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FAMOUS MINERAL LOCALITIES: WODGINA, NORTH WEST AUSTRALIA

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For many years Wodgina as a place name, was known only to a few sheep and cattle breeders and wool buyers, as it is in the midst of a district originally, and still, occupied by sheep and cattle graziers. The discovery of gold at Friendly Creek in 1888, and that of tin at several points in the district in 1902, attracted miners to the spot, and resulted in the detection of tantalum minerals, then only of scientific interest. The invention however of the tantalum lamp materially changed the position, and Wodgina became known throughout the world as the main source of high grade tantalum ore. The replacement of tantalum in lamps by tungsten, and a drop in the price of tin led to the almost complete abandonment of Wodgina by miners. The recent invention of malleable tantalum sheet, and its utilization in the chemical industry has however led to the reopening of the Wodgina mines, which still hold premier place as sources of supply of this rare metal.

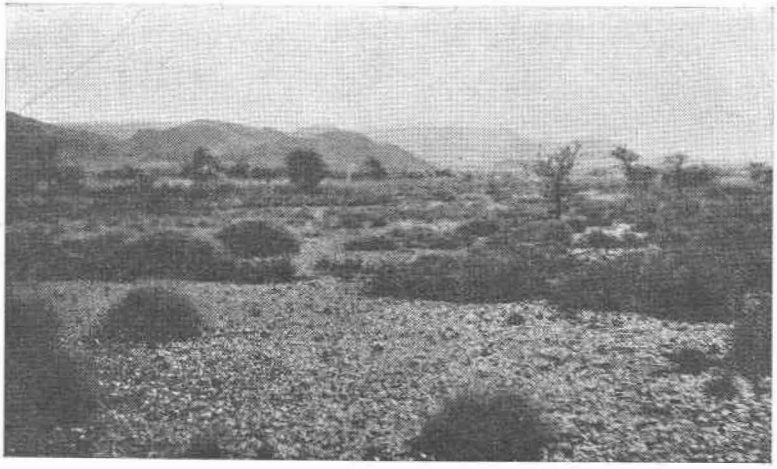

FIG. 1.

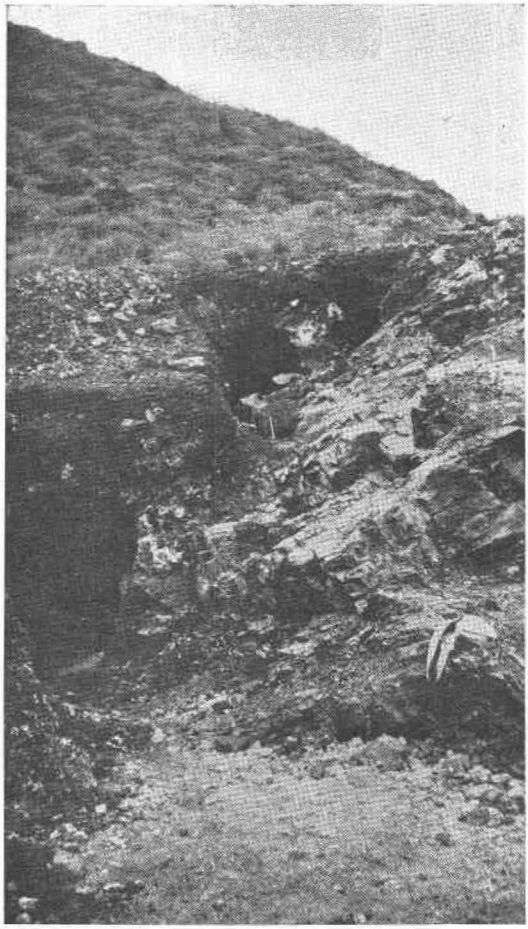

FIG. 2.

To students of historical geology, Wodgina has a special interest because the lead-uranium ratio of one of its minerals fixes the age of the enclosing rocks at 1260 million years, the most extreme age yet determined by this method.[1]

Taking the Wodgina District as embracing an area included in a circle with a center at Mt. Tinstone[2] and a radius of 20 miles,

[1] A. Holmes. The Age of the Earth, p. 74.

[2] Approximate Lat. 21° 12′ S, Long. 118° 40′ E.

it includes seven mining centers, viz., Wodgina, West Wodgina, Stannum, Mt. Francisco, Abydos, Greens Well, and Friendly Creek. The greater part of this area is occupied by a low sandy coastal plain thickly covered with spinifex grass and sparsely dotted with flowering shrubs and small trees. It is crossed by numerous creeks, dry for most of the year, whose beds reveal the underlying Archaean granite at many points. Low domes of the same rock emerge from the plain at intervals. Rising abruptly out of this plain to heights of 500 to 1000 feet are island hills, five to fifty square miles in area, of Archaean greenstone, the highest points often occupied by jasper bars. The greenstone of the island hills and the granite near them are seamed with pegmatite veins which are homes of the tin and tantalum ores, as well as many other minerals of scientific and industrial interest. Both these veins and the adjacent soils and stream beds have been, and are still being, worked over for cassiterite and tantalite. On the western side of the area quartz reefs are prominent features of the granite-greenstone boundary. They have been worked in the past for gold and copper at Friendly Creek.

The complete list of minerals recorded from this area is as follows:

Bismuth	Microcline	Nontronite
Gold	Albite	Mackintoshite
Molybdenite	Oligoclase	Thorogummite
Galena	Labradorite	Pilbarite+
Chalcocite	Hypersthene	Hydrothorite+
Blende	Spodumene	Microlite
Pyrrhotite	Hornblende	Columbite
Chalcopyrite	Beryl	Manganocolumbite
Pyrite	Helvite	Tantalite
Fluorite	Grossularite	Manganotantalite
Quartz	Spessartite	Calciotantalite+
Chalcedony and Jasper	Olivine	
Corundum	Vesuvianite	Tapiolite
Hematite	Topaz	Ixiolite
Ilmenite	Gadolinite	Tanteuxenite+
Spinel	Metagadolinite	Monazite
Magnetite	Epidote	Lithiophilite
Rutile	Allanite	Purpurite
Cassiterite	Hemimorphite	Apatite
Limonite	Schorl and Indicolite	Autunite
Psilomelane	Muscovite	Anglesite

Calcite	Lepidolite	Ferberite
Cerussite	Biotite	Scheelite
Smithsonite	Prochlorite	Ferritungstite
Bismutosphaerite	Talc	Ferrimolybdite
Malachite	Kaolin	
	Chrysocolla	

Of these 77 minerals those marked thus + are species first described as new from this district. Many of the others have not yet been recognized elsewhere in Australia.

A few short notes will explain the occurrence of the minerals.

Bismuth. Alluvial pebbles of native bismuth coated with yellow bismutosphaerite have been picked up with manganocolumbite at Mt. Francisco.

Gold. This is only found at Friendly Creek on the western edge of the area. Originally discovered in 1888, some thousands of ounces were won from quartz reefs in greenstone schist, and from the derived alluvial deposits. A large nugget of 165 Troy ounces was found in 1892 and sold to the Mint for £641.0.0.

Molybdenite and Ferrimolybdite. A few coarse flakes of the sulphide have been found at Mt. Francisco and West Wodgina. At both localities it is associated in quartz with dendritic films of ferrimolybdite.

Galena, Blende, etc. There are no commercial lead or zinc ores in the district, but a little galena, anglesite and cerussite are present in the gold reefs of Friendly Creek. In a quartz reef in granite at West Wodgina finely granular galena is fairly abundant. It is associated with some blende, while close to the surface their place is taken by a mixture of anglesite, cerussite, smithsonite and hemimorphite. = Calamine

Chalcocite, Chalcopyrite, etc. At Friendly Creek small quantities of these minerals and malachite are present in the gold reefs while quartz veins often carry bunches of richer carbonates and sulphides. At West Wodgina one wall of the galena lode mentioned above carries strings and bunches of chalcocite, malachite and brilliant green chrysocolla.

Pyrrhotite. A little of this is associated with coarse cassiterite in a biotite chlorite schist forming one wall of a pegmatite at Wodgina.

Pyrite. Plentiful in the gold ores of Friendly Creek and distributed throughout the greenstones of the district in small specks.

Quartz and Chalcedony. Quartz veins are not very common in either greenstones or granite except at Friendly Creek. Neither is quartz ever more than a minor constituent of the pegmatites. White chalcedony occurs in several of them, apparently as a replacement of microcline. Immense bands of yellow, brown and grey jasper are conspicuous and plentiful in the eastern half of Wodgina proper, where they often form the highest points of the Archaean greenstone hills. Similar bands are present at Friendly Creek.

Corundum. Magnificent specimens of corundum occur in a narrow band of gneiss in the granite at Abydos. Though nearly every piece is recognizable by its rhombohedral parting and imperfect basal cleavage to be a single crystal individual, the bounding faces are usually imperfect, though the general outline is that of a long tapering bipyramid, either alone or associated with a hexagonal prism. The mineral is subtranslucent and possesses an unusual violet color ranging from Ridgway 57′m through 59″ to 65″ b.

Hematite. Is a constituent in minor amount of the jaspers.

Ilmenite. It occurs as a microscopic constituent of the greenstones and as fine black sand in the alluvium. At Mt. Francisco there is some gravelly ilmenite, probably derived from a pegmatite.

Spinel. This mineral is found in nodules from an ounce or less up to about a pound in weight in a narrow belt of greenstone at Mt. Francisco. It is dark green and transparent in thin section, and has the following composition:

MgO	FeO	MnO	NiO	Fe_2O_3	Al_2O_3	Cr_2O_5	SiO_2	TiO_2	Total	D
14.64	17.42	0.80	0.62	3.96	61.22	nil	1.74	0.09	100.49	3.81

The accompanying minerals are chlorite, talc, biotite, olivine, hypersthene, magnetite, ilmenite and apatite.

Magnetite. Numerous large octahedral crystals are to be seen in a pegmatite vein close to the spinel. Many of the exposed ones are wholly converted into martite. Stream tin ore obtained a few miles further south was contaminated with pea-like grains of magnetite.

Rutile. A few small specimens of black rutile have been found at Mt. Francisco.

Cassiterite. It is a most important mineral throughout the district. The primary deposits are pegmatite veins traversing either granite or greenstone within a few miles of their mutual boundary. The chief component of the pegmatite is albite, followed by microcline and quartz, with minor amounts of spessartite, muscovite, etc. In one mine only, important quantities of tin have been secured from a band of altered greenstone (chlorite biotite schist) adjacent to a pegmatite. From this mine several masses of clean cassiterite, each over 200 lbs. in weight, were obtained. The alluvial deposits derived from the pegmatites are neither deep nor broadly extensive but are still important sources of ore. Cassiterite has been mined at all the centers mentioned and altogether some hundreds of tons have been obtained up to date. Excellent crystals are obtainable at Mt. Francisco, either simple unit bipyramids, or combinations of this with (101). Distortion by elongation parallel to a pyramid edge is common.

Limonite. It is widely distributed in the greenstone country, all the surface of the rocks being stained red-brown with it, while the soil is a limonitic clay loam. Desert polished pebbles of limonite strew the surface in many places and occasionally there is a gossan outcrop to be seen.

Psilomelane. This is the ultimate product of alteration of lithiophilite, and other manganese minerals.

Calcite. No limestones or calcite veins are known, but thin crusts of hard travertine cover an occasional acre or so in the greenstone country, the run off of rain water not being sufficient to carry away all the usually soluble products of rock weathering.

Microcline and Albite. Feldspar veins from 1 ft. to 30 ft. in width are plentiful both in granite and greenstone. The most abundant feldspar in almost every case is albite, usually coarsely crystalline and snow white in color except just on the surface. No specimens were seen illustrating the replacement of microcline by albite, but at times the two feldspars are intergrown, and quite abruptly pure white microcline in coarse crystals will become the predominant constituent of the vein. The feldspar veins are the homes of the valuable tin and tantalum ores, as well as being the matrix of other scientifically interesting minerals.

Oligoclase and Labradorite. These are rock forming minerals only, the former in the granite, the latter in the less altered greenstones (epidiorites).

Spodumene. The writer found this mineral rather plentiful in the tin bearing pegmatite of one vein at Wodgina. It is in flat cleavable plates of pale grey color, reaching a maximum size of about $2 \times 1 \times 0.5$ inches.

Hornblende. Dark green hornblende is the chief constituent of the epidiorites, amphibolites and hornblende gneisses which make up the greenstone island hills.

Beryl. This mineral is plentiful in rather well shaped crystals of a pale green color, and from one ounce up to 50 lbs. in weight, in a columbite bearing pegmatite at Mt. Francisco. In one part of the main tantalum lode at Wodgina there are large irregular masses of beryl, translucent and pale milk white in color, and so closely resembling quartz in appearance that for many years it has been mistaken for that mineral.

Helvite. Mr. H. Bowley (Assistant Government Mineralogist) has recently recognized helvite in fairly large masses in pegmatite sent from Mt. Francisco. This is the first time the mineral has been found in Australia.

Spessartite. This garnet is found in several pegmatite veins and the adjacent alluvium at Wodgina, either in large shapeless masses or in smaller well formed crystals. The usual form is (110) bevelled slightly or largely by (211). The color is very pale brown, yellow or pink, but alluvial crystals often have a very thin coat of black psilomelane. A typical unweathered crystal had the following composition:

SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Total	D
36.03	0.03	20.84	tr.	4.18	37.79	0.19	0.81	99.87	4.16

Vesuvianite. Dense and drusy masses of olive brown vesuvianite have been found at Wodgina and Mt. Francisco where pegmatites cut the greenstones. Typical specimens from the former place show the compact granular mineral passing inwards into dense radiated masses, and thence into short free prisms combining (110), (100) and (001).

Topaz. Only a single specimen of this mineral has been recognized at Wodgina.

Gadolinite. Detrital masses of black glassy gadolinite, thickly coated with brown metagadolinite, have recently been found at

Abydos. The largest one weighed 24 ounces. Under the microscope the mineral is dark green and mostly anisotropic but some specimens are isotropic and others include both types.

Epidote. It is frequently seen in the granite country close to greenstone dykes.

Tourmaline. Fairly large black crystals of schorl are abundant in the greenstone near some of the pegmatite veins at Wodgina and Abydos. Near the spodumene at Wodgina are large dense masses of almost microscopic prisms of indigo blue indicolite.

Muscovite and Biotite. These are rock forming minerals only, except at Mt. Francisco where occasional books of muscovite reach 5 inches in diameter.

Lepidolite. Large bunches of fine scaly lepidolite up to many feet in diameter occur at irregular intervals in the pegmatites at Wodgina. Smaller masses have been seen at Stannum and Mt. Francisco.

Prochlorite. This appears to be the common species of chlorite in the occasional chloritic alterations of the Archaean greenstones.

Nontronite. Yellowish green nontronite forms small seams in partly weathered amphibolite on the east side of Wodgina where the rock is traversed by jasper bars.

Mackintoshite, Thorogummite, Pilbarite, Hydrothorite. These form a genetically related series of minerals of which the parent is the mineral provisionally called mackintoshite though it differs in some respects from the type from Texas. All are massive and isotropic, but while the first two are hard and vitreous, the last two are earthy and much softer. They occur as infrequent "pebbles" in the albite of the main tantalite vein, particularly at its northern end, where they are often associated with lithiophilite. The compositions of the Wodgina minerals are:

	Mackintoshite	Thorogummite	Pilbarite	Hydrothorite
SiO_2	16.19	15.30	12.72	15.77
P_2O_5	n.d.	n.d.	1.08	1.33
K_2O	nil	nil	0.09	nil
Na_2O	nil	nil	0.04	nil
CaO	1.28	1.62	0.57	1.65
PbO	7.90	7.78	17.26	1.25
MgO	0.15	0.16	0.21	0.60
MnO	0.07	nil	nil	nil
FeO	0.20	nil	nil	nil
Fe_2O_3	nil	trace	0.20	nil
Al_2O_3	trace	trace	0.15	0.88
Ta_2O_5	0.67	0.40	0.47	nil
UO_3	present	37.33	27.09	2.98
UO_2	35.60	nil	nil	nil
ThO_2	24.72	24.46	31.34	57.79
Ce_2O_3	0.10	0.12	0.19	0.24
Y_2O_3	0.25	0.32	0.49	0.73
H_2O-	0.88	4.19	3.50	9.12
H_2O+	12.04	8.37	4.16	6.06
CO_2	nil	nil	nil	1.50
Total	100.05	100.05	99.56	99.90
D.	4.45	4.13	4.68	?
R.I.	?	1.617	1.74	1.638

On the basis of the lead-uranium ratios in mackintoshite the age of the Wodgina pegmatite veins has been calculated to be 1260 million years.

So far these minerals have been found in quantities far too small to be used as a commercial source of radium or thorium.

Microlite and Calciotantalite. A few small water worn pebbles of microlite have been collected at Greens Well. These were described in detail in 1907.[3] Their composition is given below with that of a second lime bearing tantalate, also very rare, which appears to be a calciferous tantalite, to which the author has given the name "calciotantalite."

	Ta_2O_5	Nb_2O_5	SnO_2	TiO_2	CaO	FeO	MnO	MgO	K_2O	Na_2O
Microlite	73.54	3.62	0.90	n.d.	13.46	3.64	0.60	0.42	0.20	1.66
Calcio-tantalite	73.82	6.44	0.72	0.54	7.78	8.42	1.39	0.62	nil	nil

Ign.	Rare Earths	Total	D
1.28	nil	99.32	5.42
trace	nil	99.73	6.04

[3] E. S. Simpson. Tantalum and Niobium in Austraila. *Aust. Ass. Adv. Sci.*, **1907,** p. 450. *Idem*, **1909,** p. 314.

Ferrotantalite and Ferrocolumbite. These are rarities, occasional alluvial pebbles, and lode specimens only having been recorded from Greens Well.

Manganotantalite and Manganocolumbite. These are of common occurrence throughout the district both in pegmatite veins and alluvium, in the latter case often associated with cassiterite. Well over 100 tons of manganotantalite concentrate, assaying 64 to 68 per cent Ta_2O_5 has been marketed. The greater part of this has come from Wodgina itself, with smaller parcels from Greens Well, etc. In the "main tantalite lode" at Wodgina and its adjacent detritus the clean mineral is remarkably uniform in quality, the Ta_2O_5 content running from 68 to 72 per cent, with 12 to 16 per cent of MnO. There is no associated columbite or cassiterite, and the gangue minerals, albite, microcline and quartz, with lesser amounts of kaolin, beryl, spessartite and lithiophilite, are easily separated by jigs and concentrating tables. The largest mass yet recovered from the lode weighed about 40 lbs. One of the most interesting specimens found in the adjacent soil was a well formed twin on (021) weighing 8 lbs. Simple crystals are common, showing the forms (100) (010) (001) and (133).

Minerals rich in tantalic oxide are less abundant both at Wodgina and the outlying mining centers than are ones with less than 52 per cent of Ta_2O_5 and, therefore, properly classified as manganocolumbite. Several deposits in which the mineral carries 40 to 50 per cent Ta_2O_5 are known at Wodgina. At Mt. Francisco an ore is plentiful in a pegmatite in granite about two miles from the greenstone boundary. Two tons of this have been collected from the outcrop. It varies in density from 5.46 to 6.32 indicating percentages of Ta_2O_5 ranging from 12 to 45.

At Abydos there is manganocolumbite with 5 to 18 per cent of Ta_2O_5. Greens Well ore has assayed 45 to 73 per cent Ta_2O_5. (In every case crystals are not at all uncommon.)

Tapiolite. Some small twinned crystals of this mineral found at Greens Well were described by the author in 1917.[4] No further specimens have been collected.

Ixiolite. A manganese tantalate totally different in habit, color and translucency to the normal manganotantalite, has been found in one of the workings on the main tantalite lode at Wodgina.

[4] E. S. Simpson. On Tapiolite in the Pilbarra Goldfield. *Min. Mag.* **18**, 116-7.

Its composition also is unique, perfectly homogeneous masses carrying 9 per cent SnO_2. Measurable crystals have not been found, but on several other grounds it is classified as ixiolite.[5]

Tanteuxenite. Normal euxenite is a titano-niobate of yttrium. The corresponding titano-tantalate of yttrium, first found at Cooglegong, 55 miles E.S.E., of Wodgina, and later much nearer to that town, at Woodstock, Mt. Francisco and Abydos, has been named "tanteuxenite" by the author. The mineral occasionally exhibits imperfect tabular orthorhombic crystals, is resinous in lustre, light to dark brown in color and breaks with a conchoidal fracture. Its density is notably higher than that of typical euxenite, 5.4 to 5.9, as compared with 4.6 to 5.0. At Abydos and Mt. Francisco it is associated with alluvial cassiterite.

Monazite. Small brown water worn pebbles of this mineral have been seen in alluvial tin from Abydos and Mt. Francisco. Crystals up to 0.5 inch in diameter are not uncommon at the latter place, the usual combination of forms being (100), (110), (121), or (100), (110), $(\bar{1}11)$, or (100), (001), $(\bar{1}01)$, (110), $(\bar{1}11)$.

Lithiophilite and Purpurite. Lithiophilite has been observed by the writer in masses of one pound to ten hundred-weight in pegmatite veins at Wodgina and Mt. Francisco. Close to the surface it is more or less completely altered into a black mass of purpurite and psilomelane. The unaltered mineral is pale grey in color, translucent and exhibiting the typical cleavages. Weathering alters the color first to amber yellow, then to brown with blood red flakes (pure purpurite), finally to black, by staining with psilomelane. Two analyses have been made. (1) is of pale yellow mineral from Mt. Francisco and (2) of a brown mineral with red flakes, an intimate mixture of lithiophilite and purpurite, from Wodgina.

	P_2O_3	MnO	Mn_2O_3	FeO	Fe_2O_3	Co_2O_3	CaO	MgO	Li_2O
(1)	45.99	30.80	—	10.44	—	—	2.78	0.94	7.87
(2)	42.98	22.88	13.44	4.25	2.51	0.10	3.32	0.84	4.50

	Na_2O	K_2O	F	H_2O+	Total	D
(1)	0.34	nil	nil	1.11	100.27	3.39
(2)	0.15	0.05	nil	5.65	100.67	3.24

Some still further altered material contained only 1.55 per cent of Li_2O, with 36.25 per cent of P_2O_5.

[5] E. S. Simpson. Further Occurrences of Tantalum and Niobium in W. A. *Aust. Ass. Adv. Sci.*, **1909**, 314.

Apatite. Narrow veins of white or pale grey apatite have been observed in several masses of lithiophilite, and there are other masses of similar apatite isolated in the pegmatites of Wodgina and Mt. Francisco. In one pegmatite at Wodgina a large body of lepidolite is dotted with pieces of apatite of a deep greenish blue color (Ridgway 43′m to 45′m).

Autunite. A few minute scales have been observed at the junction of lithiophilite and thorogummite.

Ferberite, Scheelite and Ferritungstite. At Friendly Creek numerous specimens of iron tungstate have been obtained from alluvial concentrates with cassiterite and gold, while scheelite has been found in carbonate copper ore. At West Wodgina scheelite occurs in biotite schist alongside a pegmatite and at Wodgina it is occasionally seen in alluvial tin and tantalum concentrates. Some of the Friendly Creek ferberite is partly replaced by ferritungstite.