterly from the Tantalite lode.

At Mount Francisco several benches and open cuts have been put in on gently dipping pegmatites cropping out in an area northwest of the trigonometrical station B10. Beryl and tantalite were seen in the workings, and it is assumed that these mines produced most of the beryl recorded from the Mount Francisco centre, although descriptions of the positions of the unsurveyed tenements listed in Table 3 place some of them at other locations.

Beryl was also mined from a quartz-cored pegmatite at Numbana where is it associated with columbite and books of muscovite.

Lithium

Lithium minerals such as lepidolite, spodumene and lithiophyllite occur in many of the pegmatites in the Wodgina district, although as yet no production has been recorded.

Lepidolite is known from the main Tantalite lode, from the Tinstone lease, and from a vein about 1 mile (1·6 km) north of Wodgina along the Port Hedland Road. It is present in the tin pegmatites at West Wodgina, Stannum, and the Eve Eva mine at Mount Francisco. A chip sample of the pegmatite at Stannum assayed 1·62 per cent Li_2O.

Lithiophyllite occurs in the Tantalite and the Rock Hole lodes at Wodgina, and in the Mount Francisco centre. Samples have assayed from 4·5 to 7·9 per cent Li_2O. Spodumene is known from the Mount Cassiterite and Stannum tin mines.

Copper

About 8 tons (8·1 tonnes) of copper ore were mined from Stannum and Mount Francisco. The latter deposit was not located, but Low (1963) considers it to have been in a quartz vein in granite.

At Stannum, disseminated malachite was worked in two places, on, or immediately below a felsite sill. Although low in grade, the "stratiform" disposition of the lode should be an encouragement to further prospecting. About 1½ miles (2·4 km) west of Stannum, a copper bearing shear in amphibolite schist has been recently opened up. The lode is about 150 feet (45 m) long, up to 6 feet (1·8 m) wide and contains malachite and chalcanthite.

Iron ore

The pisolite and canga deposits, although not sampled, are probably of comparable grade to similar material in the Hamersley Range area. The largest pisolite mesa is estimated to contain about 1 million tons (1,000,000 tonnes) of limonite. Total resources of the area would be in the order of 5 to 10 million tons (5 to 10 million tonnes) of pisolite and canga.

Other minerals

Simpson (1928) records 74 minerals from the Wodgina district, including such potentially economic minerals as bismuth, gold, molybdenite, galena, chalcocite, sphalerite and mineralogical curiosities such as the radioactive minerals thorogummite, pilbarite, hydrothorite, maitlandite and nicolayite.

The large area of ultramafic rocks gives the district potential for the discovery of nickel and associated metals.

TABLE 1. TIN PRODUCTION FROM THE WODGINA DISTRICT

Centre	Tenement No.	Name of Lease or Operator	Period	Concentrate Produced				Value $ Aust.	Remarks
				Lode Tons	Stream Tons	Total Tons	Metal Content Tons		
Wodgina....	MC 84	Mount Cassiterite	1904–08	133·52	13·85	147·37	N.A.	28,368.00	Part same ground
	ML 84, 93, 148	Mount Cassiterite Leases....	1908–18	195·50	1·60	197·10	N.A.	33,826.00	
	ML 93	Mount Cassiterite North	1906–07	9·67		9·67	N.A.	1,942.00	
	ML 89	Tinstone	1906–09	14.70		14·70	N.A.	2,780.00	Part same ground
	ML 255	Mount Tinstone	1913–14	2·45		2·45	N.A.	560.00	
	MC 109	McLeod, D. W.			3·94	3·94	2·12	5,757.13	
	ML 86, 87, 95	H.M.—Anchorite Leases	1917		5·00	5·00	N.A.	1,000.00	Part same ground
	ML 195	Cassiterite No. 1	1912	0·35		0·35	N.A.	98·00	
	ML 85	Commonwealth	1906	2·95		2·95	N.A.	696.00	
	ML 88	Chamberlain	1906	0·35		0·35	N.A.	120.00	
	Sundry Claims		1903–51	5·78	50·94	56·72	N.A.	11,633.84	
West Wodgina	ML 203	Wodgina Queen	1912–13	1·60		1·60	N.A.	380.00	
	ML 213	Referenda	1912	1·05		1·05	N.A.	294.00	
	DC 732	McLeod, D. W.	1968		3·93	3·93	2·42	5,955.31	
Stannum	ML 77	Stannum	1902–06		6·10	6·10	N.A.	922.00	Same ground
	ML 198	Stannum	1912	0·90		0·90	N.A.	252.00	
	ML 192	Comet	1912	0·30		0·30	N.A.	72.00	
Mills Find	ML 178	Siffleete's Reward	1910–13	3·50		3·50	N.A.	712.00	
	Sundry Claims		1906		0·85	0·85	N.A.	138.00	
Mount Francisco	MC 390	McPherson, N. E. and Fetwadjieffa	1957		0·13	0·13	N.A.	144.80	
	MC 910	Crow, Yegarla	1967			5·67	3·03	7,874.00	Mainly stream tin
	DC 15 WP	McLeod, D. W.	1967			1·54	0·97	2,654.13	
	PAs. 312, 313 WP	Nomads Pty. Ltd....	1965			2·48	1·73	6,004.50	
	PA 2751	McLeod, D. W.	1965			0·25	0·18	604.80	
	Crown Land	Sundry Persons	1963–64			1·57	0·83	1,828.20	
						470·47			

TABLE 2. TANTALO-COLUMBITE PRODUCTION FROM THE WODGINA DISTRICT

Group	Tenement No.	Name of Lease or Operator	Period	Tantalite			Tantalite/Columbite (Mixed Oxides)			Tantalo-columbite Total		Remarks
				Tons	Ta_2O_5 Units	Value $ Aust.	Tons	Ta NbO_5 Units	Value $ Aust.	Tons	Value $ Aust.	
Wodgina	MLs 86, 87, 95	HM & Anchorite	1905–29	104·49	N.A.	38,822.00				104·49	38,822.00	Part same ground
	ML 293	May Be	1925	2·00	N.A.	480.00				2·00	480.00	
	MC 107, etc.	Northwest Tantalum NL	1956	·60	30·15	2,550.50				·60	2,550.50	
	MC 107, 355	L. J. Wilson	1957–67	3·18	191·98	20,777.82				3·18	20,777.82	
	ML 89	Tinstone	1934	·50	N.A.	260.00				·50	260.00	
	ML 352	Terra Nova	1932	·45	N.A.	282.00				·45	282.00	
	PA 2438	J. H. Walkerden	1955				·15	10·53	796.00	·15	795.30	
Stannum	PC 732	D. W. McLeod....	1968	2·79	86·62	15,098.61				2·79	15,098.61	
Mills Find(?)....	PAs 2454, 2456, 2458	McPherson & Party	1956				0·37	23·57	1,862.00	·37	1,862.00	
Mount Francisco	MC 350	J. Ball	1956	·04	·84	53.40				·04	53.40	
	MC 390	McPherson & Fetwadjieffa	1957				·05	3·12	18.05	·05	18.05	
Numbana	PA 2413	L. C. Stein & Party	1953				1·26	95·98	7,161.30	1·26	7,161.30	
	MCs 294,306	Rare Metals Ltd.	1954				1·70	128·22	10,840.00	1·70	5,420.00	
	MCs 373, 378 379, 380	and Graydon & Party	1956				·56	35·93	2,836.00	·56	2,836.00	
Miscellaneous Tenements	MC 340	Sherlock & Parker	1956	·07	1·44	93.80				·07	93.80	10 miles SE Mt. Francisco
	DC 126, 127	Northern Minerals	1956				3·01	187·76	14,060.00	3·01	14,060.00	Pastoral Ck 8 miles E Wodgina
	MC 364, 365 MC 260	Syndicate Blanithensca	1955				2·18	132·71	9,174.00	2·18	9,175.30	14 miles SE Mt. Francisco
Crown Land & Sundry Person			1905–64	54·77	N.A.	23,693.08				54·77	23,693.08	
										178·17		

TABLE 3. BERYL PRODUCTION FROM THE WODGINA DISTRICT

Mining Centre	Tenement No.	Operator	Period	Production			Remarks
				Beryl Tons	BeO Units	Value $ Aust.	
Wodgina	MC 107 etc.	Tantalite Ltd. (Defence Project 83)	1943–52	754·26	8,607·68	51,496.00	Same ground
	MC 107	L. J. Wilson	1958	0·91	7·36	227.40	
	MCs 305, 314, 355	Northwest Tantalum Ltd.	1955	0·64	7·41	209.00	
	PA 2438	J. Walkerden & Party	1954–55	4·15	45·27	1,367.20	Near MC 310
	PA 2575	M. Seigne	1957–59	4·08	46·61	1,451.20	¾ mile S ML 88
	PA 2096	A. E. Rogers	1944	3·32	43·79	256.60	
	PA 2104	G. Lamont	1944	46·68	563·66	3,569.80	Location unknown
	PA 2116	G. Hooley	1944	4·29	56·59	331.70	
	PA 2337	J. Gilbert	1950	0·99	12·61	185.70	
Stannum	MC 352	W. Marshall	1956	4·27	48·28	1,361.50	
Mount Francisco	MC 365	Hooley, Rogers & Radley	1947–48	27·54	347·80	2,511.22	
	MC 350	J. A. Johnston	1954–56	46·69	545·70	15,855.70	
	MC 512	W. Hall	1959	13·90	156·89	5,059.80	
	PA 2411	Thompson, Coffin & Ball	1953	10·36	118·70	3,338.70	
	PA 2534	F. O'Donnell	1956–57	2·71	32·24	995.90	Partly same ground
	PA 2559	R. H. Otway	1957–58	8·83	105·35	3,255.40	
	MC 234	R. H. Otway	1951–53	6·71	81·17	2,276.12	
	MC 286	W. Coffin	1953–54	18·22	194·82	5,844.60	
	MC 614 (PA 2591)	D. J. Butterfield	1959–62	9·62	109·41	3,368.40	
	MC 311	A. Hall	1954	2·09	25·48	718.40	
	MC 393 (PA 2467)	W. Ball	1955	2·16	26·00	733.30	
	PA 2442	C. Newlands	1955	0·57	6·92	195.00	
	ML 370	J. M. Henderson	1958–62	30·56	353·70	11,179.20	
Numbana	PA 2413 (MC 306)	Stein & McAlpine	1952	2·91	36·72	1,035.60	
	MC 294, 306	A. E. Hall & F. D. Pinchin....	1953–54	4·78	55·11	1,560.90	
Miscellaneous	MCs 340, 343	Sherlock & Parker	1954–62	19·53	236·81	7,032.40	15 miles SSE Wodgina
	PA 2410	Bell Bros. & D. C. Watkins....	1953	·75	9·66	277.80	19 miles N Wodgina
Wodgina-Mount Francisco area	Crown land	Sundry Persons	1945–61	146·23	1,701·36	39,979.34	
				1,177·75	13,583·10		

TABLE 4. COPPER PRODUCTION FROM THE WODGINA DISTRICT

Centre	Tenement No.	Operator	Period	Production		Value $
				Tons ore	Units Cu	
Mount Francisco	P.A. 2529	P. Coffin	1957	4·17	17·67	16.40
Stannum	P.A. 2687		1963	3·65	22·81	47.90

REFERENCES

Blatchford, T., 1913, Mineral resources of the North West Division; Investigations in 1912: West. Australia Geol. Survey Bull. 52, p. 61–72.

Blockley, J. G., 1970, Preliminary report on tin granite in the Pilbara Goldfield: West. Australia Geol. Survey Ann. Rept. 1969, p. 34–37.

Cleland, E. D., 1913, Pilbara and West Pilbara Goldfields: West Australia Geol. Survey Bull. 52.

Ellis, H. A., 1950, Some economic apsects of the principal tantalum-deposits of the Pilbara Goldfield: West Australia Geol. Survey Bull. 104.

Finucane, K. J., and Telford, R. J., 1939, Tantalite deposits of the Pilbara Goldfields: Aerial Geol. Geophys. Survey North Australia Rept. West. Australia 46.

Low, G. H., 1963, Copper deposits of Western Australia: West. Australia Geol. Survey Mineral Resources Bull. 8.

Maitland, A. G., 1906, Third report on the geological features and mineral resources of the Pilbara Goldfields: West. Australia Geol. Survey Bull. 23, p. 46–68.

Miles, K. R., Carroll Dorothy, and Rowledge, H. P., 1945, Tantalum and niobium: West. Australia Geol. Survey Mineral Resources Bull. 3.

Montgomery, A., 1907, Report on the Pilbara and West Pilbara Goldfields: West Australia Dept. Mines Rept. of State Mining Eng.

Noldart, A. J., and Wyatt, J. D., 1962, The geology of portion of the Pilbara Goldfields: West Australia Geol. Survey Bull. 115.

Simpson, E. S., 1912, Radium-uranium ores from Wodgina: West Australia Geol. Survey Bull. 48, p. 9–12.

——— 1919, Rare metals of Western Australia: Mining Handbook of Western Australia Sect. 18: West. Australia Geol. Survey Mem. 1.

——— 1928, Report on the Pilbara tin and tantalum deposits: West. Australia Dept. Mines Ann. Rept. Chem. Branch p. 223–225.

——— 1948, Minerals of Western Australia; Vol 1: West Australia Govt. Printer.

——— 1951, Minerals of Western Australia, Vol. 2: West. Australia Govt. Printer.

——— 1952, Minerals of Western Australia, Vol. 3: West Australia Govt. Printer.

Trendall, A. F., 1965, Pisolitic tuffs in Western Australia: West. Australia Geol. Survey Ann. Rept. 1964, p. 51–55.

Woodward, H. P., 1910, Wodgina tin mining centre: West Australia Geol. Survey Ann. Rept. 1909. p. 17–18.