1945.

WESTERN AUSTRALIA.

DEPARTMENT OF MINES.

MINERAL RESOURCES OF WESTERN AUSTRALIA

BULLETIN No. 3.

TANTALUM AND NIOBIUM

BY

KEITH R. MILES, D.Sc. F.G.S.
GEOLOGICAL SURVEY OF WESTERN AUSTRALIA,

AND

DOROTHY CARROLL, Ph.D., D.I.C.
GOVERNMENT CHEMICAL LABORATORIES.

AND

H. P. ROWLEDGE, A.A.C.I., A.W.A.S.M.
GOVERNMENT CHEMICAL LABORATORIES.

WITH FOUR PLATES AND FOURTEEN FIGURES.

Issued under the authority of the Hon. A. H. Panton, Minister for Mines.

PERTH.
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PREFATORY NOTE.

The production of tantalum ores has been one of Western Australia's contributions to the war effort and it is therefore fitting that the results of research by officers of the Mines Department should be published for the use of scientific workers and the general public.

This State has produced a large proportion of the world's supply of high grade tantalite and is unique in the number of localities in which tantalum and niobium minerals are found.

The study of the mineralogy and chemistry of the tantalum minerals which was initiated by the late Dr. E. S. Simpson many years ago and carried on by the Mineral Section of the Government Chemical Laboratory has proved invaluable in tackling the many production problems of these strategic minerals. A considerable part of the information given in this bulletin was obtained from the unpublished records and notes kept by the late Dr. Simpson and is complete to the end of 1943. With the bibliography it can be considered a comprehensive reference book for the Western Australian resources of tantalum and niobium.

The bulletin is divided into three parts:—Part 1 is submitted by the Government Geologist, Mr. F. G. Forman; Parts 2 and 3 by the Government Mineralogist, Analyst and Chemist, Mr. H. Bowley.

Part. 1. "Tantalite in Western Australia" was written by Dr. K. R. Miles, Geological Survey, and gives a general outline of the geology of the productive areas, the minerals occurring and mined, hints to prospectors searching for tantalum minerals, and information about marketing and values.

Part 2. "The Properties and Uses of Tantalum and Niobium," by Mr. H. P. Rowledge, A.A.C.I., A.W.A.S.M., Government Chemical Laboratory, lists all the known tantalum and niobium minerals and gives methods of extracting the metals from the ores, the properties of tantalum and niobium, the alloys and compounds formed, and the uses made of metals and alloys.

Part 3. "Western Australian Tantalum and Niobium Minerals," by Dr. Dorothy Carroll and Mr. H. P. Rowledge, Government Chemical Laboratory. The introduction gives a brief description of the general occurrence in Western Australia and the associated minerals, together with an outline of the mineral groups adopted, and some general details of their group properties. A table of their distribution according to localities is added. In the descriptive part which follows, each mineral is taken in order and described from all the known localities. Details of the crystallography and of physical, chemical and optical properties are given.

A. H. PANTON,
Minister for Mines.

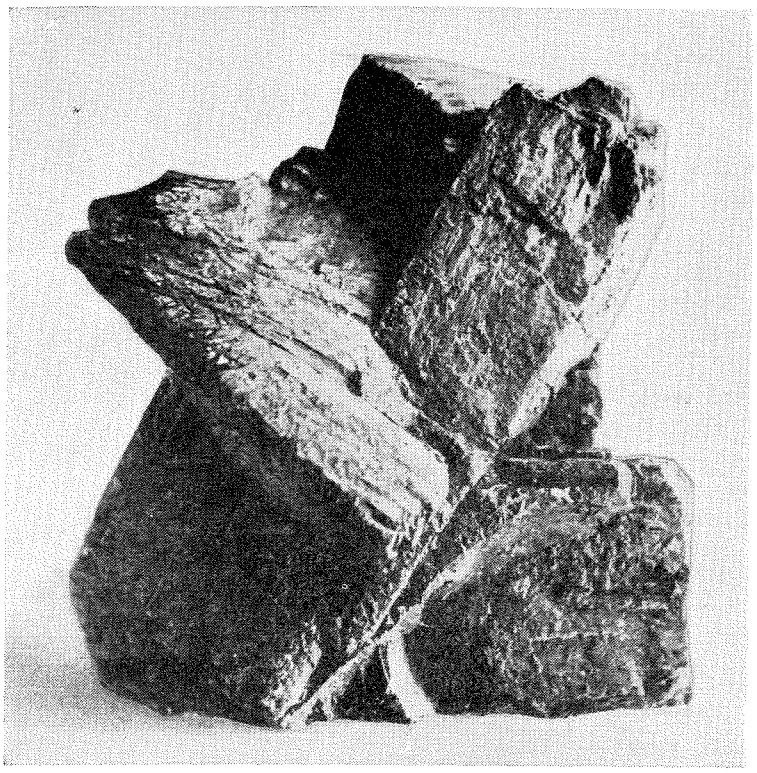

Fig. 1.—Twinned Crystals of *Manganotantalite* from Wodgina, Pilbara District, N.W. Weight 8 lbs. 2 ozs. Scale two-thirds natural size.
G.S.W.A. Neg. 506.

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PART I.

Tantalite in Western Australia.

By Keith R. Miles, D.Sc., F.G.S.

CHAPTER I.

INTRODUCTION.

The mineral tantalite is an ore of the two rare metals tantalum and niobium, or as it is frequently called, columbium. These two elements which are invariably found associated in nature were first discovered in 1803 and 1801 respectively. It was not, however, until about 1904 that the metals were prepared in a sufficiently pure state for their intrinsic qualities to be determined and (in the case of tantalum) to be utilised. From that time onwards the special physical properties of tantalum metal have gradually brought it more and more into demand in the industrial world.

However, although many interesting and important uses for tantalum have been proposed, its high cost of production and its comparatively limited world occurrence has so far restricted its use in commerce to those purposes not requiring large quantities of the metal. The preparation of pure tantalum oxides from its ores has always proved an intricate and expensive process because of the difficulty of extracting from it the associated and chemically very similar niobium oxide. Furthermore owing to the high melting point of tantalum metal and the readiness with which it absorbs large quantities of gases, special pains must be taken during the rather involved process by which the pure metal is produced from its pure oxide, and consequently its price must be expected to remain relatively high compared with many of the more common metals.

The twin metal niobium (or columbium) has not as yet achieved quite such distinction as tantalum in the commercial world, until very recently only small amounts of the pure metal having been prepared and consequently its intrinsic properties are less widely known. However in recent years several very important uses have been found for this metal, and since throughout the world deposits of niobium-rich minerals are relatively far more abundant in nature than those rich in tantalum, a fact which should encourage further investigations of its properties, it is probable that many new uses will be found, and niobium may be confidently expected to become of much increased importance in the coming years.

Tantalum has for many years been of particular interest and importance to Australians as Western Australia has been intermittently the world's chief and almost only source of high grade tantalum

ore since about 1905. Tantalum ores are also known to occur in the Northern Territory and Queensland, though there has been comparatively little production from these fields. Deposits of tantalum and niobium-bearing minerals have been found in a large number of countries outside Australia, including Bavaria, France, Finland, Greenland, Norway, Sweden, Russia, Spain, Madagascar, Nigeria, West Africa, South-West Africa, Southern Rhodesia, Union of South Africa, Uganda, Belgium Congo, Canada, United States of America, Brazil, India, Japan and the Malay States: but most of these occurrences are small and uncommercial, or more or less undeveloped. In recent years an appreciable tonnage of niobium-rich ore is reported to have been produced in Nigeria, and also small quantities have been mined in the Black Hills of South Dakota, U.S.A., whilst in 1937 when a phenomenal rise in the price of tantalum ores occurred, Uganda threatened to equal Western Australia in tantalite production, and at the present time the output of lower grade ore from both Belgian Congo and Brazil is said greatly to exceed that of Australia. Generally speaking however, the development of the world's deposits has not hitherto been carried out on account of the limited demand for the metals.

It has been the writer's endeavour, in the following pages to provide an account of the geology and distribution of all known occurrences of the more important tantalum bearing minerals in Western Australia, which will be a guide for the prospector and a source of information to quicken the interest of mining men in prosecuting a more intensive search for deposits of a rare and valuable mineral of which this State apparently possesses more than its share. At the same time it is considered that this account, supplemented by the details of mineralogy in Part 3 of this Bulletin, gives a more or less complete record of our present knowledge, admittedly very meagre in many places, of the occurrence, mineralogy, mining and production of the tantalum minerals of Western Australia. In order to make the descriptions of distribution in Chapter II. more intelligible to the technically untrained reader and to the prospector unfamiliar with the tantalum ores, brief notes on the more important tantalum minerals have been included below, but for more complete details of these minerals reference should be made to the appropriate sections in Part 3.

PREVIOUS LITERATURE.

A fairly complete list of all the important general and specific references in past literature to the tantalum and niobium bearing minerals of Western Australia, together with a few general references on the chemistry, property and uses of the metal tantalum, has been prepared in the bibliography at the close of this Bulletin. The writer

has drawn freely upon these works during the preparation of the following text, but wherever possible he has endeavoured to indicate the particular reference used, by the insertion of the appropriate index number in parenthesis.

It might be mentioned here that a large part of our existing knowledge of tantalum bearing minerals in Western Australia, as may be seen from the bibliography, is a monument to the interest and energy of the late Dr. E. S. Simpson who held the position of Government Mineralogist in this State from 1897 to 1939, and in whose honour a new tantalum mineral *simpsonite,* was recently named.

THE TANTALUM ORES.

Tantalum and niobium differ from most other metals in that their compounds with sulphur are not known. They are seldom found in the native state, the only known occurrences in the world being in the Altai and Ural Mountains, Southern and Central Russia respectively, where very small quantities of metallic tantalum containing niobium have been recognised in gold washings. They usually exist in combination with oxygen and one or more other metals, the oxides forming tantalates and niobates. In Nature as already stated, they invariably occur in conjunction, replacing one another isomorphously in varying amount, the tantalate of a metal often passing by insensible gradations into the niobate without change of external form or physical characters except for a corresponding gradual decrease in specific gravity, tantalum having an atomic weight double that of niobium.

The two most important and most commonly occurring tantalum ore minerals found in Western Australia are *tantalite* and *columbite,* the tantalates and niobates or columbates respectively of iron and manganese. The normal varieties contain more iron than manganese; but when the reverse is the case, i.e., manganese is in excess of iron (as is very common in Western Australia), these minerals are known as *manganotantalite* and *manganocolumbite* respectively.

Tantalum and niobium also occur in Western Australia in a number of rarer minerals, the most important of which, listed in approximate order or importance are—*tapiolite,* which is essentially a tantalate of iron and is free from manganese; *microlite,* a tantalate and niobate of lime; *simpsonite,* essentially a basic tantalate of aluminium and lime; *stibiotantalite,* tantalate and niobate of antimony; *ixiolite,* or cassitero-tantalite, a tantalate and niobate of manganese, often tin-

bearing; and tantalates and niobates associated with the rare earths yttrium, erbium and cerium, etc., viz., *fergusonite, yttrotantalite, euxenite* and *tanteuxenite,* and *samarskite.*

There are a number of other minerals containing minor amounts of tantalum and/or niobium in varying combinations found in Western Australia, but in these the total tantalum and niobium content is invariably so low and the minerals themselves are of so rare occurrence that they have never been considered as possible sources or ores of tantalum-niobium, and consequently need not be discussed here. Full details of all tantalum and niobium bearing minerals known in Western Australia will be found in Part 3 of this Bulletin.

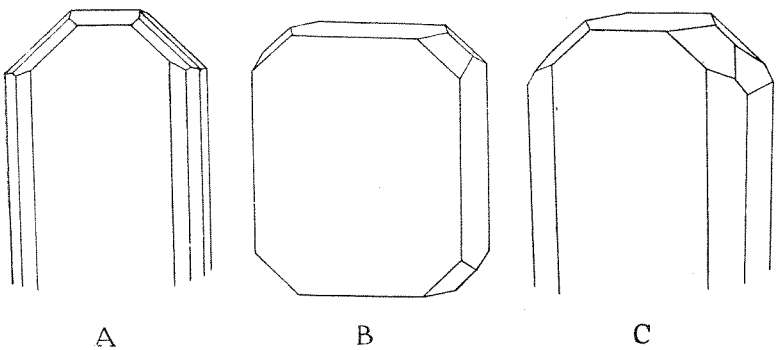

Fig. 2.—Tantalite-Columbite Crystals. A. Black Hills, South Dakota (After Dana). B. McPhee's Range N.W. (After Simpson). C. Wallareenya Station N.W.

Tantalite and *manganotantalite* are the most important ores of tantalum in those deposits which have been worked in Western Australia. None of the previously mentioned rarer minerals have been found to exist separately in workable deposits in this State, though each of the above listed minerals except the rare earth tantalates has been detected in limited quantities associated with one or other of the tantalite deposits which have been mined in the past. The rare earth tantalates are of very limited occurrence and distribution. All of the above minerals, where found in situ, i.e., in primary ore bodies, occur either in acid pegmatites, particularly those in which the predominating felspar is albite, or in quartz veins, usually in the neighbourhood of intrusive granite bosses.

Tantalite-columbite, including *manganotantalite* and *manganocolumbite* crystallises in the orthorhombic system, but is frequently found in more or less massive fragments showing little evidence of crystalline form. Where well crystallised, tantalite-columbite crystals usually have a prismatic habit, occurring either as short blocky rectangular prisms (see Fig. 3), or as comparatively thin tabular plates which may

show distinct pyramidal forms at one end, being irregularly broken at the other. Fig. 2 illustrates the faces developed in several typical forms of tantalite-columbite crystals whilst many other examples have been figured in Figs. 8 and 9 (see pp. 80, 81).

It is noticeable from specimens collected that in Western Australia single well crystallised crystals more commonly belong to the niobium-rich end of the series, i.e., are columbite rather than tantalite (see Fig. 4.) Quite frequently tantalite or manganotantalite occurs in aggregates of parallel twin crystals which may show well developed pinacoid, pyramid and basal faces (see Figs. 10 and 11). These

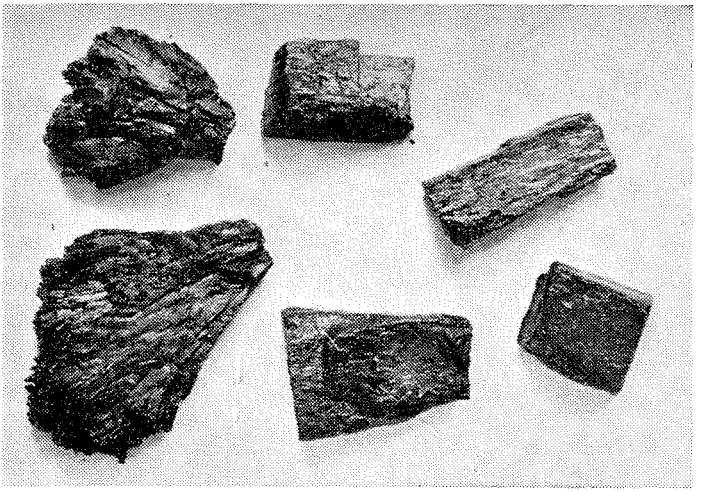

Fig. 3.—Fragments of Manganotantalite Crystals from Wodgina, N.W. Natural scale.

crystal aggregates are sometimes found in intersecting twins (see frontispiece), wedge shaped or fan shaped masses (see Fig. 12), or sometimes grouped in radiating fans or "rosettes" (see Fig. 3). Individual crystals in these groups are often vertically striated.

In the field the typical form of broken, or partly crystallised individual fragments of tantalite-columbite, whether from lode or detrital ore deposits, is an irregular blocky rectangular habit which often serves to distinguish them from associated more equidimensional fragments or otherwise similar looking-tin ore, cassiterite.

In colour Western Australian tantalite-columbite is usually pure black on clean, freshly broken surfaces with a brilliant submetallic

lustre.* Weathered surfaces (particularly of detrital ore) are usually stained a dark rusty brown colour, due mainly to a thin adhering film of ferruginous clay. The mineral is rather brittle and breaks with an uneven to subconchoidal fracture. It is fairly hard (H = 6) will scratch ordinary glass, is barely scratched by a knife but fairly easily by quartz, and has a dark grey to black streak.

Fragments of tantalite and manganotantalite are characterised by their heaviness, the exact specific gravity of any individual specimen depending upon its composition, i.e., the relative proportions of tantalum and niobium present. The specific gravity ranges from about

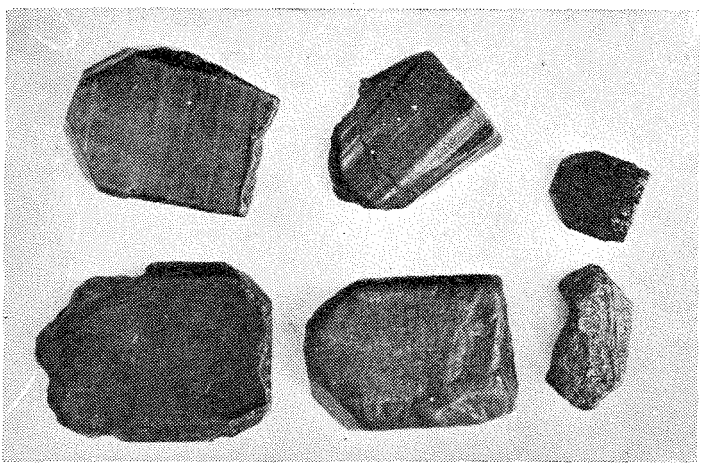

Fig. 4.—Manganocolumbite Crystals from Pilgangoora (McPhee's Range), N.W. Natural scale.

5.2 for pure niobate (columbite) to about 7.9 for nearly pure tantalate (tantalite) (see below).

In composition the tantalite-columbite series of minerals have the general forumla (Fe, Mn) $(Ta, Nb)_2O_6$ i.e., tantalite and columbite represent the end members of what is known as an isomorphous series of tantalates and niobates of iron and manganese, *tantalite* being the tantalate and *columbite* being the niobate, but in nature it is found that the series grade insensibly into each other. In Western Australia the absolutely pure end products are not known and the ores from different

*Mr. H. A. Ellis has recently brought to the writer's notice the observation that high grade tantalite and manganotantalite in Australia frequently has a rather steely grey-back colour on fresh broken surfaces whereas columbite and low grade tantalite is more commonly pure black in colour. There are many exceptions to this rule however.

deposits, and in some cases even from the same deposit, contain all gradations from tantalate-rich niobate-poor tantalites or manganotantalites to tantalate-poor niobate-rich columbites or manganocolumbites, respectively. Thus it should be understood that in the following pages, minerals described as tantalites may contain an appreciable quantity of niobium and columbites a considerable percentage of tantalum. Minerals containing over about 52 per cent. Ta_2O_5 are classified as *tantalites,* and when containing less than 52 per cent. Ta_2O_5 they are termed *columbites.* Small amounts of tin and tungsten are common impurities in tantalite-columbite concentrates.

In 1937 the late Dr. E. S. Simpson published a graph which may be used to determine fairly closely the actual percentages of tantalic oxides and niobic oxides present in any mineral of the tantalite group by means of the specific gravity of a specimen. This can be used equally well for specimens of either ferrotantalite or manganotantalite.

Writing of this graph Simpson says (69, pp. 24-5)—

> " . . . . . It has been repeatedly checked in the Government laboratory against analyses of actual crystals. The difference in molecular weight between the corresponding iron and manganese compounds is so slight, that the curves for the two series $FeTa_2O_6$—$FeNb_2O_6$ and $MnTa_2O_6$—$MnNb_2O_6$ are practically coincident.
>
> The specific gravity being an easily determined factor, the graph can be used as a means of determining rapidly and closely the composition of a crystal or pebble of a mineral of this series in respect of the metallic acids . . . ."

Fig. 5 is a reproduction of this extremely useful graph. A similar graph has since been prepared for the stibiotantalite-stibiocolumbite series and is reproduced in Fig. 13 (p. 116).

Tantalite-columbite is most likely to be confused in the field with tourmaline, wolframite and cassiterite (tin oxide), the last especially in alluvial deposits. Tantalite may be distinguished from tourmaline by its orthorhombic crystallisation, common short rectangular forms, submetallic lustre, and most particularly by its much higher specific gravity; from wolframite by its much less distinct cleavages (wolframite commonly occurs in plates or blades). A simple field test to detect the presence of cassiterite in a tantalite concentrate is as follows:—

Place the mineral sample (preferably in small grains) either in a zinc dish or on a watch glass to which zinc foil is added, and pour over the sample dilute spirits of salts (hydrochloric acid) sufficient to cover the sample. After a short while a dull light grey deposit of tin will form on any cassiterite present, but the tantalite will remain unchanged.

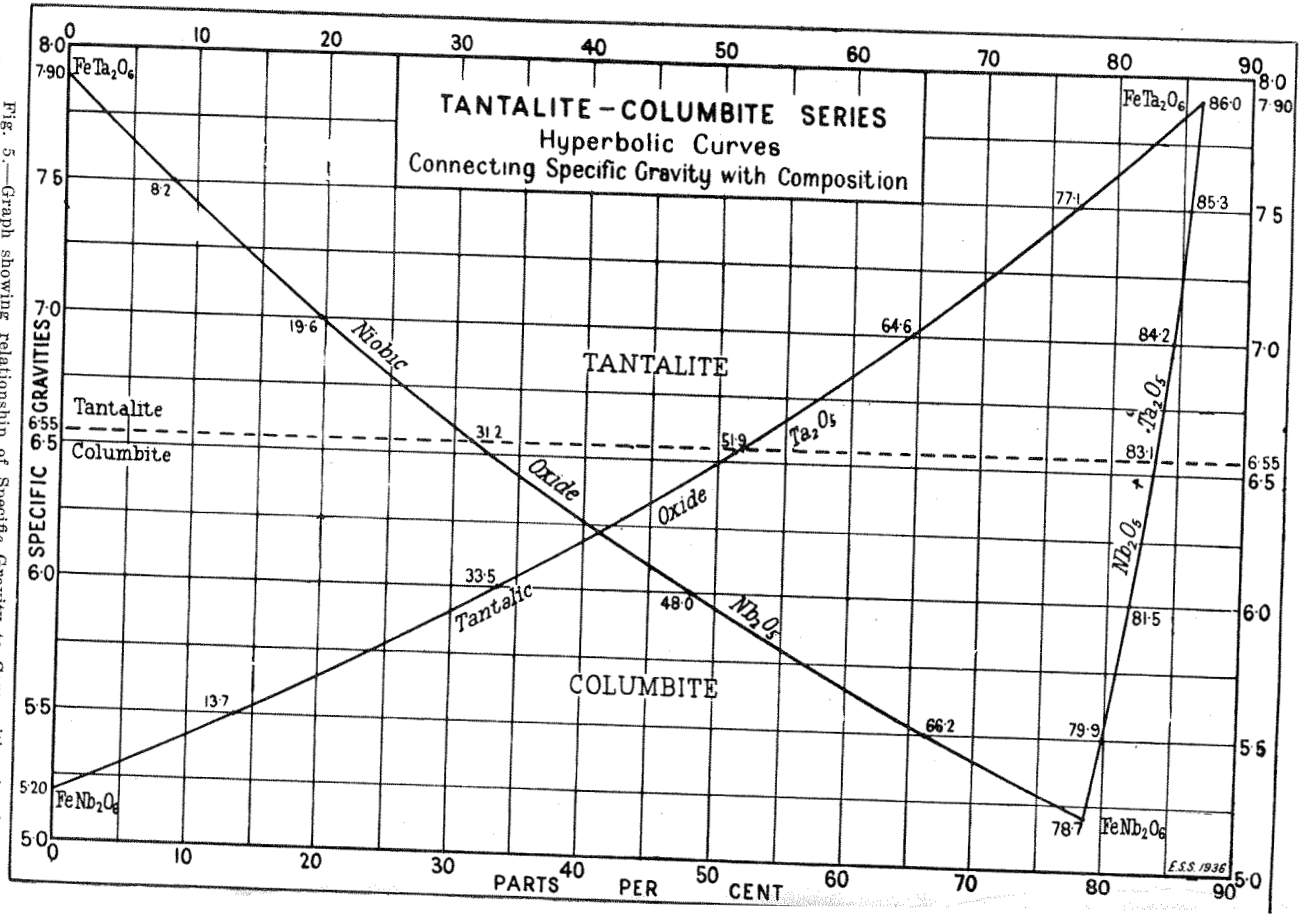

Fig. 5.—Graph showing relationship of Specific Gravity to Composition in the Tantalite-Columbite Series. (After E. S. Simpson.)

[Reproduced by courtesy of the Royal Society of W.A.]

In modern plant practice tantalite ore is separated from cassiterite in tantalite concentrates by treatment in an electromagnetic separator, tantalite being weakly magnetic and cassiterite entirely non-magnetic.

Tapiolite.—This mineral has the approximate composition $FeTa_2O_6$, though in nature a small amount of niobium and manganese is invariably present. It differs from tantalite chiefly in crystalline form as it crystallises in the tetragonal system, usually occurring in square, occasionally elongated, pyramidal crystals. The colour on fresh faces is pure black, and the mineral may easily be mistaken for cassiterite. It has a hardness similar to tantalite (H = 6) and specific gravity 7.3-7.8. Since this mineral contains an average of about 80 per cent. Ta_2O_5 it can be a useful source of the metal tantalum.

Tapiolite occurs associated with manganotantalite and cassiterite in very small quantities in alluvial or eluvial deposits in the Pilbara District of the North-West of Western Australia whilst a few specimens have also been recorded from Jimperding, South-West Division, (60) and from Greenbushes, South-West (70, p. 94).

Microlite.—This fluotantalate of calcium and sodium $CaNaTa_2O_6F$, which usually carries minor amounts of niobium, is said to crystallise in the cubic system and have an octahedral habit. The colour is reputed to range from yellow to brown. The only fragments so far found in Western Australia, however, have shown little evidence of crystallisation, but have usually been roughly rounded and waterworn. The colour of all specimens seen by the writer has generally been a light grey or buff colour to light pinkish brown, sometimes darkening to liver colour.

Microlite has a hardness of about 5.5 and specific gravity about 5.5-6. The approximate content of Ta_2O_5 in this mineral is about 68-70 per cent. It has been recorded from a number of localities in the Pilbara District of the North-West Division, and from Mt. Dockrell in the Kimberley Division, but only in very small quantities usually associated with alluvial or eluvial tantalite and cassiterite. In many cases the microlite from these localities has been found apparently intergrown with and partially replacing manganotantalite and tapiolite.

Simpsonite was described for the first time in 1939 (74) and named after the late Dr. E. S. Simpson, and is so far known in only one locality in the world, viz., Tabba Tabba in the Pilbara District, North-West. The composition has been determined as $2H_2O.CaO.5Al_2O_3.4Ta_2O_5$, i.e., a basic tantalate of aluminium and lime, containing over 70 per cent. Ta_2O_5.

X-ray studies (75) have shown that simpsonite crystallises in the hexagonal system. It usually occurs in small crystalline fragments having a hexagonal outline, and pronounced tabular habit, with fre-

quently a strong pyramidal development. The colour is usually creamy-yellow from alteration but freshly fractured surfaces often appear transparent and almost colourless. Surfaces are normally dull and lustreless. Specific gravity is 5.9-6.5. The composition of the cream coloured isotropic alteration product with which the simpsonite has invariably been found intergrown has not yet been thoroughly investigated but has been provisionally named *metasimpsonite*. Simpsonite has been found in situ in portion of a quartz-rich pegmatite which elsewhere carries normal manganotantalite. The total quantity so far separated amounts to only a few pounds weight.

Stibiotantalite is essentially a tantalate and niobate of antimony $(SbO)_2$ $(TaNb)_2O_6$, analysed specimens containing 51-57 per cent. Ta_2O_5 and approximately 40 per cent. Sb_2O_3 (67). It was the first tantalum-bearing mineral to be recorded in Western Australia, when it was identified in tin concentrates from Greenbushes, South-West Division, in 1893 (1). It has since been found in only two other localities in the world (Mesa Grande, California and Topsham, Maine, U.S.A.). Western Australian stibiotantalite seldom shows many traces of external crystalline form, being usually rounded and waterworn and occasionally cellular in structure. Colour and transparency are immensely variable. Some fragments are pale lemon yellow to amber coloured and perfectly transparent; others are commonly more or less opaque and ranging in colour from light yellow to grey brown or nearly black (17, p. 455), (67). The mineral crystallises in the orthorhombic system and has hardness H = 5.5 and specific gravity 6.4-7.5 (approx.).

Stibiotantalite has also been found at Greenbushes in minute veins and occupying vugs in masses of normal tantalite indicating that the stibiotantalite is a later formed mineral derived by interaction and replacement of earlier tantalite by antimonial solutions in the later pegmatite stages (67). No separate bodies of stibiotantalite lode are known and the mineral cannot on its own be considered as a commercial source of tantalum.

Ixiolite.—This mineral is now generally considered as related to (isomorphous with) the tapiolite series and to have an essential composition $MnTa_2O_6$, i.e., tantalate of manganese. In the past the term was applied to manganese tantalates which contained a notable amount of tin oxide (probably present as a mechanical mixture). It crystallises in the tetragonal system and has physical properties similar to *tapiolite*. Tin bearing ixiolite has been recorded from the Wodgina District, North-West (23, pp. 314-315). This is said to occur as indistinct crystalline aggregates with a resinous lustre and having a pale cinnamon brown to dark brown colour. Hardness is about 7 and specific gravity about 7.1. A mineral referred to ixiolite has also been recorded from Londonderry in the Coolgardie Goldfield (21), (33).

The occurrences at Wodgina and Londonderry are of mineralogical rather than commercial interest as the total quantity of the mineral recognised to date amounts to little more than a few scattered fragments.

The tantalates and niobates associated with the rare earths yttrium, erbium, cerium, lanthanum, etc., together with the radio-active uranium, are, because of their rarity, of considerable mineralogical interest, but up to the present time have nowhere been found in quantity sufficient to be of use as a source of either tantalum-niobium or of the rare earth. The total tantalum-nobium content of certain specimens of the rare earth tantalates found in the North-West has in some cases proved considerable, however, and consequently the attention of prospectors and others is here drawn to the existence of these little-known minerals in the hope that they will not be overlooked during the search for the more common tantalum ores.

The principal recorded rare earth tantalates as far as at present known occur almost exclusively in the Pilbara district of the North-West of Western Australia. The chief of these so far identified are *fergusonite,* a niobate (and tantalate) of yttrium, erbium, cerium, uranium, etc., in varying amounts—also iron, calcium, etc.*; *yttrotantalite,* a tantalate and niobate of iron, calcium and yttrium, erbium, cerium, etc., with some combined water; *euxenite* or *tanteuxenite;* niobate or tantalate respectively and titanate of yttrium, erbium, cerium and uranium; and *samarskite,* tantalate and niobate of iron, calcium uranium and the earths cerium and yttrium chiefly.

The rare earth tantalates are all characterised by a fairly high specific gravity (G. usually 5.5-5.9). They can hardly or seldom be scratched by a knife (H = 5.5—6.5). They are seldom seen in well crystallised forms but where crystals are well developed it is found that fergusonite crystallises in the tetragonal system, the others in the orthorhombic. They are usually brittle, having a conchoidal fracture, and freshly broken surfaces usually show a brilliantly vitreous to greasy resinous lustre. The colour may be yellow-brown to brown or black, though the only variety of samarskite so far found in Western Australia—a lime rich variety called *calciosamarskite*—is described as occurring in pebbles of greyish white colour (70, p. 94).

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* The original specimens of fergusonite identified and analysed by Dr. E. S. Simpson in 1909 were found to contain fairly high percentages (51-55%) Ta_2O_5. Simpson later considered this mineral to be yttrotantalite on account of its apparent orthorhombic crystallisation, and the much higher content of tantalum than niobium. Samples from the original material analysed were recently forwarded to Professor H. Berman of the Department of Mineralogy and Petrography, Harvard University, U.S.A., for X-ray examination. One of these has indeed proved to be a tantalum-rich end component of the fergusonite series for which Berman has proposed the name of "formanite." This name has been entered into the new edition of Dana's System of Mineralogy which is now going to press. Personal communication H. Berman to F. G. Forman. March, 1943.

Little is known regarding the field occurrence and associations of the rare earth tantalates in Western Australia, most specimens identified having been obtained either from samples of tin and tantalite concentrates or from odd samples of alluvial pebbles sent in from time to time. Most of the material is of detrital origin though at least one specimen of so-called "fergusonite" has been recorded from a pegmatite lode formation at Cooglegong in the Pilbara district, North West Division (33, p. 49). Further details of the mineralogy and distribution of the rare earth tantalates are available in Part 3 of this Bulletin. (See Table III).

TESTING TANTALUM ORES IN THE FIELD.*

In the preceding section a brief description has been given of the principal tantalum-niobium bearing minerals met with in Western Australia and some of the more important physical properties by which they may be recognised have been enumerated. The following notes are intended to indicate the methods which may be applied by the prospector and mining man in the field to test both individual specimens and small samples of concentrates reasonably suspected of being tantalum ores.

For Tin Ore.

Firstly assuming the specimen or sample to be heavy, black in colour with a submetallic to subvitreous lustre on fresh broken surfaces, and to be as hard as or harder than a knife, it is advisable first to test for the presence of tin oxide (cassiterite) according to the method outlined above (see p. 15). Care should be taken that all fragments of mineral should be in direct contact with the zinc and all fragments should be washed as clean as possible before treatment. The liquid should be stirred occasionally. Brown tin oxide usually needs longer treatment than the black oxide. If the sample of grains treated is a representative sample from a parcel of concentrates it is possible by picking out the tin-covered grains to estimate by volume, or if a set of scales is available to calculate by weight the percentage of tin oxide in the original parcel.

For Magnetite.

Once the tin oxide has been removed it is advisable to treat the sample with a hand magnet, if this is available, to remove any grains of magnetic iron oxide, magnetite.

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*The following notes have been prepared by the writer in collaboration with his colleague, Mr. H. A. Ellis.

Specific Gravity.

The remaining material which is *presumed* to be tantalite or columbite can only be further tested in the field by determining its specific gravity. To do this it is necessary to have some simple form of apparatus, of which a suitable type is the Walker's Steelyard. Two forms of this instrument are illustrated in Fig 6. It consists essentially of a long, light, graduated beam (say one foot to 18 inches) which is pivoted at X near one end and in the first type of instrument is counterbalanced by a heavy weight suspended to the short arm (see Fig. 6A). The specimen is suspended by cotton or very thin thread and moved along the beam until it counterbalances the constant weight (at position Y say). The reading (a) on the graduated scale at Y, (*i.e.,* the distance XY) is taken. The specimen is then totally immersed in water and moved along the beam until the constant weight is again balanced (at Z). A second reading (b) (XZ) is then obtained. Since (a) and (b) are inversely proportional to the weights of the sample in air and in water respectively, the specific gravity

$$G = \frac{1/a}{1/a - 1/b} = \frac{b}{b - a}$$

Therefore the second reading (b), divided by the difference between the second and first readings (b — a), gives the specific gravity. This type of apparatus which can be very simply constructed is particularly adapted to determine the specific gravity of relatively large individual specimens of a mineral.

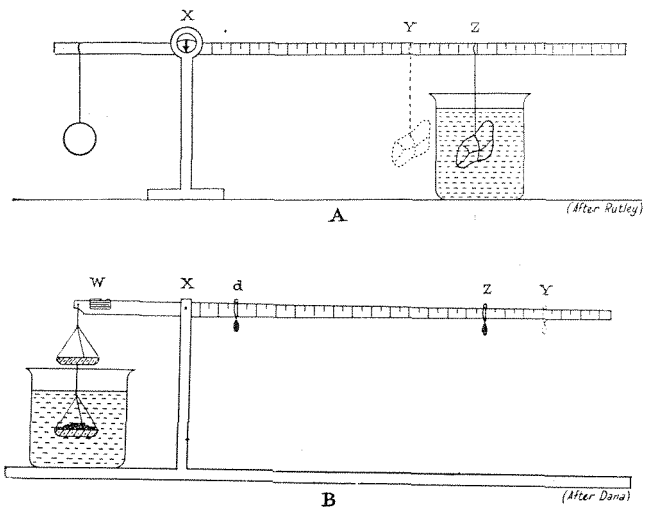

Fig. 6.

The second type known as the Beam Balance, illustrated in Fig. 6B is a rather more refined piece of apparatus which is useful for testing not only individual specimens but also samples of comparatively small grains of mineral. In this the constant heavy weight on the short arm is replaced by two small metal trays suspended one beneath the other and connected by a single wire. The long arm of the beam is usually tapered somewhat and a weight W is attached to the short arm in order very nearly to balance the system when the lower pan is immersed in water. An exact balance is then obtained by moving the small rider weight D which is then kept stationary and its position disregarded in the subsequent readings.

To obtain the specific gravity the mineral is first placed in the upper pan and with the lower pan still immersed in water the beam brought to balance by moving a small weight near the outer end of the beam to position Y. The reading (a) (*i.e.,* the distance XY) is then taken. The mineral is then transferred to the lower pan (immersed in water) and the beam again balanced by moving the same weight back to Z. The second reading (b) (XZ) is then noted. The specific gravity is then $G = a/(a - b)$, *i.e.,* the first reading (a) divided by the difference between the first and second readings (a — b) gives the specific gravity.

When carefully carried out determinations of specific gravity by this method can be quite accurate. Care must always be taken, however, that the material to be tested is clean, dry and free from other minerals.

To construct either a Walker's Steelyard or a Beam Balance in the field should not be beyond the powers of the ingenious prospector or mining man. The beam should swing very freely about its pivot. The graduations may be on any convenient scale, though subdivision into inches and tenths of inches is probably most suitable. Pans for the Beam Balance should be about two to two and one-half inches in diameter, the lid of a cocoa tin making a pan of convenient size. A small hook should be soldered to the bottom of the upper pan or a thin wire attached through its centre by some other means, in order to suspend the lower pan.

Use of Graph.

The specific gravity of the tantalite-columbite mineral having been satisfactorily determined (it is advisable to make several check determinations for each specimen or sample), it is now possible to estimate the approximate tantalic oxide content by means of the graph (Fig. 5) mentioned above (p. 16). If the determined specific gravity is less than about 5.2 it is probable that the mineral is not a tantalum-niobium ore. If the specific gravity lies between 5.2 and 7.9 the percentage composition of tantalic and niobic oxides can be read off by

drawing a horizontal line through the graph so as to pass through the left hand scale at the required figure for G. This line will then intersect at one point, each of the curves for tantalic oxide and niobic oxide. By drawing vertical lines downward from these two points on the curves to the horizontal scale graduated in parts per cent. at the foot of the graph it is possible to read off directly the corresponding percentage of tantalic oxide and niobic oxide present in the mineral. For example if the specific gravity of the sample tested was 6.55 the composition would be approximately 31.5 per cent. Nb_2O_5, 51.5 per cent. Ta_2O_5. Minerals with specific gravity higher than 6.55 are called tantalite or manganotantalite, and are called columbite or manganocolumbite respectively if the specific gravity is less than 6.55. The steep curve on the right hand side of the graph gives the total percentage of tantalum + niobium oxides present in any mineral of the tantalite-columbite series having a known specific gravity.*

Sampling.

The preceding notes have indicated the methods whereby it is possible to test, in the field, the value of either an individual specimen or a small sample of tantalum ore. Checking of individual specimens of tantalite-columbite mineral, whilst very useful to the prospector in helping him to identify the mineral for which he is seeking, is however quite useless as a means of estimating the value of a deposit, whether of lode or detrital tantalite. Attempted quantity estimates based on tests of selected fragments too frequently result in disappointment and loss to prospectors.

In order to guard against this it is necessary to take *"representative" samples* whether for field tests or for assays, of all parcels of concentrates obtained from the deposit, be it alluvial, eluvial or lode. A "representative" sample is a small proportion of the original bulk, containing, in unchanged percentages, all constituents of the original lot.

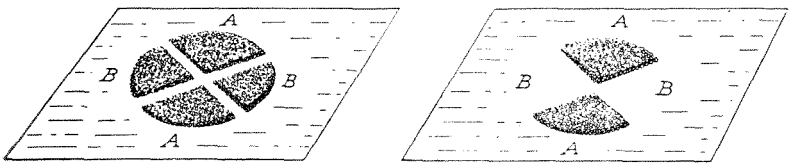

Fig. 7.—How a Sample should be Quartered.

*It should be clearly understood that this graph only applies to those minerals which are unaltered members of the tantalite-columbite or tapiolite series. The correct Ta_2O_5 content of specimens of microlite, simpsonite, or of tantalite, etc., containing alteration products, cannot be obtained from the specific gravity by the use of this graph.

Providing individual parcels of concentrates are not too large the most accurate method of obtaining true representative samples is by the method of quartering down. Before quartering down, it should be seen that the ore is broken down to pieces of an even grade and well mixed. Quartering down means that the broken material, after mixing, is piled into a cone on a floor of cloth, and that the cone is flattened and subdivided into four equal parts by two cuts at right angles. If the ore is sufficiently broken and mixed, the sample obtained by taking the two opposite quarters AA, has a value equal to the rejections BB, as illustrated in Fig. 7. At each quartering care should be taken to sweep all rejections away. By successive finer crushing and quartering a sample of about ¼ to ½ lb. of concentrate should be obtained. It is usually essential, in reducing a large sample, that the lumps of ore be broken smaller by about a half between each quartering. This is particularly the case with concentrates obtained from the lode material. In carrying out the routine tests for cassiterite, etc., described above it is not practicable to use more than about a 2-3 oz. sample.

When sampling parcels of detrital tantalite concentrates it may be advisable to sift the product into a number of different grade sizes and then to quarter down each grade size and test the samples in the manner outlined above, separately. Knowledge of the relative values of different grade sizes of his concentrates may assist the prospector materially in working out the best method for treatment of the deposit. Final sale of all concentrates will, of course, in most cases be dependent on the results of laboratory assay.

CHAPTER II.

DISTRIBUTION IN WESTERN AUSTRALIA.

INTRODUCTION.

The first record of a tantalum-bearing mineral occurring in Western Australia was made in 1893 when stibiotantalite was discovered at Greenbushes (1-5). In 1900 tantalite was detected in the Geological Survey Laboratory, in some of the alluvial ores from the Greenbushes Tinfield (9); manganotantalite in 1904 in material sent from Wodgina; and in 1905 manganocolumbite, and calciotantalite (or microlite) from Wodgina and Mount York (Chingamong) about 20 miles east of Wodgina (now known as McPhee's Range). Since those early days, and following upon the discovery of the tantalum filament electric lamp first made by Siemens and Halske in 1905, and upon the various experiments later made with tantalum-steel alloys, the search for tantalum bearing minerals in this State became greatly stimulated, due to their suddenly enhanced commercial value.

As a result, many new deposits of tantalum ores were found, opened up and tested, whilst many new records of the discovery of mineral species were made. Later again, however, following a slump in tantalum prices from about 1910 to 1925 interest in the tantalum ores waned considerably. Towards the close of the nineteen twenties interest again revived with the discovery of further uses for tantalum in commerce, and from that time onwards up to the outbreak of the present war both mining and prospecting for tantalite have continued intermittently, and our records of new minerals and new mineral localities have steadily increased.

The most usual primary occurrence of the mineral tantalates and niobates throughout the world is in pegmatite veins, as already mentioned, especially those characterised by the presence of abundant albite, and so far the Western Australian deposits appear to provide no exceptions to this rule. In these veins the tantalum minerals are commonly accompanied by quartz, microcline and mica (lepidolite and muscovite), as well as albite, whilst garnet, zircon, topaz, beryl, monazite, cassiterite and tourmaline, and other less common minerals are often present.

Most native tantalates and niobates offer considerable resistance to chemical change, and, being in addition both heavy, dense and hard, and consequently highly resistant to abrasion, are of frequent occurrence in residual detrital deposits, both alluvial and eluvial. These have no doubt frequently been overlooked in the past except in such

areas where gold or tin have been sought. The detrital tantalite deposits of Western Australia have so far yielded the bulk of the State's tantalite production.

The following is a fairly complete list of the general localities from which specimens of the more important tantalum and niobium bearing minerals such as were described above, have so far been recorded in Western Australia. These localities have been arranged according to Divisions running from north to south (see Plate I), and subdivided where necessary into districts, viz.:

Kimberley Division.

Mt. Dockrell, Collier Bay.

North-West Division.

Pilbara District: Strelley, Tabba Tabba, Wodgina, West Wodgina, Kangan, Stannum, Pilgangoora (McPhee's Range and Green's Well), Moolyella, Mt. Francisco, Abydos, Woodstock, Hillside, Eley's, Cooglegong, Split Rock.

Gascoyne District: Yinnietharra, Mooloo Downs, Dalgety Downs.

Murchison District: Coodardy, Poona.

East Murchison District: Kathleen Valley.

South-West Division.

Melville, Lake Moore-Lake Monger, Jimperding, Mt. Dale, Greenbushes, Balingup (Ferndale), Smithfield, Ravensthorpe.

Central Division.

Coolgardie District: Londonderry (Fraser's Find and Tantalite Hill or Mercer's Find), Victoria Rocks, Gibraltar, Ubini, Larkinville, Logan's Find.

Yilgarn District: Holleton.

Eucla Division.

Dundas, Norseman, Fraser Range, Bellinger (Israelite Bay).

It cannot be too strongly stressed that the foregoing is a list of the localities from which *specimens* of tantalum and niobium-bearing minerals are reported to have been obtained—but this does not mean that commercial quantities of the minerals are known to be available at all these localities. Indeed workable deposits of the tantalum ores are limited according to our present knowledge, to less than half a dozen of the above localities, whilst as will be seen in the following pages, for a considerable number of the remainder the known total amount of material obtained has been little more than a mere handful of specimens, or in some cases only to one or two crystals or fragments of crystals.

The most important area for the recovery of tantalum ores in Western Australia is the Pilbara District of the North-West Division (see Plate II.), a few centres of which viz., Wodgina, Tabba Tabba, Strelley and McPhee's Range, have up to the last few years been supplying almost the entire world market for high grade tantalite. There has in the past also been a small production of tantalum ores from Greenbushes, whilst with a revival of active mining in the district in the last few years further small parcels of ore are being obtained.

As has already been pointed out in the foregoing chapter there are only a limited number of known tantalum bearing minerals sufficiently high in the rare metals to be mined as ores in Western Australia and of these manganotantalite is by far the most important. The chief minerals mined at the various localities have been:—

North-West Division—Pilbara District—

Wodgina: Manganotantalite, manganocolumbite, microlite.
Strelley: Tapiolite, manganotantalite, microlite.
Tabba Tabba: Manganotantalite, manganocolumbite, simpsonite, microlite.
Pilgangoora: Manganotantalite, manganocolumbite, columbite, microlite, tapiolite.

South-West Division—

Greenbushes: Tantalite (tapiolite), stibiotantalite, columbite.

Central Division—

Londonderry: Manganotantalite, manganocolumbite, ixiolite.

It is possible that in one or two of these localities (particularly Mt. Francisco and Pilgangoora in the Pilbara District) columbite or manganocolumbite may be obtainable sufficiently high in niobic oxide to be mined as an ore of niobium alone but so far prices have been such that there has been little inducement to mine such ores (see Chap. III.).

KIMBERLEY DIVISION.

Mt. Dockrell, East Kimberley.—Official reports have recorded the presence of tantalite associated with tin in alluvium obtained from an area to the east of Mt. Dockrell, East Kimberley (70, p. 94), and sometimes referred to the north end of Cummins Range (17). This is probably the same locality as Bren's "Tin Show" lying at the head of Willy Willy Creek, about 9 miles south-east of Mt. Dockrell. Blatchford, in a report published in 1929* described this as an area of Pre-Cambrian Mosquito Creek Series, mica schists and phyllite, etc., crossed and recrossed by more recent basic dykes and pegmatites. Small quantities of stream tin and tantalite occur in some of the narrow

*Blatchford, T. "Bren's and Lidster's Reported Tin Lodes, 9 miles south-east of Mt. Dockrell." Ann. Prog. Rept., Geol. Surv., W.A., 1929, pp. 9-10.

gullies joining the upper courses of the Willy Willy Creek, but as these courses are invariably narrow, it is doubtful if any large deposits of alluvial would be available here. A sample of one of the pegmatites exposed by prospectors yielded negative results for both tin and tantalite. Samples from this area, reported in 1927 and 1937 respectively were found to contain tantalite (77 per cent. Ta_2O_5) (46) and manganocolumbite intergrown with microlite (70, p. 94).

This area was further sampled and reported on by K. J. Finucane of the Aerial Geological and Geophysical Survey of Northern Australia in 1938 (79). The various pegmatite dykes were mapped and tested and alluvium from any creeks adjacent to these dykes was tested by pits and the wash sampled. The concentrates from these samples were assayed and found to contain cassiterite and manganocolumbite. Samples from four of the principal creeks yielded—

Cassiterite, per cent.	75.8	70.7	7.4	61.8
Manganocolumbite, per cent. ..	24.1	26.9	87.2	33.6

The amount of wash available however is reported to be very limited, whilst the calculated content of concentrate in the wash was also low, the yield in lbs./cubic yard for the four samples being 0.93, 0.32, 0.10 and 0.17 respectively. Furthermore most of the tantalum mineral was manganocolumbite comparatively low in tantalite oxide. No tantalite or columbite was found in the pegmatite dykes knapped.

Collier Bay, West Kimberley.

The only official record of this comes from the Mines Department Chemical Branch Report, 1929 (55), which states, "Saleable ore assaying 68 per cent. of tantalic oxide has also been reported as coming from the proximity of Collier Bay in the Kimberleys."

This is the same district as that described by C. M. Harris in 1930 (56) in a report on prospecting in the north-west of Western Australia by the Kimberley Exploitation Syndicate. This writer states that rich floaters of lode tin and alluvial tantalite were found along a narrow coastal belt of mineralised greenstone country extending south-eastwards from Water Point copper lode (which lies at the south-western end of Yampi Sound, West Kimberley) for a distance of about 30 miles.

NORTH-WEST DIVISION.

Pilbara District.

The first records of tantalum ores in this now world famous mineral district were made in 1904, when manganotantalite was detected in a parcel of tin concentrates sent to the Government Laboratory from Wodgina. Since that time the district has yielded an amazing variety of rare mineral species including several minerals so far found nowhere else in the world. Apart from the different varieties of tantalum and niobium ores described above, variable quantities of the ores of such

rare metals as lithium, beryllium, yttrium, cerium, and the other rare earths, thorium, vanadium, uranium, radium, rubidium, caesium and zirconium, not to mention minerals of the better known metals tin, antimony, lead, bismuth, tungsten, titanium, molybdenum, iron, gold, manganese, etc., have been obtained from this district.

Wodgina.

The Wodgina area may be said also to embrace the West Wodgina and Stannum groups of workings, about 3 miles west and 8 miles south-west of Wodgina respectively. Wodgina is situated about 70 miles by road due south of Port Hedland. The general geology of the Wodgina district was first described by A. Gibb Maitland in 1905 (11, p. 8) (18, pp. 256 *et seq*) and in 1938 the field was re-mapped by members of the Aerial, Geological and Geophysical Survey of Northern Australia (80). This and neighbouring centres were briefly inspected by the present writer late in 1942.

The Wodgina hills form a rugged range consisting of highly folded and steeply dipping banded ferruginous quartzites, banded quartzites and slates, interbedded with basic lava flows (greenstones) now metamorphosed to amphibolites and amphibolite and chlorite-schists, all members of the Warrawoona (Pre-Cambrian) Series. These rocks are intruded by some granitic dykes and abundant pegmatite dykes and quartz reefs, which are probably apophyses of the granite which constitutes the bulk of the surrounding flat plains, covered by sand and alluvial soil, and strewn with spinifex grass and sparsely dotted shrubs and small trees.

The tin and tantalum ores in this district occur in many of the pegmatite dykes and in the detritus, soil and alluvium, immediately surrounding them. These dykes are very irregular both in width, length, strike and dip, and some are more persistent than others; they vary from mere threads to veins over 500 feet wide whilst their dip or underlie has neither any prevailing angle nor direction. Finucane and Telford (80) point out that the majority of the pegmatites occurring in the banded ferruginous quartzites are tin bearing whilst tantalite tends to be confined to those dykes intruding the basic lavas and other members of the greenstone series.

The main tantalite-bearing lode is situated some half a mile northeast of the old Wodgina townsite. It extends roughly north and south over a length of more than 2,000 feet and appears to be a fairly continuous body. It dips at approximately 40° to the east and in true width ranges from less than 10 feet to more than 35 feet. At its extreme southern end the lode disappears below the alluvium of an east to northeast running creek, tributary of the Turner River, known as McCarthy's Creek.

Prior to 1929 the bulk of the tantalite obtained from this locality consisted of detrital ore sieved from the alluvial of McCarthy Creek and obtained from the surface soil and sloping ground surrounding the lode, by dryblowing. Much coarse detrital tantalite was obtained in this way, Maitland recording that pieces as much as 35 lbs. weight were "not uncommon" (18, p. 274).

The Main Tantalite Lode is composed of coarsely crystallised albite with irregularly distributed bunches of quartz, microcline and lepidolite and occasional pale green mica. It is enclosed on both sides by greenstone (actinolitic amphibolite). In the central portion of the dyke, in the worked zone, the lode contains a central granitic lens dividing the more highly felspathic parts. Manganotantalite is distributed somewhat sporadically throughout the lode but in the central worked zone is confined almost exclusively to the felspathic portions. It occurs in irregular fragments of all sizes, usually ranging from one to 5 lbs. weight, though Maitland records that one large piece obtained in 1905 weighed about 5 hundredweights (18, p. 274).

At the northern end of the Main Lode, and some 180 feet east, is a large irregular mass of pegmatite apparently not connected with the main lode. Here in contrast to the Main Lode, manganotantalite is found in a finely divided state associated with segregations of a pale greenish coloured mica in a more granular granitic type of pegmatite.

Manganotantalite is almost the sole tantalum mineral found in this lode though it has been recorded that occasional traces of microlite replacing the tantalite have been found (17, p. 450). An important feature of this manganotantalite is its remarkable consistency of composition within very narrow limits throughout the lode formation. From the assays of a large number of samples taken over many years Dr. Simpson has shown that the average composition of the minerals is:—(47, p. 224).

	Per cent.
Tantalic oxide Ta_2O_5	68
Niobic oxide Nb_2O_5	15
Manganese oxide MnO ..	13
Iron oxide FeO	2

Complete analyses of typical ore are given in Part 3. (See Table VIII., p. 92.)

Other minerals associated with the tantalite in different portions of the Main Lode include spessartite (manganese garnet), which is occasionally found intergrown with the tantalite, lithiophilite, a phosphate of lithium and manganese (often altered to a mixture of

purpurite and psilomelane), gahnite (zinc spinel) and the rare radioactive thorium and uranium bearing minerals maitlandite, nicolayite, pilbarite and hydrothorite. Greyish white caesium-bearing beryl (rosterite) is abundant in large lumps intergrown with felspar in some portions of the lode, particularly the southern and northern ends, but shows no definite association with the tantalite. In the northern end of the workings can be seen blocks of fine grained massive scaly lepidolite (lithium ore) enclosed in the pegmatite, but this mineral also is not an obvious constituent of the tantalite bearing portions of the lode. Tin ore (cassiterite) is conspicuous by its absence in this lode. This fact, the absence of titanium and the remarkably uniform grade of the manganotantalite from the Main Lode, have made this the most highly valued deposit of tantalum ore known.

Immediately east of the southern end of the Main Lode however is a narrow tin-bearing pegmatite dyke which runs in a north-northeast—south-southwest direction. Alluvial shed from this dyke somewhat contaminated the tantalite which was mined along McCarthy's Creek at the southern foot of the main tantalite workings.

Shallow surface workings on the Main Lode consist of open cuts, trenches and pot holes, and extend along the lode for a total length of about 1,500 feet. The main underground workings cover a length of about 480 feet, occurring in two groups separated by a northwest-southeast fault in the lode which has thrown the southern workings about 60 feet to the west.

In the South Workings the lode has been mined to a mean vertical depth of 26 feet, at the northern end of which the workings are mainly on the footwall or felspathic portion whilst further south the pegmatite is all felspathic. The lode has been displaced at the southern end by a north-south fault dipping 48° west and by a small northeast trending fault which dips southeast at 45° (80).

In the North Workings the hanging wall felspar has been mined to about 30 feet and the footwall to 12 feet. An underlay shaft has been sunk to a vertical depth of 64 feet on the footwall felspar and a crosscut extends 35 feet east to cut the hanging wall felspar. This is the greatest depth at which the lode has so far been exposed.

The most important working on the northern end of the lode is an adit driven from the northern side of the hill along the hanging wall section (50, Fig. 2, p. 458). A considerable amount of stoping has been carried out from this adit, and some rich tantalum ore obtained. This was the site of the discovery of pilbarite and the other uranium-thorium minerals.

To the writer, from his inspection of the workings at Wodgina in 1942, it was quite apparent that there had been so far little attempt

to institute a programme of continuous mining and development of the lode. From 1925-29 the lode and adjacent alluvial deposits were worked by a syndicate of which Young and Moulden were the principals. During this period a total of about 70 tons of tantalite, mostly alluvial or detrital, was produced. From 1931-42 the mine was controlled by the company Tantalite Ltd., and up to the outbreak of war efforts had been made to produce regular parcels of ore (mostly lode). The very erratic nature of the tantalite market, the difficulty of obtaining steady contracts and the sporadic distribution of the tantalite in the lode itself have no doubt all combined to justify this company in not attempting any systematic development. What has amounted virtually to surface mining of a number of rich shoots, together with treatment of material derived directly from the disintegration of outcrops of these shoots, has in the main been sufficient to provide enough ore to fill the company's intermittent contracts.

It is probable, therefore, that there is still a great deal of tantalite yet to be obtained from this lode. The ore body is large, continuous, and has yet to be thoroughly tested below the surface. This can only be done by underground mining development. It is to be hoped that the world demand for tantalum will be sufficiently stabilised in the future for this development to be carried out, when, by treatment of large quantities of possibly low grade lode-stuff it should be possible to maintain for some time a steady output of tantalum ore from this deposit.

A number of other pegmatite dykes or lodes are said to contain tantalite at Wodgina. About a mile north-north-east of the main tantalite lode on M.C. 140 is a spessartite-studded albite pegmatite dyke about 40-50 yards long and about five feet wide running a little west of north. Microlite or "grey tantalite," in addition to manganotantalite, has been obtained from this dyke and from the soil and detritus sloping down to the east of the lode. Little work appears to have been done on this lode however.

To the west and north-west of the main lode are other small pegmatites, some of which are reputed to carry tantalite, but there is little sign of them having been worked in the past. An inspection was made by the writer of an occurrence of tantalite associated with spodumene in a pegmatite lode in banded quartzite country. This lode is situated at the head of a steep east-running gully near the north-west corner peg of the late Terra Nova M.L. 352, about quarter of a mile south-east of Mt. Tinstone Cairn ("Captain Kettle's Trig."). This lode has not been opened up extensively, its isolated position and relative inaccessibility from the main tracks no doubt deterring many prospectors.

West Wodgina lies on the western slopes of the Wodgina hills. Both tin and tantalite bearing lodes are reputed to occur here. Thin, comparatively short pegmatite dykes can be traced here and there scattered over a belt of several miles of country, running in a general north-south direction.

There are signs of several old workings in the northern portions of the belt but these are in tin bearing pegmatites and are all small. Very little alluvium has been worked here. Tantalite is reputed to occur in a few small workings in the southern end of this belt.

Tantalite has been recorded from alluvial tin concentrates from *Stannum,* an area which has recently been referred to as the Eastern Creek field, but the pegmatites from this locality are predominantly tin bearing, no lode tantalite to the writer's knowledge having been found *in situ.*

Tabba Tabba.

This small tin and tantalum mining centre lies about 40 miles south-east of Port Hedland and eight miles south-south-west of the 35-mile post on the Marble Bar railway. The main tantalite bearing lode here is a coarsely crystalline albite pegmatite dyke intruding greenstone (amphibolite) in an area more or less enclosed by granitic country. This dyke trends in a general north-westerly direction over a length of more than 1,500 feet, and has a width varying from about 40 feet up to about 150 feet. The pegmatite dips flatly to the east.

The main workings and the principal occurrence of tantalite in this lode is near its south-eastern end where there is a thick body of quartz underneath which is a thin facing of beryl which is itself underlain by several feet of highly felspathic material. The tantalite is found adhering to the beryl facing or irregularly scattered through the felspathic zone.

Just north of the main workings some cassiterite is found in portions of the pegmatite whilst north of this again is a micaceous tantalite-rich zone. Towards the northern end also, the heavy yellowish simpsonite is found in small fragments usually associated with bluish glassy quartz.

A mile to the north-west of the main workings are further pegmatite dykes containing microlite associated with tantalite, and about half a mile south of the main workings tantalite occurs with mica in a quartzose pegmatite (80).

A considerable amount of detrital (eluvial) tantalite has been obtained by sieving the soil and detritus surrounding these various pegmatite lodes. It has generally been found necessary, however, to treat the sieved concentrates under an electromagnet to remove the large percentages of associated tin ore.

The tantalum ore from Tabba Tabba consists principally of manganotantalite with lesser amounts of manganocolumbite, assays of concentrates indicating compositions ranging from 72 per cent. down to 36 per cent. tantalic oxide. Simpsonite and microlite represent useful "sweeteners." Dressed concentrates invariably carry a small percentage of cassiterite.

Strelley.

The existing tantalite workings at Strelley are approximately 40 miles east-south-east of Port Hedland, 6 miles S.E. of Strelley station homestead, and little more than a mile north of the Port Hedland-Marble Bar railway line. This centre was at one time called Tabba Tabba Creek. The country here is far less rugged than at Wodgina, the principal tantalite ore body consisting of a large pegmatite dyke intruding slates and chloritic schists, and forming a low ridge. The loam of the rubble-covered slopes flanking this ridge, which runs approximately N 20° E, has in the past yielded the greater part of the tantalite from this centre.

The pegmatite itself is lens-shaped and extends over a length of about 2,400 feet varying from less than 100 feet up to more than 700 feet wide in its central portion. The dyke is composed of a coarse intergrowth of crystalline quartz, albite, and pale greenish mica, and contains some large irregular bodies of quartz. The workings in this pegmatite are scattered over a length of approximately 1,000 feet and consist of irregular pot holes, trenches, open cuts and shallow shafts.

The tantalite within the ore body is very sporadically distributed, occurring usually associated with irregular lenses of greenish mica often in proximity to masses of quartz and frequently not exposed at the surface. The ore is mainly manganotantalite of good grade together with some tapiolite, occasionally intergrown with microlite. The tin content of concentrates assayed has usually been low.

It appeared to the writer that no systematic mining of the body had yet been attempted here, whilst workings in the open cuts were, at the time of his visit, considerably choked by residual mullock. The greatest depth to which workings have so far been taken is less than 20 feet. The dimensions of the pegmatite at Strelley are distinctly impressive, and despite the undoubtedly erratic occurrence of the tantalite within it, there appears every likelihood that systematic testing of its downward continuation should result in an extended tantalite production from this ore body.

About ½ mile north of the main workings are traces of tantalite in an alluvial flat, but very little work appears to have been done at this spot which is known as "Strelley Half Mile" (M.L. 344).

At about 2 miles north-north-west of Strelley are some old workings known as Cotton's Perseverance, in several pegmatite dykes surrounded by alluvium. Some high grade well crystallised tantalite containing up to 80 per cent Ta_2O_5 (tapiolite?) is said to have been obtained from here. Most parcels of tantalite (alluvial) have averaged about 55 per cent. Ta_2O_5 however, the ore being diluted by columbite and tin from other adjacent pegmatites. About 3 tons of tantalite is reported to have been obtained from this show.

Pilgangoora (Green's Well), McPhee's Range.

This belt of country lies about 14 miles east-north-east of Wodgina and consists of a series of steeply dipping amphibolite schists (greenstones) intruded by pegmatite veins, on the western slopes of a north-south range of hills (McPhee's Range). The pegmatites at Pilgangoora contain cassiterite, tantalite and columbite and a little microlite. A few miles further to the north-east in these hills gold has been found at McPhee's Patch.

The tantalum-bearing minerals were first found in the vicinity of Mt. Chingamong (now known as Mt. York) towards the southern end of the range as early as 1905, and since then prospectors have at various times claimed that fabulous quantities of tantalite are available from great lengths of lode at Pilgangoora. In a recent inspection, however, the writer found that the lodes are invariably narrow and often quite short and impersistent though scattered intermittently over a north-south length of more than 3 miles. Few of the pegmatite dykes in this belt of country have been systematically worked as yet, the bulk of the tin and tantalite production from the area having been derived from alluvial deposits in several of the larger creeks and from eluvial detritus on the slopes.

The tantalum content of the Pilgangoora ore apparently varies considerably, ranging from normal good grade manganotantalite down to manganocolumbite and ferrocolumbite. Samples assayed at the Government Chemical Laboratory are reported to show a range of from 24-53 per cent. Ta_2O_5 and from 56-30 per cent. Nb_2O_5 whilst individual pebbles from different parcels range from 7-81 per cent. Ta_2O_5 and from 72-4 per cent. Nb_2O_5. Such variations in tantalum content have made concentrates from here often much more difficult of sale in past years.* The columbites are frequently in a very well crystallised form (see Fig. 4). Other tantalum minerals from this centre include a little ferrotantalite, tapiolite and microlite. Tin-bearing lodes occur most abundantly in the southern end of the belt. In the northern end are considerable quantities of massive scaly lepidolite in one or

* With the existing urgent war time demand for tantalum ore containing as low as 30% Ta_2O_5 (see Chap. III.), this difficulty should not arise at the present time.

two dykes, whilst a certain amount of spodumene—sometimes actually enclosing tantalite grains—was noticed in some portions of the pegmatites.

The foregoing localities are all those from which tantalum ore has actually been produced in the Pilbara district. Tantalum-bearing minerals have been reported from the localities briefly mentioned hereunder, but it is doubtful if many of these can be considered as potential sources of supply.

Moolyella Tinfield.

This field, which includes the centres of Moolyella, Tadgebanna and Mud Springs, is situated in granite country traversed by very abundant quartz-albite pegmatite veins, of which a few are rich in tin ore, at about 10 miles east-north-east of Marble Bar. Alluvial gravel in the vicinity of these dykes has in the past been worked for tin. Samples of stream tin concentrates from this locality all show a small percentage (average probably less than 10%) of manganocolumbite with occasionally a little manganotantalite and some monazite (47). There is no record of tantalite having been obtained from the pegmatite in this vicinity.

Cooglegong-Eleys-Hillside.

This belt of tin-bearing country at roughly 30 miles south-west of Marble Bar stretches south from Pilga homestead, west of *Split Rock* to the vicinity of *Hillside* homestead (Plate II.). It consists principally of undulating granite country traversed by numerous small pegmatite veins and later epidiorite or dolerite dykes. The pegmatites in this area are occasionally tin-bearing and prospectors have here and there worked the alluvial gravel formed from the disintegration of such lodes. Tantalum and niobium-bearing minerals obtained as residues from alluvial tin are mainly fergusonite (formanite or yttrotantalite?) and tanteuxenite at Cooglegong and tanteuxenite at Eleys (47), (48), whilst microlite, yttrotantalite and calciosamarskite specimens have been recorded from the area lying west of Hillside Station (70). Fergusonite (formanite?) has also been recorded *in situ* in a pegmatite dyke on Trig Hill, Cooglegong (33).

Woodstock, Abydos.

Amidst rough granite ranges about 12 miles south of Woodstock homestead (which lies some 25 miles west of Hillside) a very small quantity of tanteuxenite has been found in pegmatite veins. Another occurrence of tantalum ore from this belt of country is reported from near the head of the Western Shaw River on pastoral lease 2591/96 at about 23 miles south of Tambourah. Samples from here are said to contain manganotantalite, columbite and some tapiolite altering

to microlite (see Part 3, pp. 122, 141). No details of geology or field occurrence are available. Further north, at about 10 miles south-west of Abydos homestead some detrital manganocolumbite has been found associated with gadolinite and monazite from an alluvial tin show (47). This occurrence is of mineralogical rather than of any commercial interest however.

Mt. Francisco.

Tantalum and niobium-bearing ore was first found in this locality in 1906, but it has so far proved of too low grade for commercial sale.* Mt. Francisco lies about 16 miles due south-south-west of Wodgina but 33 miles by road. Abundant manganocolumbite occurs in an albite pegmatite vein in granite about four miles east of Francisco Well. This is known as Hooley's Columbite Lode (47). Other minerals in the lode include beryl, lepidolite, quartz and microcline. Manganocolumbite is also abundant in the soil surrounding the outcrop. This may yet prove a commercial source of niobium ore. Assays of clean concentrates show:—(47, p. 224).

Tantalic oxide ..	maximum	51.9%	minimum	13.7%
Niobic oxide ..	maximum	65.9%	minimum	31.3%

Tanteuxenite associated with monazite has been recorded in tin concentrates from a find five miles south of Mt. Francisco.

Gascoyne District—*Yinnietharra-Dalgety Downs.*

There are several records in the publications of the Chemical Laboratory of low grade tantalum ore obtained from the vicinity of a bismuth mine on the west bank of Nardoo Creek, a south flowing tributary of the Gascoyne River, on Yinnietharra Station, situated in approximate latitude 24° 31′ S. and longitude 116° 03′ E. The area consists of a complex of gneiss and mica schist liberally invaded by coarsely crystalline pegmatite dykes, many of which are valuable as sources of commercial mica. Associated minerals of possible importance include bismuth carbonates, beryl and felspar.

Tantalum minerals recorded from Yinnietharra consist principally of the orthorhombic manganocolumbite (73), (77), though Simpson has suggested that a black angular pebble collected from near Morrissey Hill and analysed in 1922 probably represents the corresponding tetragonal species for which he suggested the name manganomossite (39). Assays of specimens taken from a parcel of 8 hundredweights of this ore gave Ta_2O_5 ranging from 48%-22%, and Nb_2O_5 35-38%, the mean being Ta_2O_5 34.5%, Nb_2O_5 47.2% (73). For further details of parcels see Part 3, p. 124.

*But on present prices (see Chap. III.) it is possible that ore from here would be saleable for its tantalite content.

Other samples of tantalum-bearing minerals sent in for identification from the Yinnietharra district are stated to have been located 30 miles north-east of Mooloo Downs Station south of Yinnietharra, whilst there is a record of tantalum-bearing ilmenorutile and struverite (see Part 3, p. 125), from 10 miles east of Dalgety Downs Station homestead (Plate 1) hence it would appear that the tantalum minerals may have a fairly wide spread distribution in this district.

Murchison District—*Coodardy, Poona.*

These two old mining centres lie at approximately 17 miles and 35 miles respectively north-west of Cue in the Murchison Goldfield. Geologically the areas are very similar, consisting essentially of Pre-Cambrian rocks—greenstones, made up of metamorphosed basic igneous and sedimentary rocks now amphibolite and mica schists, with quartzites, etc., invaded by granite, porphyry, pegmatite and quartz reefs, and occasional later dolerite dykes.* Some of the quartz reefs in these areas are auriferous whilst many of the pegmatites are tin-bearing.

In the Coodardy district the goldbearing lodes are confined to the southern end at what has now become the Big Bell goldmining centre. Tin-bearing albite pegmatite lodes at Coodardy occur about 2 miles north of Big Bell. These form a series of interlacing dykes, half a mile in length and about four chains in width intersecting amphibolite schist. A sample of detrital material (eluvial) gathered from the surface in the vicinity of the main lode system on late M.L. 13 "Coodardy," proved to contain a considerable proportion of manganocolumbite associated with cassiterite, epidote, and minor amounts of wolframite, scheelite, magnetite (34. p. 51).

Both tin and beryl-bearing quartz-felspar pegmatite veins are abundant at Poona. Very little lode mining for tin has been carried out here however, the principal source of tin being alluvial deposits in a small northwest-running creek in the southeast corner of the field on late M.Ls. 12, 19, 59 and 52.† Samples of concentrates from this creek were found to contain detrital manganocolumbite associated with cassiterite, wolframite, magnetite, etc., whilst both manganocolumbite and manganotantalite were recognised in a sample of detrital material obtained from near the cap of the "Great Eastern" lode in the northwest corner of the area (late M.L. 14). Other heavy minerals from here included cassiterite, iron ores, garnet and monazite. It is stated that the manganocolumbite could here largely be separated from

*Woodward, H. P. "A Geological Reconnaissance of a portion of the Murchison G.F. Geol. Surv. W.A. Bull. 57, 1914. Plates I-V.

† See plan accompanying report by Wilson, R. C. "The Beryl Deposits of Poona and Ferndale." Ann. Rept. Dept of Mines W.A. for 1925, pp. 81-3.

the detrital tin by the diggers in the field due to the fact that the columbite occurs in much larger pieces and therefore could be removed by sifting (34, p. 59).

East Murchison District—*Kathleen Valley.*

Whilst on a recent visit to the School of Mines, Kalgoorlie, the writer was shown some specimens of tin lode—cassiterite-bearing lepidolite-albite pegmatite, together with a small parcel of detrital crystals having the apparent form and physical properties of tantalite-columbite. These specimens had just been received from a prospector working in the Kathleen Valley district north of Mt. Sir Samuel. At the time there were no further details available regarding the deposit from which these specimens were alleged to have come. Further material stated to have been obtained from 2-2½ miles south of Kathleen Valley has since been received at the Government Chemical Laboratory and identified as manganotantalite (see Part 3, p. 98).

SOUTH-WEST DIVISION.

Melville (Noongal), Lake Moore-Lake Monger.

These two localities are both within the Yalgoo Goldfield. Melville is situated about 15 miles north-northeast of Yalgoo, the country consisting of Pre-Cambrian greenstones (amphibolites) intruded by granite and associated dykes of porphyry, quartz-felspar pegmatite and quartz. In the vicinity of Melville itself the country is remarkable for the intricate network of acid dykes with which it is traversed.* Minerals associated with the quartz and pegmatite veins include gold, scheelite, bismuth ores, molybdenite, corundum, ilmenorutile (see Part 3, p. 126) lepidolite, beryl, gigantolite and spessartite, andradite, grossularite and topaz. There is a brief record that samples of black pebbles from the outcrop of a topaz-bearing quartz-microcline-albite pegmatite just south of a place called The Basin at Melville were found to consist of manganotantalite containing 65% Ta_2O_5 (61, p. 61).

The only records of the Lake Moore occurrence are of four pieces of low grade tantalum ore (presumably columbite) reported to have come from between Lake Monger and Lake Moore, at the southern end of the Yalgoo Goldfield (33). No further details as to the locality or occurrence of these specimens are available.

Jimperding, Mt. Dale.

From these two localities situated about 33 miles northeast and 25 miles southeast of Perth respectively have come specimens of tantalum minerals which are of mineralogical interest. The Jimperding

*Clarke, E. de C., "Geology of Melville (Noongal), Yalgoo Goldfield." Ann. Prog. Rept. Geol. Surv. W.A. for 1919, pp. 25-6.

area consists of a series of interbedded highly metamorphosed sedimentary and igneous rocks, quartzites, gneisses, basic schists, micaceous schists and andalusite schists of Pre-Cambrian age, known as the Jimperding Series* intruded by granite and later acid dykes (aplites, pegmatites and quartz veins), and by still later basic dykes (dolerites). The quartz in at least one locality in the area is auriferous† whilst the pegmatites have been found to contain several interesting minerals including beryl, molybdenite and columbite (Prider, op. cit. p. 10). Columbite and tapiolite have been identified in black alluvial gravel from a tributary of the Jimperding Brook (60).

At about 5 miles northeast of Mt. Dale is a small beryl-bearing pegmatite intersecting granite, and from this pegmatite have been collected a few small fragments of euxenite and manganocolumbite (61, pp. 61, 2).

Greenbushes.

Situated in the extreme south-west corner of the State, the Greenbushes tinfield, whose centre lies some 42 miles south-east of Bunbury, was as has already been mentioned, the scene of the first discovery of tantalum minerals in Western Australia. The following notes have been compiled by the writer's colleague, Mr. R. A. Hobson, who, together with Mr. R. S. Matheson, has recently been engaged in a re-survey of the geology and mining in the Greenbushes tinfield:—

"The mineral field is portion of a laterite capped highland, which is dissected by numerous steep sided valleys. Basement rocks consist, in all probability, of metamorphosed greenstones (amphibolites) and sediments (gneisses and schists) intruded by numerous granitic dykes, which are frequently stanniferous and which occasionally contain tantalum minerals. Exposures of basement rock are very rare, but additional information has been gained as a result of mining operations.

"In addition to small amounts of recent alluvium associated with the existing streams, there are extensive areas of what has been called old alluvium, which is not associated in any way with the present streams. The mode of origin of this old alluvium is uncertain, but it is not improbable that it is a lake deposit. It belongs to a physiographic period prior to the present one. It is of economic importance since from it most of the alluvial tin has been obtained. The laterite extends over the old alluvium.

*See Prider, R. T., "The Geology and Physiography of the Jimperding Area." Jour. Roy. Soc. W.A. Vol. XX. 1933-4, pp. 1-6.

†Forman, F. G., "Lode Mining at Yinniding Creek, Toodyay District." Ann. Prog. Rept. Geol. Surv. W.A. for 1934, pp. 12, 13.

"The chief tantalum mineral from Greenbushes is high grade ferrotantalite containing up to 80% Ta_2O_5, while stibiotantalite occurs in minor quantities (16, pp. 112-3). Quite recently traces of tapiolite (70, p. 94) and ferrocolumbite (73) have been recorded in tin concentrates from the district. The total production of tantalite officially recorded to the end of 1941 is 3.94 tons, but it is probable that 10 tons would be a closer approximation (see Chap. III). Much of the tantalite produced in the early days of the field was not reported to the Mines Department. The total production since 1941 to the end of 1942 is approximately 1.5 tons (see footnotes, pp. 42, 43).

"The main production has been from the workings on "Enterprise," late M.L. 369, which is close to the Greenbushes-Bridgetown road and approximately one mile from Greenbushes. (Plates III and IV.) Both lode and alluvial tantalite have been obtained from these workings. The principal lode workings were inaccessible when inspected in 1942, but it is evident that quite a lot of work has been done since these workings were inspected by Campbell in 1905 (11, p. 18). It would seem probable that the main shoot has been worked to just below water level. The ore body was 18 inches wide and has been described (17, p. 453) as being a crushed rock (greisen) composed almost wholly of pale green mica with accessory quartz, tourmaline, cassiterite and tantalite in fragments from the size of sand up to an inch in diameter. According to descriptions given by old residents of Greenbushes, the tantalite occurred in more or less isolated patches, each containing up to 20 lbs. of tantalite. The strike of the ore body is given by Campbell (11, p. 18) as N. 37° W. and its dip as 22° S.W.

"Eluvial tantalite was obtained in the early days of the field from the west side of the road and later from a number of shallow pits on the east side. During 1942 there was some production from a shallow pit just east of the road. During June and July of 1943 the workings were extended across the road—special permission being given for this. These workings, which nowhere exceeded 12 feet in depth, produced the 1.5 tons of tantalite noted above. Assay information for all of the tantalite produced is not yet available, but most of it is believed to be of good grade. A parcel of 1,999 lbs. sent away in July, 1943, contained 73.5% Ta_2O_5. Most of the tantalite occurred in pieces having a diameter of half an inch or more, but some fine-grained concentrates were obtained by sluicing. Some large pieces of tantalite up to 52 lbs. in weight were found at the north end of the pit. The distribution of these suggests that they have not come from the lode on the west side of the road, but have been shed from a lode occurring under the road. At the time of writing (Aug-

ust, 1943) a strip of country extending from the road in a south-easterly direction towards the main gully is being worked by means of scoops. The material is being carted away and sluiced*.

"During July, 1943, approximately 30 yards of ore was broken from a lode in shaft B, which was reported to contain tantalite. (Plate IV.) The ore body is portion of what is evidently a large pegmatite dyke and contains very abundant tourmaline. The shoot, which strikes N 40° W and dips 40°-50° south-west, has been stoped over a length of 15 feet, over a width of from two to three feet and over a height of 12 feet. It is seen to be still in the floor of the drive, which is approximately seven feet above water level. A preliminary examination of the concentrates obtained as a result of sluicing showed that these consisted mainly of cassiterite (Government Chemical Laboratory number 7414). No assay information is available.

"Campbell (11) records that a little tantalite has been found associated with cassiterite on two leases—the 'Wills,' M.L. 370 and the 'Dill McKay,' claim 755—in the vicinity of M.L. 369. He also notes that some is reported to have occurred on M.L. 379, 'Galtemore.' There are two specimens of tantalite in the Geological Survey collection, which are reported to have come from this lease—one of lode tantalite and one of alluvial tantalite. It is reported that a micaceous lode containing tantalite was found at a depth of 40 feet in a shaft. M.L. 379 comes within an area of old alluvium† recently examined. Numerous shafts have been sunk in this vicinity, but only a few have bottomed on granitic material. Those shafts, which have so bottomed, are outside the boundary of M.L. 379.

"During 1942 and 1943 the writer was shown a number of other localities from which it is reported there has been a small production or from which specimens of tantalite have been obtained. These are indicated on Plate III. At all these places the tantalite is reported to have occurred in pegmatite dykes. At one of these localities—marked shaft C on Plate III.—the writer was shown a very micaceous pegmatite dyke in some shallow workings, from which some tantalite was reported to have been obtained. The concentrates obtained from a single sample taken by the writer consisted almost entirely of cassiterite. In addition to the localities shown on Plate III. the writer was told that a few specimens of tantalite had been obtained in the vicinity of Greenbushes railway station—probably close to the north-

* As a result of the recent work carried out here from November, 1942, up to November, 1943, a total of 2.13 tons of tantalite concentrates having an estimated value of £A3,553 have been produced and shipped, or prepared for shipment. In addition a parcel of 54 bags of mixed tin and tantalite concentrates are awaiting shipment to Sydney for separation. This is estimated to contain about two tons of tantalite ore valued at £A2,512. December, 1943.

† Hobson, R. A., Interim report on some recent work in the vicinity of D.C. 95 and M.C. 48, Greenbushes. Unpublished report on Geological Survey file 8/1943.

west corner of M.C. 26—and that these had been sent to the late Dr. Simpson for examination. Subsequent prospecting by a local resident failed to reveal any further tantalite, however.

"Alluvial tantalite was associated with tin ore in the upper portion of Bunbury Gully and also in that portion of Floyd's Gully near the head of Bunbury Gully. It is reported to have occurred in pieces from the size of fine shot to 13 lb. in weight (16, p. 112). The writer was told that the concentrates from the sluicing cut close to the north-east corner of W.R. 289 (the last work done in Bunbury Gully) contained 15 per cent. tantalite.

"Lode tin concentrates from 'Amanda,' M.L. 56 have been found to contain a small percentage of mixed tantalum and niobium oxides (17, p. 453). Some recent parcels of concentrates from the Vulcan workings on M.C. 4, yielded approximately 20 per cent. of a magnetic product containing from 72 to 81 per cent. mixed tantalum and niobium oxides.*

"The Greenbushes tantalite generally shows no crystalline form, but one water worn fragment did show radiated structure similar to that seen in some of the Moolyella ore (23, p. 315).

"Tantalum has been detected in clean cassiterite from Greenbushes. A crystal of cassiterite from the South Cornwall Mine was found to contain 1.76 per cent. Ta_2O_5, while a pebble from North Greenbushes contained 1.15 per cent. Ta_2O_5 (23, p. 315).

"Later investigations have shown that while such crystals of cassiterite contain some tantalite in solid solution tantalite also occurs free (78)."

Balingup, Smithfield.

Traces of manganocolumbite crystals associated with beryl, microcline and albite felspar have been recorded from a large pegmatite dyke at Ferndale, four miles south-east of Balingup, north-west of Greenbushes (54), (61). Geologically the country hereabouts is very similar to that of the Greenbushes field, rare outcrops at this locality consisting of hornblende schist (amphibolite?) striking N 10° W, intersected by several coarsely crystalline pegmatite dykes.†

One of these, lying about a quarter mile south of Lower Balingup School, is approximately 300 feet wide and is traceable over a length of

* In October, 1943, 2·79 tons of columbite, assaying 37–38% Ta_2O_5 were sold for £1,143·8 after separation from under 20 tons of tin concentrates. In the same month a further 3½ tons of tin concentrates were sent away for magnetic separation treatment. This yielded a further 0·69 tons of columbite assaying 37·9% Ta_2O_5. The total production from this source is thus 3·48 tons valued at £A1,483. (Mar., 1944.)

† See Wilson, R. C., "Beryl at Ferndale (near Balingup)" Annual Report, Department Mines, W.A., for 1925, pp. 82-3.

about 10 chains on a bearing N 50-60° W. Several small parcels of beryl were obtained from this dyke which was later mined for felspar. The tantalum mineral was first identified from this deposit in 1929.

A little cassiterite has been reported from south-west of Bridgetown in three or four places. From one of these, near Loc. 11472, Smithfield, a few hundredweight of tin concentrates were obtained in 1931. One parcel was found to contain about 20% cassiterite, and 10% ferrocolumbite which had the composition 60.3% Nb_2O_5, 20% Ta_2O_5. These concentrates were obtained from alluvial ground. Little is known of the nature and composition of the underlying rocks in this vicinity as these are largely masked by soil and ferruginous laterite deposits heavily timbered with jarrah forest and undergrowth. It is probable, however, that the sequence of basement rocks is similar to that found at Greenbushes.

Ravensthorpe.

At about 1¾ miles north-north-west of Ravensthorpe townsite, crossing Cattlin Creek and the main Ravensthorpe-Newdegate road on W.R. 17, are several large dykes of pegmatite. One of these runs in the approximate direction N 45° W. for about half a mile.* This dyke which cuts through what has been mapped as greenstone country, is notable for containing appreciable quantities of the lithium ores spodumene and lepidolite, as well as beryl, quartz, felspar, etc. In 1934 samples of tantalum ore were recorded as obtained from this dyke, one of these proving to be manganocolumbite with about 35% Ta_2O_5 (64, p. 83). The writer recently saw further specimens of detrital material obtained from the bed of Cattlin Creek in the vicinity of the dyke, by Messrs. MacDonald and Manson, of the School of Mines, Kalgoorlie. This material consisted of fairly well crystallised fragments of typical rectangular form and is probably manganocolumbite. Nothing is known as to what quantity of tantalum ore can be found in this locality.

CENTRAL DIVISION.

Coolgardie District—*Londonderry.*

The first discovery of tantalum ore in the Coolgardie district was made in 1909 at Fraser's Find, now shown as Richter's Find on the Mines Department 40 chain-inch litho, four miles south-south-west of Londonderry townsite (which is about eight miles south-south-west of Coolgardie), by Mr. Hugh Fraser while in search of tin ore. Fraser later discovered tantalite at what became known as Mercer's Find but is now officially listed as Tantalite Hill, about 1½ miles north

* See Geological Map of Ravensthorpe accompanying Geol. Surv. W.A. Bull. 35, 1909, by H. P. Woodward.

of Fraser's Find. Geologically the country consists of amphibolite schists striking approximately north and south, intersected by numerous coarse-grained pegmatite dykes of variable size. Fragments of detrital tantalum ore were first found in the vicinity of a large weathered dyke at Fraser's Find. These proved to be mainly manganocolumbite having an average composition of about 49% Ta_2O_5, 34% Nb_2O_5, with lesser quantities of manganotantalite and a little ixiolite. Up to the time of the late Dr. Simpson's visit in 1928 no tantalite had been seen in the large pegmatite lode itself but he found that it had been worked in several places for sheet mica and felspar (51, p. 110). Since that time, however, quarrying operations have been continued on a large scale and this pegmatite body has become in recent years the source of several thousands of tons annually of high grade microcline used in the glass manufacturing industry. Occasionally fragments of tantalum minerals (mainly manganocolumbite) from mere specks up to lumps 4 to 5 lbs. in weight have been found in the pegmatite but these are comparatively rare. Other minerals from this pegmatite include lepidolite, petalite, and pseudopetalite, quartz, albite, beryl, garnet, biotite and apatite.

At Mercer's Find specimens of detrital tantalum ore were found in the vicinity of several pegmatite dykes in 1909 (21). These proved to be manganotantalite and manganocolumbite with ixiolite. Three samples taken averaged Ta_2O_5 56%, 51%, 37%; Nb_2O_5 24%, 29%, 43%. Associated minerals included ilmenite, garnet and a little cassiterite.

In 1928, when Dr. Simpson inspected this district, he found two prospecting areas being worked at 3 miles west-south-west of Londonderry Railway Siding. Here albite pegmatite veins intrude amphibolite schists of the Londonderry Hills. A few small pieces of tantalite were seen embedded in a pegmatite vein at one point whilst fragments of detrital tantalite were scattered about the gentle slope on the north side of this vein. This ore proved to be mainly high grade manganotantalite ranging from 65.7-79.3% Ta_2O_5, 18.1-6% Nb_2O_5. Very little work had been done here at that time however (51).

In 1938 the pegmatite vein mentioned above was opened up by Londonderry Minerals, N.L., and further prospecting work was carried out in the immediate vicinity of the locality which had become known as Tantalite Hill. Later, in 1939, the property was taken over by a newly formed company, British Tantalite Ltd., a treatment plant was erected and, if newspaper reports are to be believed, sinking of a shaft was commenced with the object of driving on the lode at depth.

A small tonnage of tantalum ore (claimed to be lode tantalite) was reported from this mine in the early months of 1940 but problems of marketing together with mining difficulties due to the erratic distri-

bution and, probably, low percentage of the tantalite in the lode caused the company to cease active mining in May of the same year. It is probable that the grade of the ore also proved rather variable providing at that time a further drawback to the sale of the mineral. Specimens of detrital manganotantalite and manganocolumbite from this locality in 1937 (70, p. 94) varied in composition as much as from Ta_2O_5 76.9, Nb_2O_5 8.31 to Ta_2O_5 19.2, Nb_2O_5 61.2%.

The writer paid a visit to the Londonderry district early in 1943 and was surprised and disappointed to find that the newspaper reports of the mining at Tantalite Hill had been greatly exaggerated. The apparent tantalite lode formation consists of an albite pegmatite dyke less than 20 feet wide running in an approximate northwesterly direction on the northern slopes of a wide range. A small parallel and apparently barren pegmatite dyke was noticed further westward and higher up the gentle slope. There are no signs of any shafts or underground workings on the lease and the only place where the principal pegmatite lode has been opened up at the surface is in one shallow open cut or trench approximately 30 feet long by 10 feet wide and about 10 feet deep, whose bottom was filled with water.

The principal minerals in the pegmatite here are albite, microcline, quartz, a dark silvery mica having a peculiar spheroidal structure, and here and there a little lepidolite. Several small bunches of beryl are reported also to have been obtained from the pegmatite in this open cut. No tantalite was visible in those portions of the pegmatite still exposed to view.

Judging by the relative sizes of the workings it would appear that the principal source of tantalite on the lease has been the eluvial workings. These cover less than an acre, most of the gravel and loam lying to the immediate north of the slope below the pegmatite having evidently been sieved or dry blown. It was found possible still to "speck" a few fragments of detrital tantalite from the scattered mounds of soil and gravel, and a small handful was collected during the writer's short inspection. These crystal fragments ranged from about 0.1 inch to 0.5 inches in diameter.

The only remains of a treatment plant left on the lease were a large water storage tank on the crest of the hill to the southwest, several old tanks, an ore chute and several small residues dumps. It would appear that this deposit at Tantalite Hill had proved too small to be worked on a commercial scale.

Victoria Rocks.

In addition to his finds at Londonderry, H. Fraser reported the occurrence of tantalite at Victoria Rocks, about 16-17 miles southwest of Londonderry and at intervals between Victoria Rocks and his Lon-

donderry finds (33, p. 50). Specimens collected near Victoria Rocks have proved to be tantalite with specific gravities ranging from 7.49-6.69, indicating Ta_2O_5 contents from about 77% to 57% and Nb_2O_5 8.4% to 27%. Manganocolumbite is also reported from this locality. (see Part 3, p. 113).

Gibraltar.

This centre is situated about 13 miles west-southwest of Coolgardie and lies in a belt of highly schistose amphibolitic rocks, here and there cut by granite and pegmatite dykes. A few small fragments of manganocolumbite were first found in the Gibraltar area "near a large buck reef on G.M.L. 5036" in 1921 (42). Analysis showed that a typical specimen of this mineral contained 27.28% Ta_2O_5, 51.17% Nb_2O_5 whilst specific gravity tests of further pieces collected by Simpson in 1928 indicated compositions Ta_2O_5 22.5-50.0%, Nb_2O_5 57.7-32.2% (51, p. 111). No ore has been discovered in the pegmatite reef itself. A few small pebbles of manganocolumbite have also been found near the southwestern boundary of the late Lloyd George G.M.L. 4580 at Gibraltar.

It would appear that whilst low grade tantalum ore does exist in the pegmatites in this district, as far as is yet known the material is present neither in sufficient quantity nor is it of sufficiently high grade to be of any commercial use.*

Ubini.

A few fragments of detrital tantalum ore were found in 1909 during a search for tin at a place about 3 miles north of Ubini railway siding, which is some 4 miles north of Gibraltar and 13 miles west of Coolgardie. The site of this find is an amblygonite bearing dyke which Blatchford[1] describes as a pegmatite but which H. A. Ellis[2] considers to be a quartz reef containing scattered marginal pegmatitic facies. This reef is situated on late G.M.L. 64 and is traceable on a general strike of N 20-25° W for about 15 chains intersecting decomposed greenstones. Concentrations or bunches of amblygonite and of microcline or albite and mica occur at several points along the margin of this reef, which has been mined for both the amblygonite and the felspar. Other highly felspathic pegmatite dykes occur in the vicinity. The tantalum ore proved to be good grade manganotantalite with 68.24% Ta_2O_5 and 14.38% Nb_2O_5. Later, in 1918, prospecting in the same area resulted in the finding of a few more pieces, the largest weighing 2 oz. and containing 51.5% Ta_2O_5, 30.8% Nb_2O_5 (51, p. 111).

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*The last remark applies for all prices ruling prior to September, 1943.

[1]Blatchford, T. "Geological Investigations in the Burbanks and Londonderry Mining Centres." Geol. Surv. W.A. Bull. 53, 1913, pp. 17-18.

[2]Personal communication.

No further tantalite has been located in this or any of the adjacent pegmatite lodes and no commercial supplies can be hoped for from this deposit.

Larkinville, Logan's Find.

These two gold mining centres are situated to the south-east of Coolgardie, the former about 38 miles from Coolgardie on the Coolgardie-Norseman railway and Logan's Find about 7 miles west of Larkinville. Records of tantalum ores from these centres are confined to one or two entries in the annual reports of the Chemical Branch. Specimens from Larkinville noted in 1934 proved to be pebbles of low grade manganocolumbite (av. 15% Ta_2O) (64, p. 83). A few crystals of manganocolumbite said to come from albite pegmatite at Logan's Find also proved to be low grade, with average composition Ta_2O_5 16% Nb_2O_5 65% (77, p. 146). There are no further available details as to the geology of these occurrences.

Yilgarn District—*Holleton.*

Holleton is situated in the Yilgarn Goldfield about 54 miles south-south-west of Southern Cross and 3 miles east of the 48-mile peg, No. 1 Rabbit Proof Fence. The country is mainly soil or laterite covered, but the underlying rock is probably massive or gneissic greenstone intersected by lenticular quartz and albite pegmatite reefs. A tin-bearing pegmatite at Holleton was examined by R. C. Wilson accompanied by Dr. Simpson in 1929,* but it was not stated that any tantalum ore was discovered. In the Mineralogy section of the Chemical Branch Report for the same year however, H. Bowley states that "tantalite has been recognised in small quantities in an albite pegmatite from Holleton." (55).

EUCLA DIVISION.

Dundas, Norseman, Fraser Range.

Traces of tantalite have been recorded in specimens of pegmatite sent in from seven miles north of Dundas and 12 miles south-south-east of Norseman respectively (43), (46, p. 217). The tantalite in the former specimen is said to contain approximately 70 per cent. Ta_2O_5. A single specimen of euxenite has been reported from the Fraser Range, approximately 70 miles east-north-east of Norseman (33, p. 50). No further details of the geology of these occurrences is available.

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*Wilson, R. C. Tin Find at Holleton. Ann. Rept. Dept. Mines W.A. for 1929, p. 55.

Bellinger (Israelite Bay).

About 12 miles west of Point Malcolm and 11 miles south-south-east of Mica Hill, in this section of the South Coast is a granite rock formation traversed by veins of pegmatite, one of which has yielded a little mica of commercial quality. In 1907 in the course of mining operations on M.L. 112H in this locality, a small quantity of irregular broken fragments and a few imperfect tabular crystals of tantalum ore were obtained. This proved to range from ferrotantalite to manganocolumbite in composition, with Ta_2O_5 from 75 per cent. to 15 per cent. (23, p. 315). It is doubtful if any commercial quantities of the ore could be obtained from this deposit.

There is a further record of tantalite with clay from Bellinger Sand Patch, some 2-3 miles north of Bellinger Island, Cape Pasley (probably late M.C. 18H). A sample of tantalite submitted to the Government Mineralogist in 1907 was found to contain an average of 50 per cent. Ta_2O_5.*

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*Refer Mines Files 1389/07, 2586/21.

CHAPTER III.

PRODUCTION AND GENERAL INFORMATION.

MINING AND TREATMENT.

The chief source of tantalum ores in Western Australia has, until the last 10 years or so, been detrital deposits (both eluvial and alluvial) and these are usually worked by prospectors by methods of dry blowing or by sifting on a 20-30 mesh wire screen. Natives employed in the North-West have acquired a considerable dexterity in what is known as "yandying" whereby heavy detrital minerals are concentrated at one end of a flat or slightly curved oval shaped sheet or bark, wood or iron, by means of a peculiar and continuous rippling, gyratory motion supplied by the operator.

As has already been described, the only mining of other than a superficial nature on lode has been carried out at Wodgina, Tabba Tabba and Strelley by Tantalite, Ltd. At Wodgina only about 40 per cent. of the felspar mined from the main workings has been treated. The ore dressing plant at Wodgina consisted of crusher, jigs and Wilfley concentrating tables. The tantalite concentrates from the tables were dried and then passed through a magnetic separator after which the ore was ready for bagging and transport to the coast for shipment. The final concentrate from Wodgina consisted almost entirely of clean manganotantalite with traces of spessartite and occasionally scheelite.

Prior to the war a small concentrating plant was also operated by Tantalite, Ltd., at the Strelley Mine. Ore from Tabba Tabba was sent to the Strelley plant and the crude concentrate obtained from both centres was then taken by truck to the main plant at Wodgina where it was passed through the magnetic separator before being bagged ready for shipment.

PRODUCTION AND MARKETING.

Tantalite Production.

The following table gives the details of tantalite production from the various centres up to the end of November, 1943. These figures are based on official returns reported to the Mines Department Statistician. It may be pointed out here that the figures for the Pilbara

District include a number of corrections and amendments to those given by Finucane and Telford in 1939 (80). The total recorded production from all sources in the State amounts to about 260.4 tons valued at approximately £107,082.5. The overwhelming bulk of this production has been from the Pilbara District and it may be observed that the greater part of this has been from alluvial sources. Attempts at mining the pegmatite lodes have only been made during the past ten years.

It may also be of interest to note here that official figures for all tantalite concentrates exported from Western Australia up to December, 1942, amount to approximately 288 tons valued at £156,071. The large discrepancy between this and the reported production to 1942 (254 tons at £100,765), viz. 34 tons valued at £55,306, suggests that in the past the unreported production, probably of small parcels, has been considerable. It is difficult to allocate a source for all this unrecorded ore but it is probable that at least a third of it came from the Greenbushes District in the early years of this century, the remainder from sundry claims in the Pilbara District.

All tantalite concentrates produced in Western Australia have been exported to other countries for final treatment and the production of tantalum metal. In the early part of the century a great proportion went either to England for transhipment to Germany or direct to Siemens-Halske and Co., Berlin. Since about 1932 when tantalite production in Western Australia was taken over by Tantalite Ltd., this company has been for the most part under contract to Fansteel Metallurgical Corporation, Chicago, U.S.A., though small parcels of ore have also been sold to Electro-Metallurgical Co., Niagara Falls, and to Great Britain (about nine tons) and Japan (about 12 tons).

The three companies mentioned above have been the world's chief producers of tantalum and columbium. The world's consumption of tantalum ore per annum has varied considerably in the past but prior to the outbreak of war averaged between 15 and 20 tons and was increasing.

Tantalum concentrates most in demand are those containing not less than 60 per cent. Ta_2O_5 and not over 25 per cent. Nb_2O_5. Ore with more than 60 per cent. Ta_2O_5 is considered high grade. Elements objectionable in the ore include tin, titanium, tungsten and chromium, and penalties may be imposed on the unit price of the ore when these elements are present in excess of a certain amount. Permissible limits for these impurities apparently vary somewhat with the buyers, being a matter for private arrangement between the buyers and the producers.

TABLE 1.

TANTALITE PRODUCTION IN WESTERN AUSTRALIA.

Pilbara District.

(A) *Wodgina.*—M.Ls. 86, 87, 95, 293, 298, 338, 300, and 301, and M.Cs. 107 and 109.

Year.	Alluvial.	Lode.	Total.	Value.	Purchased from Prospectors.	Value.	Remarks.
	tons. (2,240 lbs.)	tons.	tons.	£A	tons.	£A	
1905 ...	26·00	...	26·00	3,425	...	...	M.Ls. 86 and 87.
1906 ...	6·30	1·80	8·10	2,020	...	...	
1909 ...	...	0·45	0·45	113	...	...	M.L. 95 added.
1917 ...	12·50	...	12·50	1,782	...	...	
1925 ...	4·25	...	4·25	510	...	...	
1926 ...	19·45	...	19·45	2,357	...	...	
1927 ...	15·28	...	15·28	3,808	...	...	
1928 ...	7·19	...	7·19	1,798	...	...	
1929 ...	11·27	...	11·27	3,598	...	...	
1932 ...	...	4·44	4·44	1,194·85	3·50	1,077	Leases taken over by Tantalite, Ltd.
1933 ...	...	0·21	0·21	70	4·10	1,380	Leases converted to M.Cs. 107 and 109.
1934 ...	...	0·50	0·50	130	...	...	
1935 ...	1·10	3·28	4·38	1,752	0·92	367	
1936 ...	0·80	8·03	8·83	4,347·6	...	...	
1937 ...	2·88	6·92	9·80	12,153	...	...	
1938 ...	2·64	10·86	13·50	18,890	...	...	
1939 ...	...	1·59	1·59	2,294·8	...	...	
1940 ...	...	0·45	0·45	635	...	...	
Total ...	109·66	38·53	148·19	41,467·25	8·52	2,824	

(B) *Strelley.*—M.Ls. 321, 322, 341, and 344, and M.C. 106.

1928 ...	0·57	...	0·57	165	...	...	M.Ls. 321, 322 (Strelley North Leases).
1932 ...	0·46	...	0·46	148·5	...	...	M.Ls. 321, 322, 341, and 344. Taken over by Tantalite, Ltd., 1931.
1933 ...	0·35	...	0·35	100	...	...	Converted to M.C. 106, 1933.
1935 ...	0·08	...	0·08	32	...	...	
1936 ...	2·04	...	2·04	1,094	...	...	
1937 ...	2·51	...	2·51	3,963	...	...	
1938 ...	5·77	...	5·77	8,038	...	...	
1939 ...	...	4·43	4·43	6,540·5	...	...	
1940 ...	...	2·53	2·53	3,633	...	...	
1943 ...	...	...	...	...	0·86	760*	Alluvial.
Total ...	11·78	6·96	18·74	23,714	0·86	760	

(C) *Tabba Tabba.*—M.Ls. 317, 312, and M.C. 116.

1928 ...	1·00	...	1·00	250	...	...	M.L. 317 (Koolinda North).
1932 ...	0·05	...	0·05	15	...	...	Taken over by Tantalite, Ltd., 1931, as M.L. 312.
1933 ...	0·39	...	0·39	100	...	...	M.L. 312 converted to M.C. 116.
1935 ...	1·77	...	1·77	708	...	...	
1936 ...	4·11	...	4·11	2,047·8	...	...	
1937 ...	5·69	...	5·69	11,812	...	...	
1938 ...	0·53	...	0·53	755	...	...	
1939 ...	...	3·11	3·11	4,581·3	...	...	
1940 ...	...	0·84	0·84	1,203	...	...	
Total ...	13·54	3·95	17·49	21,472·1	...	...	

* Figures for 1943 approximate only.

TABLE 1—*continued.*

(D) *Pilgangoora.*—M.Cs. 160, 161, 162.

Year.	Alluvial.	Lode.	Total.	Value.	Purchased from Prospectors.	Value.	Remarks.
	tons. (2,240 lbs.)	tons.	tons.	£A	tons.	£A	
1942 ...	0·66	...	0·66	321·7	...	...	Messrs. Collett & Co.
Total ...	0·66	...	0·66	321·7	...	...	
(E) *Sundry Claims.*							
1905 ...	44·95	...	44·95	5,500	...	...	From vicinity main leases, Wodgina.
1906 ...	5·65	...	5·65	530	...	...	
1907 ...	0·90	...	0·90	94	...	...	
1925 ...	2·00	...	2·00	240	...	...	M.L. 293 (Maybe).
1932 ...	0·32	...	0·32	103·6	...	...	M.L. 353 (Sir F. Moulden).
1943 ...	0·01	...	0·01	19·2*	...	...	P.A. 818 (Kangan).
Total ...	53·83	...	53·83	6,486·8	...	...	
Total, Pilbara District	189·47	49·44	238·91	93,461·85	9·38	3,584	
Greenbushes District.							
Greenbushes.							
1905 ...	2·34	...	2·34	1,590	...	...	M.L. 369 (" Enterprise ").
1909 ...	0·85	...	0·85	214	...	...	M.L. 369 (" Enterprise ").

1929 ...	...	0·30	0·30	70	...	...	D.Cs. 81, 83.
1932 ...	0·45	...	0·45	135	...	...	M.L. 640 ("Eureka").
1942 ...	0·17	...	0·17	121·5	...	...	M.C. 1 (Tantalite, Ltd.).
1943 ...	1·96	3·49	5·45	5,566·15*	...	...	M.C. 1 and M.C. 4 (Lode).
Total ...	5·77	3·79	9·56	7,696·65	...	...	
Coolgardie District.							
Londonderry.							
1940 ...	...	2·50	2·50	2,340	...	...	M.Ls. 85, 90, 93 (British Tantalite, Ltd.).
Total ...	...	2·50	2·50	2,340	...	...	
Grand Total, State	195·24	55·73	250·97	103,498·50	9·38	3,584	

* Figures for 1943 approximate only.

It has already been pointed out that the occurrences of tantalum ores in the Pilbara District of Western Australia hold a unique place in the world because of the uniformly high grade of ore which can be produced. In this connection it may be noted here that the average grade of all tantalum ore exported from the Pilbara field between 1931 and 1940, from samples assayed was Ta_2O_5, 63.5 per cent.; Nb_2O_5 12.0 per cent.; SnO_2, 6.6 per cent. The range in composition was Ta_2O_5, 51.0-71.8 per cent.; Nb_2O_5, 2.4-22.5 per cent. (generally 14-16 per cent.); SnO_2 2.2-13.4 per cent.

Discussion of the uses to which the metal tantalum has been put will be reserved for a following section (see Part 2, pp. 69-70), but it may be mentioned here that despite popular belief, until very recently there was evidently no call for the extensive use of tantalum in armaments or other wartime industries, as production of tantalite in the Pilbara District ceased soon after the outbreak of present hostilities. This cessation was at the time due primarily to the failure of the company Tantalite Ltd., to obtain further contracts for the supply of the ore to America or other countries, rather than to lack of manpower or of shipping space. Evidently the American market had temporarily reached saturation point, production of the refined metal having outpaced its consumption. Apparently important wartime uses for the metal have been devised in the last year or so, however, and at the present time there is an immediate and urgent demand for as much tantalum ore as Australia can produce. Such is the urgency of the tantalum requirements that the American Government is at the time of writing evidently prepared to purchase lower grade concentrates than had hitherto been called for, prices recently announced (see below) including ore containing as low as 30 per cent. Ta_2O_5.

Columbite Production.

Although from time to time small quantities of columbite or low grade tantalum ore must undoubtedly have been produced in Western Australia, it is probable that most of this has been disposed of by mixing small parcels with higher grade tantalite concentrates. The relatively low price offered for columbite in the world's markets (see below) has so far prohibited the mining of columbite ores in this State. The only official record of the disposal of columbite prior to 1943 is in 1938 when a parcel of about 7½ hundredweight of columbite containing 31.25 per cent. Ta_2O_5 was sold for £35 18s. at the rate of £3 per unit or £93 15s. per ton, delivered Melbourne. This parcel which came from Pilgangoora, was sold as a low grade tantalum ore and not as a niobium ore, i.e., was sold for its tantalum content.

PRICES.

Tantalite.

The price of tantalum ore has suffered many vicissitudes during past years, appreciable rises and falls being a natural consequence of a very limited demand and a highly restricted market. As recently as 1930 the market price for concentrates was about £2 13s. 6d. per unit of tantalic oxide on the basis of ore containing 60 per cent. Ta_2O_5, but this steadily rose to about £10 per unit in 1935. In the succeeding years up to the commencement of the war with the virtual cessation of mining activities, concentrates from the Pilbara District were sold by Tantalite, Ltd., under contract to the United States Fansteel Metallurgical Corporation at prices up to about £A1,500-1,800 per short ton for good grade ore, i.e., over £A25 per unit for 60 per cent. ore, whilst it is reported that in 1937 the price rose to over £A2,000 per short ton for 65 per cent. ore.

There is now a considerable demand for tantalum metal for war purposes and in 1942 the Commonwealth Government, through the Controller of Minerals Production, arranged for the purchase of tantalum concentrates from all available sources, for transhipment to the Metals Reserve Corporation, U.S.A.

The first price quoted by the Controller of Minerals Production under this arrangement was in September, 1942:—"2.05 dollars (approx. £A0/12/7½d.) per lb. of contained Ta_2O_5 F.O.B. boat or plane Melbourne plus or minus 4 cents (3d.) per lb. for each 1% above or below 60% Ta_2O_5." It was also stated that "payment of 50% of the estimated value would be made against the shipping documents." This price is equivalent to approximately £A757 10s. per short ton or about £12 12s. 3d. per unit for 60% ore.

In February 1943 a new price was announced, viz. "13/4d. per lb. of contained Ta_2O_5 for concentrates averaging 60% Ta_2O_5 plus or minus 3d. per lb. for each 1% above or below 60% down to 50% Ta_2O_5." Furthermore it was stated that "the price of ore containing under 50% down to 40% Ta_2O_5 is obtained by deducting 3.75d. per lb. per unit from the price of 60% ore." From this price quotation it can be seen that a market had developed for low grade tantalite (columbite). These prices are equivalent to £A800 per short ton or £13 6s. 8d. per unit for 60% ore, down to £A308 6s. 8d. per short ton or approximately £7 15s. 8d. per unit for 40% ore.

More recently still, i.e. in September, 1943, a new schedule of prices for tantalite concentrates (given below) was supplied to the Controller of Minerals Production by the American Board of Eco-

nomic Warfare. It was stated that these prices had not been actually confirmed,* but could be taken as a basis for the calculation of the value of future concentrates received. These latest prices are as follows:—"1.30 dollars (approx. 8/0d.) per lb. of contained Ta_2O_5 for concentrates containing 30% Ta_2O_5, increasing by 7 cents (approx. 5.17d.))per lb. per unit to 4.80 dollars (approx. 29/6½d.) per lb. for 80% ore." This is equivalent to £A1,256 per short ton or £20 18s. 8d. per unit for 60% ore, a decided increase on the previous prices.

Probable penalties are quoted as follows, fractions pro rata: "The price per lb. of Ta_2O_5 will be reduced by 2 cents (approx. 1.48d.) for each per cent under 60% minimum combined tantalum and columbium (niobium) pentoxide.

The price per lb. of Ta_2O_5 will be reduced by 1 cent (approx. .74d.) for each per cent in excess of 6% combined SnO_2 plus TiO_2.

The price per lb. of Ta_2O_5 will be reduced by 3½ cents (approx. 2.58d.) for each per cent. in excess of 3% SnO_2.

The price per lb. of Ta_2O_5 will be reduced by 3½ cents for each per cent in excess of 3% TiO_2."

On page 59 is a table of the latest prices given in £A per short ton rising in units from 30% to 80% of contained Ta_2O_5.

From that table it can be seen that low grade tantalite ore, i.e., columbite, containing not less than 30 per cent. Ta_2O_5 and not less than 60 per cent. combined Ta_2O_5 and Nb_2O_5, now commands a price which may encourage prospectors to develop some of the lower grade tantalite deposits in the State.†

Columbite.

The price of columbite, sold as an ore of columbium (niobium) has in the past rarely been higher than about one tenth that of the corresponding tantalum-rich ore. It is reported that in 1935-1936 Nigerian columbite concentrates averaged about £A70 per ton. During

*These prices have now beeen confirmed and apply as from 1st July, 1943. Dec. 1943.

†In this connection it may be noted that electromagnetic treatment of mixed parcels of tin and tantalite concentrates may result in the separation and beneficiation of valuable quantities of tantalum ore. Messrs. O. T. Lempriere & Co., Pty., Ltd., of Melbourne and Norman Hill & Co., Pty., Ltd., of Sydney advise that they charge a separation fee of £10 per ton of original mixed tin/tantalite/columbite concentrates. Under the latest schedule of prices prospectors should be amply repaid for the cost of such beneficiation of all dirty concentrates whether of low or high grade tantalum ore.

TABLE II.

*Revised Schedule of Prices for Tantalite Ores, September, 1943.**

Per cent. Ta_2O_5 contained in Concentrates.	Price per Short Ton. (2,000 lbs.)	Per cent. Ta_2O_5 contained in Concentrates.	Price per Short Ton. (2,000 lbs.)
	£ s. d.		£ s. d.
30	240 2 4	56	1,075 14 7
31	261 9 8	57	1,119 10 2
32	283 14 2	58	1,164 2 10
33	306 15 11	59	1,209 12 10
34	330 14 11	60	1,256 0 0
35	355 11 2	61	1,303 4 6
36	381 4 8	62	1,351 6 2
37	407 15 5	63	1,400 5 2
38	435 3 4	64	1,450 1 4
39	463 8 7	65	1,500 14 9
40	492 11 0	66	1,552 5 5
41	552 10 8	67	1,604 13 4
42	553 7 7	68	1,657 18 5
43	585 1 9	69	1,712 0 10
44	617 13 1	70	1,767 0 5
45	651 1 9	71	1,822 17 4
46	685 7 8	72	1,879 11 5
47	720 10 9	73	1,937 2 9
48	756 11 1	74	1,995 11 3
49	793 8 8	75	2,054 17 1
50	831 3 6	76	2,115 0 2
51	869 15 7	77	2,176 0 6
52	909 4 11	78	2,237 18 0
53	949 11 6	79	2,300 12 9
54	990 15 3	80	2,364 4 9
55	1,032 16 3		

*This useful table was prepared and supplied by courtesy of Mr. J. S. Foxall, *Assistant State Mining Engineer*, December, 1943.

1937-38 imports of columbium ores into the United States had average values of between £E135-140 per short ton.* These ores were probably bought as low grade tantalum ores, however, since A. W. Groves, describing the British Empire conditions in 1940† stated that "tantalite containing an appreciable amount of columbium is generally quoted at 55s. to 60s. a unit, i.e., in the neighbourhood of £150 a ton. The best columbite fetches only about half this price."

There is no record to date of the sale of columbite as niobium ore in Western Australia, and the only indication of the price of columbite ores containing less than 30 per cent. Ta_2O_5 is a recent quotation by Norman Hill and Co., Pty., Ltd., of Sydney for an ore assaying Ta_2O_5 13.9 per cent.; Nb_2O_5 39.6 per cent. The terms were:—

> Pay for the full columbium (niobium) pentoxide content 36 cents per lb. delivered F.O.B. Australian overseas port of shipment. Final settlement based on American weights and assays.

On basis of the above price an ore containing 39.6 per cent. Nb_2O_5 would be worth £98 6s. 1d. per ton F.O.B. Australian port of shipment. The Ta_2O_5 content contained in a columbite ore is not paid for.

Norman Hill and Co., announce that their works in America are most anxious to purchase regular tonnages of columbite ore.‡

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* Minerals Year Book, 1939, U.S. Bureau of Mines, p. 753.

† Groves, A. W.—"Tantalum—The Position Past and Present, of Ore and Metal." Mining Jour. London Vol. 209 No. 5463 May, 1940, pp. 281-2.

‡ Latest information from Norman Hill and Co. (March, 1944) quotes the following approximate prices received from America, covering columbite ores delivered c.i.f., New York.—

Ores assaying	60%	Nb_2O_5	£A227	11	2	per ton.
,, ,,	45%	Nb_2O_5	£A124	2	5	,,

This firm will handle such class of ores on a solely 10 per cent. commission basis. In the event of the ores requiring treatment by electromagnetic separation there would be an additional charge of £10 per ton to cover treatment costs. Final settlement is based on independent American assays and weights.

PART 2.

The Properties and Uses of Tantalum and Niobium.

By H. P. Rowledge, A.A.C.I., A.W.A.S.M.

INTRODUCTION.

Tantalum and niobium have been known to science for well over a century but until the year 1905 did not find application in the arts.

The discovery of tantalum is closely associated with that of niobium with which it is always associated in nature. The chemistry of these two elements is so closely allied that it was some time before their individual identity was definitely established.

In 1801 Hatchett, an English chemist, recognised the existence of a new element whilst examining ores from North America. This he named columbium on account of the fact that it had come from that country. A year later Ekeberg recognised a new element when examining ores from Finland and Sweden. He named it tantalum after a mythological name Tantalus, because of the tantalising difficulty in dissolving the oxide of this new metal in acids. Confusion resulted as to the existence of these two elements for some time. In 1844 Rose discovered the presence of two new elements in a sample of columbite. One was similar to Ekeberg's tantalum, the other was called niobium from Niobe, the mythological daughter of Tantalus. Various chemists during the succeeding period carried out investigations on different minerals from a number of sources which all contributed to the study of the chemical properties of these elements. Marignac investigated the constitution of the fluorides and double fluorides and showed previous methods of separation of tantalum and niobium to be faulty and for the first time succeeded in preparing pure tantalum and niobium compounds (90, 94). A modified form of his method for the separation is in use at the present time in the Government Chemical Laboratories for the analysis of manganotantalite.

In the year 1905 tantalum and niobium came into prominence as possible materials for the manufacture of filaments for incandescent electric lamps in place of carbon filaments then in use. Von Bolton then prepared in the pure state the metals, and their properties were examined. (90, 94). Tantalum proved to be satisfactory and was used between the years 1905-1911, when it was replaced by tungsten.

In later years a considerable amount of attention has been given to the properties of these metals and their alloys which has resulted in their increased use in metallurgy and chemical industry.

Tantalum and niobium do not occur to any extent in nature in the free state but almost always as the acid or negative component of the minerals with iron, manganese, calcium and rare earths as the bases. Titanium, zirconium and tin are also frequently present.

MINERALS.

The following tantalates and niobates are recorded as having been found as minerals in nature. (101).

Tantalates and Niobates of the common elements.

Tantalite	$FeTa_2O_6$
Manganotantalite	$MnTa_2O_6$
Columbite	$FeNb_2O_6$
Manganocolumbite	$MnNb_2O_6$
Tapiolite	$FeTa_2O_6$
Ixiolite	$MnTa_2O_6$
Mossite	$FeNb_2O_6$
Manganomossite	$MnNb_2O_6$
Bismutotantalite	$Bi_2Ta_2O_8$
Stibiotantalite	$Sb_2Ta_2O_8$
Stibiocolumbite	$Sb_2Nb_2O_8$
Stibiomicrolite (82)	$(CaHSb''')TaO_4.Sb'''Sb^2O_4$
Simpsonite (74)	$CaO.5Al_2O_3.4Ta_2O_5.2H_2O$

Titanotantalates and Titanoniobates of the common elements.

Struverite	$Ti_3O_6+FeTa_2O_6$
Ilmenorutile	$Ti_3O_6+FeNb_2O_6$
Nigrine	$TiO_2+Fe''Nb_2O_6+Fe'''NbTiO_6$
Dysanalyte	$NaCaTiNbO_6$

Fluotantalates and Fluoniobates of the Common Elements with Sodium.

*Microlite	$NaCaFTa_2O_6$
*Neotantalite	$NaCaFTa_2O_6$
Columbomicrolite (104)	$(NaCa)_2(NbTi_2)_2(O, OH)_7$
†Pyrochlore	$NaCaFNb_2O_6(+NaCeFTiNbO_6)$
Antimonpyrochlore (106)	$X_2Z_2(O.OH.F.)_7$ X=Na,Ca,Ce, etc., Z=Nb,Ta,Ti,Sb.
Chalcolamprite	$Na_4Ca_3(FOH)_6Nb_6(SiZr)_3O_{23}$
Woehlerite	$Na_4Ca_2F_2Nb_2(SiZr)_2O_{16}$
Epistolite	$5Na_2O.NaF.5SiO_2.TiO_2.Nb_2O_5 7H_2O$

*Microlite and Neotantalite have the same composition and crystallisation.
†Pyrochlore contains some Cerium and Titanium.

Tantalates and Niobates of the Rare Earths.

Yttrotantalite	$Y_2Ta_2O_8$
Fergusonite	$Y_2Nb_2O_8(+H_2O)$
‡Sipylite	$Er_2Nb_2O_8$
Hielmite	H, Fe, Mn, Ca, Y^4, Ta, Nb, O
Loranskite	Y, Zr, Ta, Nb, O, H_2O

Tantalates and Niobates of Uranium.

Ampangabeite	$UO_3.Fe_2O_3.4(Nb_2O_5).\times H_2O$
Hatchettolite	$UO_3.3CaO.4(Nb_2O_5)+H_2O$

Tantalates and Niobates of the Rare Earths and Uranium.

Samarskite	$Y_2Nb_2O_8+Fe''U^4Nb_2O_8$
Calciosamarskite	$Y_2Nb_2O_8+(Fe''Ca)U^4Nb_2O_8$
Plumboniobite	$Y_2Nb_2O_8+(Fe''Pb)U^4Nb_2O_8$
Ishikawaite	Ce, Y, U^4, Fe'', Nb, O
Toddite	Y, U, Fe'', Mn'', Ca, Nb, Ta, O, H_2O
Yttrocolumbotantalite (93)	$(FeMn)_2(NbTa)_2O_7+(UO_2)_2(NbTa)_2O_7+Y_4\{(Nb,Ta)_2O_7\}_3$

Titanotantalates and Titanoniobates of the Rare Earths.

Aeschynite	$3Ce(TiTh)_2NbO_8+(FeCa)TiNb_2O_8$
*Euxenite	$YTi_2NbO_8(+CaTiNb_2O_8)$
*Priorite	$YTi_2NbO_8(+CaTiNb_2O_8)$
Tanteuxenite	$YTi_2TaO_8(+CaTiTa_2O_8)$
Polycrase	$YTi_2NbO_8+Ti_4O_8$
Tantalopolycrase	$YTi_2TaO_8+Ti_4O_8$
Polymignite	Ce, Ca, Zr, Ti, Nb, O
Blomstrandine	$YNbTi_2O_8+(O\text{-}\frac{1}{4})Ti_4O_8$
Pyrochlore	Under Sodium Fluorine group
Risoerite	Fergusonite, Titaniferous variety

Titanotantalates and Titanoniobates of Uranium.

Betafite	$UO_3.CaO.2TiO_2.\ Nb_2O_5.4H_2O$
Djalmaita (87)	$UO_3.CaO.2TiO_2.Ta_2O_5.2H_2O$
Blomstrandite	U^4, Ca, Fe'', Ti, Nb, O, H_2O
Ellsworthite	Ca, Fe''', U^6, Ti, Nb, O, H_2O
Samieresite	$2UO_3.PbO.2TiO_2.5Nb_2O_5.17H_2O$

Titanotantalates and Titanoniobates of the Rare Earths and Uranium.

Wiikite	Y, Sc, U, Fe, Ti, Nb, Si, O, H_2O
Khlopinite (102)	$M_2Nb_2TiO_9.H_2O$. M = U, Th, Y, and Fe

‡Probably fergusonite.

*Euxenite and Priorite have the same composition and crystallisation.

Miscellaneous.

Containing Tungsten.

Scheteligite (83) .... $R_2(Ti, Ta, Nb, W)_2(O.OH)_7$
R = Ca, Mn, Y, Sb, Bi

Containing Tin.

Thoreaulite (85, 95) .... $SnO_2.Ta_2O_5$
Ainalite (88) .... $SnO_2+Ta_2O_5$
Zircon containing small amounts of $(NbTa)_2O_5$

Of the above listed minerals the following contain either Zr or Si or both.

Chalcolamprite	Polymignite
Woehlerite	Wiikite
Loranskite	Epistolite

It is probable that the compositions of some of the more complex minerals shown above are doubtful owing to the difficulties experienced in the isolation of their individual constituents and the possibility that some of them are mineral mixtures.

This list of minerals is compiled from "A Key to the Mineral Groups Species and Varieties" (Simpson) with the addition of later recordings numbered in the BIBLIOGRAPHY.

EXTRACTION FROM THE ORES.

Very little recent information appears to be available regarding the preparation of metallic tantalum and niobium from its ores on an industrial scale. In the laboratory it has been prepared by first extracting the pentoxide from the minerals and then reduction of the pentoxide to the metal.

The minerals mostly used are tantalite and columbite. They can be opened up by fusion with a number of fluxes, e.g., potassium acid sulphate, potassium acid fluoride, alkaline carbonates and hydroxides, etc. Of these the alkaline hydroxides and carbonates have been chiefly used. The hydrated pentoxides are then prepared by extracting the melt with water, acidifying with mineral acids, diluting and boiling. The hydrated pentoxides of tantalum and niobium are then filtered and washed with hot water. This often results in an impure product as it will be contaminated with titanium, silicon, tin and antimony when these constituents are present in the original mineral. It is necessary that they should occur only in minor quantities in the latter as the market value is deleteriously affected and penalties incurred when they are present beyond certain limits.

Tantalite and columbite always contain some niobium and tantalum respectively therefore it is necessary to separate the tantalum and niobium in the pentoxides before proceeding with the reduction to the metal. This is carried out by dissolving the hydrated pentoxides in hydrofluoric acid, adding the necessary amount of potassium fluoride to form the double fluorides with potassium and separating the potassium tantalum fluoride by means of repeated fractional crystallizations at a definite temperature. Potassium tantalum fluoride K_2TaF_7 is only sparingly soluble in dilute hydrofluoric acid and potassium niobium oxyfluoride is appreciably soluble.

These two fractions are then treated with fuming sulphuric acid to remove the fluorine and the respective hydrated pentoxides precipitated as before.

Tantalum.—Tantalite is the mineral chiefly used for industrial purposes. It should contain preferably over 60% tantalum pentoxide and a minimum quantity of titanium and tin. The pentoxide is prepared and after solution in hydrofluoric acid is separated from niobium as previously described. Very little information is available regarding the process employed to reduce the potassium fluotantalate or the tantalum pentoxide produced from it by hydrolysis to metallic tantalum. It is believed that this is carried out by the reduction of the potassium fluotantalate by fusing at high temperatures with sodium or potassium or by electrolysing the molten fluotantalate between an anode of impure tantalum and a cathode of pure tantalum. The impure products obtained then being fused in vacuo by electricity which removes any impurities by volatilisation. (90)

Small amounts of tantalum can be prepared by passing an alternating electric current through rods of tantalum tetroxide in vacuo. (90)

Niobium.—Until recently the preparation of metallic niobium was not carried out industrially as there was little demand for the metal.

It has been prepared in the laboratory chiefly by the reduction of the pentoxide with carbon, aluminium, and hydrogen. This usually gives an impure product which can be purified by heating electrically in vacuo whereby the impurities are volatilised. (90)

Carbides of Tantalum and Niobium (98).—Recent investigations carried out at the School of Metallurgy, Melbourne University, have shown that carbides of tantalum and niobium can be prepared direct from the pentoxides by heating an intimate mixture of the pentoxide with carbon in a stream of pure dry hydrogen at 1800°C. for 3 hours in a tube sintering furnace.

The pentoxides were prepared by opening up the tantalite-columbite by fusing with a mixture of sodium hydroxide and sodium carbonate, 9:1, and precipitating in the usual manner by hydrolysis. The solution of the pentoxide in hydrofluoric acid was separated in a manner similar to that already described.

PROPERTIES.

Metals.—Tantalum and niobium belong to group V in the Periodic Table of the Elements where they are classified with vanadium, neodymium, protoactinium, nitrogen, phosphorus, arsenic, antimony, illinium, and bismuth.

Tantalum.

Atomic weight	180.88 (86)
Melting point	2850°-3000°C (90)
Density	16.6 (92)

Tantalum is a white metal with a greyish tinge similar to platinum in colour and general appearance. (90)

It can be worked in the cold state without being previously annealed although it is subject to strain hardening. It can be rolled into a sheet 0·1 mm. thick and less and can be drawn into wire 0·03 mm. in diameter. It has a considerably higher tensile strength than hard drawn copper, nickel or platinum. (90)

It is not affected by air or moisture at ordinary temperatures, does not "rust" and withstands exposure to sea air, salt water and sulphur dioxide gas. (90)

When heated above dull red heat a film of white pentoxide is formed which prevents further oxidation. In oxygen tantalum wire glows without flame at white heat and yields tantalum pentoxide Ta_2O_5 if oxygen pressure is above 20 mm. The reverse happens when the pentoxide is heated in vacuo at high temperatures. Pure tantalum metal can be prepared in this way. Metallic tantalum absorbs large volumes of hydrogen when heated in this gas. It also absorbs nitrogen and minute quantities of helium and argon. (90)

It reacts slowly with sulphur and selenium probably forming the sulphide and the selenide. Hydrogen sulphide is without action at a temperature of 600°C. (90)

It is readily attacked by fluorine and burns when gently heated in chlorine forming the pentachloride. It does not react with iodine. Solutions of chlorine are without action on the metal. (90)

Tantalum is a metal which is remarkably resistant to corrosion by acids. It is not attacked by hydrochloric, nitric, or aqua regia either hot or cold, dilute or concentrated. It is not attacked by dilute sul-

phuric acid, but boiling concentrated acid slowly dissolves it. It is rapidly attacked by a mixture of hydrofluoric acid and nitric acid and in contact with platinum or carbon it is readily dissolved by hydrofluoric acid alone. (94)

Boiling solutions of the alkalies attack it slowly and fusion with caustic potash yields a tantalate of potassium. (90)

When heated at temperatures above 900°C. it reacts slowly with nitrogen forming the nitrides. (90)

Tantalum displays a phenomenon known as valve action in an electrolytic cell and in consequence is used largely in rectifiers. (90)

Niobium.

Atomic weight	92.91	(86)
Melting point	1950°C	(92)
Density	8.4	(92)

Niobium is a grey-white metal. Like tantalum it can be hammered into thin sheets but it is more difficult to draw into wire. (90)

In chemical properties it is very similar to tantalum but nobium is a stronger reducing agent. (94)

It volatilises when heated in vacuo and von Bolton observed that the electrical spluttering made it unsuitable for incandescent filament lamps. (94)

Niobium does not change on exposure to air. It is converted slowly to pentoxide when strongly heated in air or oxygen. (90)

When heated in a current of hydrogen it forms a hydride. When red hot it decomposes water vapour forming hydrogen. (94)

Sulphur and selenium react violently when heated with the metal. (94)

It also reacts with fluorine, chlorine, and bromine forming the halides. Iodine is without action. (90)

It is like tantalum in its resistance to corrosion by acids.

With nitrogen it reacts to form a nitride at 1200°C. Finely divided niobium at red heat decomposes ammonia into its elements. (90)

It displays valve action in electrolytic cells similar to tantalum. (90)

ALLOYS.

Tantalum.—Tantalum alloys with a number of other metals, but their properties and the systems produced have been little investigated until recent years.

It alloys well with *aluminium* in proportions up to about 3·5% tantalum having no effect on the mechanical strength, ductility or working properties of the aluminium. (90)

Alloys with *copper* are mechanically strong and acid resisting. *Gold alloys* resemble the copper alloys and a gold copper tantalum alloy has been formed. (90)

Tantalum alloys with *iron* in all proportions. Magnesium tantalum alloys containing about 3.5% Mg. have been obtained by reducing tantalum pentoxide with magnesium powder in a stream of hydrogen. (90)

It forms alloys with *molybdenum* in all proportions.

Additions of tantalum to *nickel* increases resistance to acids and its ductility. (90)

Platinum tantalum alloys are hard, resistant to heat, acids and fused potassium acid sulphate. They are more resistant to attack by aqua regia than platinum alone. (90.)

Silicon increases the hardness of tantalum. A substance agreeing with the formula $TaSi_2$ has been obtained by heating a mixture of tantalum pentoxide and silicon dioxide in the presence of aluminium. (90.)

Tungsten alloys with tantalum in all proportions. Alloys of tungsten and tantalum which contain cobalt, chromium and molybdenum have been formed. (90.)

Niobium. Very little information seems to be available regarding alloys of niobium. It appears to alloy with *iron* in all proportions; an alloy of 10% niobium and 90% iron is extremely hard. (90)

Aluminium and niobium alloys have been produced. A product containing 3% aluminium is harder than quartz. (90.)

When green chromic oxide and niobium are fused together in an electric furnace a brittle alloy of *chromium and niobium* is formed. (90.)

Alloys with *nickel* and *zirconium* have been prepared. (90.)

Niobium-Nickel alloys (containing 5-37% Nb) have been produced by reduction of niobium pentoxide in the presence of nickel in hydrogen at temperature of 1100°-1150°C. (91.)

Additions of niobium to nickel lower the fusing point and a eutectic, melting point 1265°C occurs at 24% niobium.

COMPOUNDS.

The chemistry of tantalum and niobium and their compounds has but slowly advanced on account of their "weakly defined chemical deportment, their remarkably close resemblance and the complexity of the greater number of their minerals." (101.)

The only well defined compounds are those derived from the pentoxides, namely, the tantalates and niobates. It is these compounds which constitute the composition of almost all the minerals found in nature.

They do not form the number of well defined stable compounds as do other metals. The following more or less stable compounds are known—chlorides, oxychlorides, fluorides, double fluorides with other bases, oxyfluorides, bromides, oxides, sulphides, hydrides, nitrides and carbides. No sulphates or nitrates have been definitely prepared. (90, 94.)

Tantalum and niobium are metals but in their chemical reactions approach the non-metals. The pentoxides possess only weakly acidic properties and are more indifferent in chemical reactivity than any of the commoner elements. Their salts even with strong alkalies are readily hydrolised by boiling aqueous solutions.

Of the above compounds, the tantalates, niobates and their corresponding pentoxides, the fluorides, and double fluorides of potassium are the most important as they are used extensively in methods of chemical analysis and in the metallurgical extraction from its ores. The potassium fluotantalate K_2TaF_6 is sparingly soluble in hydrofluoric acid solution, whilst the potassium oxyfluoniobate K_2NbOF_5 is appreciably soluble. This difference in solubilities enables the separation of tantalum from niobium to be effected.

These weak chemical reactive properties have made the problem of metallurgical extraction and the analysis of the minerals a difficult procedure, which can only be handled by the experienced chemist. A great deal of investigation has been carried out in recent years on the formation of organic complexes with the pentoxides of tantalum and niobium (Schoeller) which has contributed much towards the advancement of the chemistry of these elements. The most important of these are the tartaro and oxalo complexes, the tannin complexes and the salicylic complexes. (100.)

USES.

Tantalum metal is used in the form of wire and thin sheet between 0.004 and 0.010 inches in thickness (81), as a protective coating on other metals by *metal spraying* (84), in *alloys,* and as a constituent of hard *carbide materials* for general wear resisting surfaces. (81).

On account of its remarkable resistance to corrosion and its resistance to attack by acids, tantalum has been largely used in the fabrication of acid proof plant apparatus in *chemical industry.* (81.) It is used in the form of various types of steam heating equipment in absorption systems for *hydrochloric acid gas* on account of its ability to withstand high internal pressure and its high rate of heat transfer. It is also used for valve needles and venturi nozzles in *chlorine manufacture.* (81, 103.)

It is used in the manufacture of a number of special parts such as guides, nozzles, spinnerettes and corrosion resistant parts in *cellulose and rayon manufacture* and in *general industry* as injectors, ejectors, fountain pen parts, meter pivots, temperature control apparatus, covering pump shafts for acid solutions, valves, etc. (81, 103.)

It has found much use in the manufacture of electric discharge devices in the *electronic tube industry* (81) for ultra high frequency radio power such as for cathodes, getter cups, grids, plates, support rods, rectifiers, photoelectric cells, neon lamps, etc. The properties which adapt it to this use are its high melting point, low vapour pressure and its getter characteristics, *i.e.*, its power to absorb and keep gas even at pressures as low as 0.001 micron.

Tantalum-nickel alloys are used in radio tubes and *tantalum-tungsten* alloys in manufacture of fountain pen parts. (96.)

One of the chief sintered powder metal products is the *carbide of tantalum* (81) and is used alone or as a constituent with tungsten and nickel in hard carbide materials for cutting tools, wire drawing dies and general wear resistance surfaces. Unlike tungsten carbide, tantalum carbide has a melting point greatly above the metal. The figure given is 3875°C with an accuracy of $\pm$ 140°C. Tantalum-titanium carbides are also produced for steel cutting tools.

Niobium does not appear to have found much use as the metal in industry up to the present but it has gained some prominence as an alloy, and seems to have been used more in this form than tantalum.

The *alloys of tantalum and niobium* with *iron* have been used for hardening and toughening steels. Additions of niobium to *heat resisting steels* improve their resistance to creep. (89.) Tantalum and niobium when added to *chromium-nickel steels* of the stainless type inhibit intergranular deterioration (weld decay), when such steels are exposed to elevated temperatures and chemical corrosion. The amounts of niobium added are up to about 2%. In the case of tantalum larger percentages are required and it is not considered as economical as niobium for this purpose.

PART 3.

Western Australian Tantalum and Niobium Minerals.

By Dorothy Carroll, Ph.D., D.I.C., and H. P. Rowledge, A.A.C.I., A.W.A.S.M.

INTRODUCTION.

The tantalum and niobium bearing minerals of Western Australia were studied by the late Dr. E. S. Simpson for many years. He had unique opportunities for examining and collecting these minerals, for as Government Mineralogist he handled all minerals which were examined in the State Laboratories from 1897 to 1939 and made a collection of the best specimens. At the time of his death he was engaged in writing a book entitled "The Minerals of Western Australia." Much of the information given here has been taken from his unpublished manuscript and private notebooks; without this information a detailed description of the tantalum and niobium minerals of this State could not have been written, for although analyses and descriptions have been published from time to time in official reports and in a few scientific journals, there is much detail which has never previously been recorded.

The tantalum and niobium bearing minerals occur in early Pre-Cambrian pegmatites in a number of districts in Western Australia, and are present in sufficient quantities in two districts for high-grade tantalum ore to be produced (this applies likewise to niobium ore for which there has been no demand up to the present). The most important district is that embracing Wodgina, Strelley, Tabba Tabba and adjacent districts in the North-West. A smaller field occurs at Greenbushes in the South-West, where, in 1893, stibiotantalite, a mineral new to science, and the first tantalum-bearing mineral recorded in Western Australia, was found. Manganotantalite, tantalite, manganocolumbite, columbite, the rare-earth tantalates, tapiolite, and other tantalum and niobium minerals were subsequently discovered in various areas, often associated with tin ore.

These minerals have been chiefly found as the original constituents of pegmatite veins or in soils or gravels derived from them by weathering. The main felspar constituent of these pegmatites is always albite.

The following minerals are associated with the tantalates and niobates: lepidolite, muscovite, tourmaline, beryl, topaz, spodumene, amblygonite, lithiophilite, purpurite, psilomelane, maitlandite, nicolayite, pilbarite, petalite, gadolinite, garnet, cassiterite, helvite, apatite, autunite (rare), gahnite. The detrital deposits which include eluvial and alluvial material contain many of these minerals. Other minerals not found *in situ* in the pegmatites but occurring in concentrates of alluvial ore are: wolfram, scheelite, bismuth ochres, ilmenite, magnetite, rutile, monazite, ilmenorutile, epidote, with many common rock-forming minerals.

Cassiterite does not usually occur in the tantaliferous pegmatites but is frequently present in pegmatites adjacent to them and in consequence the detrital material often contains cassiterite as well as tantalite. The specific gravity of cassiterite, 6·9, is close to that of tantalite, 6·5-7·9, consequently it cannot be separated easily from it by gravity concentration methods. As the presence of cassiterite in the concentrates deleteriously affects the market value, it is advisable to avoid mining the tantalite-bearing material containing this mineral. Its presence can readily be detected by a simple test. Place the mineral fragments in a zinc dish and cover with hydrochloric acid, one part of acid to one part of water, and stand until effervescence ceases. The cassiterite will be coated with a greyish white deposit of metallic tin, whilst the tantalite will remain unchanged.

The presence of any tantalite or cassiterite in the detrital material will serve as a good indicator as to which is likely to be found in the adjacent pegmatites.

The tantalum and niobium minerals found in this State are described in detail in subsequent pages and are grouped in the following manner.

I. TANTALITE GROUP.
II. STIBIOTANTALITE GROUP.
III. TAPIOLITE GROUP.
IV. RARE EARTH TANTALATES.
V. MISCELLANEOUS.

I. TANTALITE GROUP.

Tantalite	$FeTa_2O_6$
Manganotantalite	$MnTa_2O_6$
Columbite	$FeNb_2O_6$
Manganocolumbite	$MnNb_2O_6$

The minerals of this group are tantalates and niobates of iron and manganese. The elements tantalum, niobium, iron and manganese are isomorphously replaceable so that there is a continuous series grading from tantalite through manganotantalite and columbite to the end member manganocolumbite. The composition is expressed $(Fe, Mn)\ (Ta, Nb)_2O_6$.

In the natural minerals iron and manganese are both always present, as are also tantalum and niobium. They have been named according to which is present in the greatest molecular proportion, *e.g.,* when iron exceeds manganese and tantalum exceeds niobium, the mineral is called Tantalite.

The tantalites and columbites crystallise in the orthorhombic system and are heavy black, opaque minerals, somewhat resembling cassiterite, but often showing well-defined orthorhombic crystal faces, generally a(100). The specific gravity varies according to the composition from 7·90 (tantalite) to 5·20 (columbite), which therefore forms a convenient method of determining the composition (see Fig. 5).

II. Stibiotantalite Group.

Stibiotantalite $Sb_2(Ta, Nb)_2O_8$.

This group contains stibiotantalite, stibiocolumbite and bismutotantalite, of which the only one so far found in Western Australia is stibiotantalite. Stibiotantalite and stibiocolumbite form an isomorphous series in which tantalum and niobium appear to be mutually replaceable in all quantities (see Fig. 13), but as far as is known bismuth only replaces antimony to a limited extent. The only place at which stibiotantalite has been found is at Greenbushes. No stibiocolumbite has so far been identified although minerals bordering on stibiocolumbite occur. Stibiotantalite crystallises in the orthorhombic system with forms somewhat similar to those of columbite. It is a brown to yellow mineral with a resinous lustre and is fairly soft and brittle. At Greenbushes it occurs intergrown with tantalite and is generally not well crystallised. Many detrital pebbles show a banding of tantalite and stibiotantalite. It may partially replace tantalite and in some polished sections described by A. B. Edwards, it has obviously crystallised after tantalite.

III. Tapiolite Group.

Tapiolite	$FeTa_2O_6$
Ixiolite	$MnTa_2O_6$
Manganomossite	$MnNb_2O_6$
Ilmenorutile	$FeNb_2O_6 + Ti_3O_6$
Struverite	$FeTa_2O_6 + Ti_3O_6$
Nigrine	$TiO_2 + Fe''\ Nb_2O_6 + Fe'''\ NbTiO_6$

The last three of these minerals are tantalates and niobates in which the titanium dioxide molecule has entered into solid solution with the tantalate and niobate. They all form a complete series of isomorphous replacements and gradate from the tantalate and niobate through to the end member, rutile. The relationships in this group are shown in Fig. 14, p. 129. These minerals crystallise in the tetragonal system, and are black and opaque with a strongly adamantine lustre approaching metallic. The specific gravity ranges from 7·90 (tapiolite) to 4·3 (nigrine). They are often well crystallised. It has been suggested by A. B. Edwards that the name ilmenorutile be replaced by "tantalorutile" or some other name which expresses the composition better than ilmenorutile as the original ilmenorutile only contained iron and not tantalum or niobium.

IV. Rare Earth and Uranium Tantalates.

Yttrotantalite	$Y_2Ta_2O_8$
Tantalopolycrase	$YTi_2TaO_8 + Ti_4O_8$
Tanteuxenite	YTi_2TaO_8 $(+CaTiTa_2O_8)$
Euxenite	YTi_2NbO_8 $(+CaTiNb_2O_8)$
Calciosamarskite	$Y_2Nb_2O_8 + (Fe''Ca)U^4Nb_2O_8$

In this group tantalum and niobium are combined with titanium and uranium in a continuous series of isomorphous replacements both simple and complex. All the rare earths are replaceable amongst themselves and with titanium, uranium, zirconium, tantalum, niobium, and the common elements, calcium, iron, manganese, etc., simple types are:—Ce:La, etc., Y., etc.; Th:U^4, (ZrTi); Ti:Zr. Th,U, etc. Complex types are:—Y_2: CaTi, CaU^4, CaZr; Ti_2: YNb, YTa; CaNb: YTi,CeTi; Fe″Nb(Ta): CeTi,Fe‴Ti, etc. Calcium, magnesium, manganese and ferrous iron appear possibly in such combinations as $CaTa_2TiO_8$,$FeNb_2TiO_8$. UO_2 is aut-oxidised to UO_3 with the simultaneous production of lead. Hydration of the original mineral gives rise to isotropic modifications.

These minerals crystallise in the orthorhombic system and are brown to brownish black with a marked resinous lustre. The specific gravity ranges between 4·6 and 6·8.

V. Miscellaneous Minerals.

Microlite	$NaCaFTa_2O_6$
Simpsonite	$CaO.5Al_2O_3.4Ta_2O_5.2H_2O$
Ainalite	$SnO_2+(TaNb)_2O_5$

This group contains three minerals which do not fit into any of the previous groups.

Microlite is a fluotantalate of sodium and calcium crystallising in the isometric system. In Western Australia it is generally grey or pinkish grey in colour. It often occurs as a coating and a replacement of tapiolite, some pebbles containing a core or a few black grains of tapiolite or manganotantalite.

Simpsonite is a hydrous tantalate of calcium and aluminium. It is a colourless mineral associated with a pale creamish alteration product which is probably microlite. It crystallises in the hexagonal system and has been found at Tabba Tabba where it is associated with manganotantalite. Both microlite and simpsonite have been included in tantalite ores sold from Wodgina.

Ainalite is a tantalum and niobium bearing cassiterite and has been found at two places in Western Australia, namely Greenbushes and Ubini. Examination of polished sections tends to the belief that they are mixtures of cassiterite with tantalite or tapiolite, the latter possibly containing some tin dioxide in solid solution.

DISTRIBUTION IN WESTERN AUSTRALIA.

Tantalum and niobium minerals have a wide distribution in Western Australia, the localities from which they have been recorded are given in Table III and are shown on the maps (Plates I and II.).

The minerals of the Tantalite Group occur in the greatest quantity and have the widest distribution. Minerals of the other groups are much less abundant and in some localities have been found as odd specimens only. Details of the occurrences are given in the following descriptions. In Part I details are given of the tantalum minerals mined as ores of tantalum in the various localities.

TABLE III.

DISTRIBUTION OF THE TANTALUM-NIOBIUM MINERALS IN WESTERN AUSTRALIA.

	Mineral.	Kimberley.	North-West.	Murchison.	South-West.	Central.	Eucla.
Group I.	Tantalite $(Fe, Mn)(Ta, Nb)_2O_6$	Mt. Dockrell	Pilgangoora (McPhee's Range), Nullagine, Tabba Tabba, Western Shaw	....	Balingup, Greenbushes	Holleton, Logan's Find	Bellinger, Dundas, Israelite Bay
	Manganotantalite $(Mn, Fe)(Ta, Nb)_2O_6$	Collier Bay	Moolyella, Mt. Francisco, Pilgangoora (McPhee's Range), Stannum, Strelley, Wodgina, Woodstock	Poona	Melville	Gibraltar, Kathleen Valley, Holleton, Londonderry, Ubini, Victoria Rocks	Bellinger
	Columbite $(Fe, Mn)(Nb, Ta)_2O_6$	....	Abydos, Carlindi, Cooglegong, Hillside, Pilgangoora (McPhee's Range), Pinnacle Hill, Stannum, Strelley, Tabba Tabba, Wodgina	....	Balingup, Jimperding, Lake Moore, Greenbushes, Smithfield	Logan's Find	
	Manganocolumbite $(Mn, Fe)(Nb, Ta)_2O_6$	....	Cooglegong, Lalla Rookh, Moolyella-Talga, Mt. Francisco, Pilgangoora (McPhee's Range), Wodgina, Yinnietharra	Coodardy, Poona	Mt. Dale, Ravensthorpe	Coolgardie, Gibraltar, Londonderry, Ubini	
Group II.	Stibiotantalite $Sb_3(Ta, Nb)_2O_8$	....	....	....	Greenbushes	....	....
Group III.	Tapiolite $FeTa_2O_6$	....	Pilgangoora (McPhee's Range), Tabba Tabba, Strelley, Woodstock, Wodgina	....	Greenbushes, Jimperding	....	....
	Ixiolite $MnTa_2O_6$	....	Wodgina	....	....	Londonderry	....
	Manganomossite $MnNb_2O_6$	....	Yinnietharra	....	....	....	....
	Ilmenorutile $FeNb_2O_6+Ti_3O_6$	....	Dalgety Downs, Globe Hill	Poona	Lake Moore, Melville	....	....
	Struverite $FeTa_2O_6+Ti_3O_6$	....	Globe Hill	....	Smithfield	....	....

Group IV.	Yttrotantalite $Y_2Ta_2O_8$	....	Cooglegong, Split Rock Station	....	....	....	....
	Tantalopolycrase $YTaTi_2O_8+Ti_4O_8$	....	Abydos, Cooglegong, White Springs	....	Greenbushes	....	....
	Tanteuxenite $YTi_2TaO_8(+CaTiTa_2O_8)$	....	Abydos, Cooglegong, Mt. Francisco, White Springs, Wodgina, Woodstock	....	....	....	....
	Euxenite $YTi_2NbO_8(+CaTiNb_2O_8)$	....	....	....	Mt. Dale	....	Fraser Range
	Calciosamarskite $Y_2Nb_2O_8+(Fe''Ca)U^4Nb_2O_8$	....	Hillside Station	....	....	....	....
Group V.	Microlite $NaCaF(TaO_3)_2$	Mt. Dockrell	Pilgangoora (McPhee's Range), Hillside, Kangan Station, Mooyella, Strelley, Tabba Tabba, Woodstock, Wodgina	....	....	....	....
	Simpsonite $2H_2O.CaO.5Al_2O_3.4Ta_2O_5$	....	Tabba Tabba	....	....	....	....
	Ainalite Cassiterite with a small percentage of $(Ta, Nb)_2O_5$	....	....	....	Greenbushes	Ubini	....

DESCRIPTION OF THE MINERALS.

(I) TANTALITE GROUP.

As mentioned previously, the minerals of the tantalite group crystallise in the orthorhombic system. The Western Australian minerals are generally well-crystallised, manganocolumbite having better developed crystals than tantalite and manganotantalite. The forms recognised for manganocolumbite are:—a(100), b(010), c(001), u(133), n(163), β(121), m(110), y(210), z(530), g(130), p(24·7·0), or (25·7·0), l(106), k(103), f(102), i(011), e(021), q(023), and several vicinal faces. Typical combinations are shown in Figures 8 and 9, which are reproductions of drawings made by the late E. S. Simpson. Further descriptions are given for the minerals in the various localities.

The orthorhombic iron-bearing tantalate is called tantalite, and includes all those minerals which contain molecularly greater proportions of iron than of manganese. Where manganese predominates the mineral is called manganotantalite.

TANTALITE.

Mt. Dockrell.—Alluvial tin ore from workings in Willy Willy Creek, nine miles south-east of Mt. Dockrell, contained 20-25% of tantalite. An analysis of this tantalite showed:—

Ta_2O_5	Nb_2O_5	FeO	MnO	H_2O+	H_2O-	S.G.
77·32	5·74	10·34	5·72	0·49	0·05	7·18

Other samples sent in from near Mt. Dockrell also contain tantalite. One of these is a pegmatite, a sample from which contained traces of cassiterite and 27% of tantalite assaying approximately Ta_2O_5, 78%; Nb_2O_5, 7%. 10-23% of tantalite is associated with alluvial cassiterite obtained 17 miles north of G. Button's block No. 2069. (46.)

Nullagine.—Concentrates obtained from several tons of the conglomerate at Nullagine consisted of the following minerals: barite, quartz, felspar, kaolin, zircon, xenotime, limonite, monazite, rutile, cassiterite, magnetite, ilmenite, chromite, tantalite, pyrite and gold. (61.)

Pilgangoora.—A little tantalite has been found associated with columbite, microlite and tapiolite at various places in the vicinity of Pilgangoora (McPhee's Range). (15, 18, 33, 50, 69.)

Yinnetharra.—Specimens of tantalite stated to have been found in the Yinnietharra district are black with a submetallic lustre. One piece is a mass of radiating tabular orthorhombic crystals which have S.G. 6·90 equal to Ta_2O_5, 62%; Nb_2O_5, 22%; FeO, 7·87%. A large irregular piece without crystal faces has S.G. 7.63 equal to Ta_2O_5, 80·1%; Nb_2O_5, 5·4%; FeO, 13·10%.

Greenbushes.—Tantalite was discovered at Greenbushes in 1900 by E. S. Simpson when examining apparently clean tin concentrates from alluvial ground. These concentrates could not be smelted and refused to yield tin.

Tantalite is moderately abundant in a greisen and in alluvium at the southern end of the tinfield where it is associated with stibiotantalite. (See Plates III. and IV.) Other occurrences are in Spring Gully, Floyd's Gully, Bunbury Gully and Elliot's Gully (for further details see Part 1, page 40). The principal occurrence is in the lode on the old Enterprise lease, now M.C.1, at the head of Bunbury Gully. The tantalite occurs in comparatively coarse and very fine pieces, devoid of all crystal faces, but exhibiting an ill-defined cleavage. It is in worn detrital pieces from the size of fine shot to masses over 24 lbs. in weight. Some of the pieces are somewhat rounded and covered with a smooth, hard, and firmly adherent coating of ferruginous bauxite. On splitting some pieces of tantalite thin fracture fillings and surface replacements of yellow resinous crystalline stitiotantalite are found and most of the samples of ore assayed contain a little of this mineral. The tantalite is black and dense and has an appearance not unlike cassiterite. It is seldom, if ever, in orthorhombic fragments like the manganotantalite from the North-West and tends to be more massive. The only crystalline faces present, and these extremely worn, have rather a tetragonal appearance suggesting tapiolite rather than tantalite. Tantalum occurs also in small amounts in solid solution in clean cassiterite and a crystal from the South Cornwall lode had the following composition: SnO_2, 97·63%; Ta_2O_5, 1·76%; FeO, 0·61%. SnO_2 in small amounts occurs in the tantalite as an essential constituent, for in a polished section of a specimen containing 1·51% SnO_2 no cassiterite was visible (78, p. 738). The tantalum in cassiterite specimens is present as a mixture of tantalite or tapiolite and Edwards has suggested "that at high temperatures cassiterite can form a solid solution with the isomorphous tapiolite molecules, to an unknown extent, but that at lower temperatures the tapiolite is precipitated and migrates to the grain boundaries of the cassiterite crystals. A small proportion of tapiolite may remain in solid solution even at ordinary temperatures."

Tantalite has been found at intervals along a north-south belt from alongside the railway station to the middle of the Vulcan, M.C. 4 (old M.L. 436 and 476).

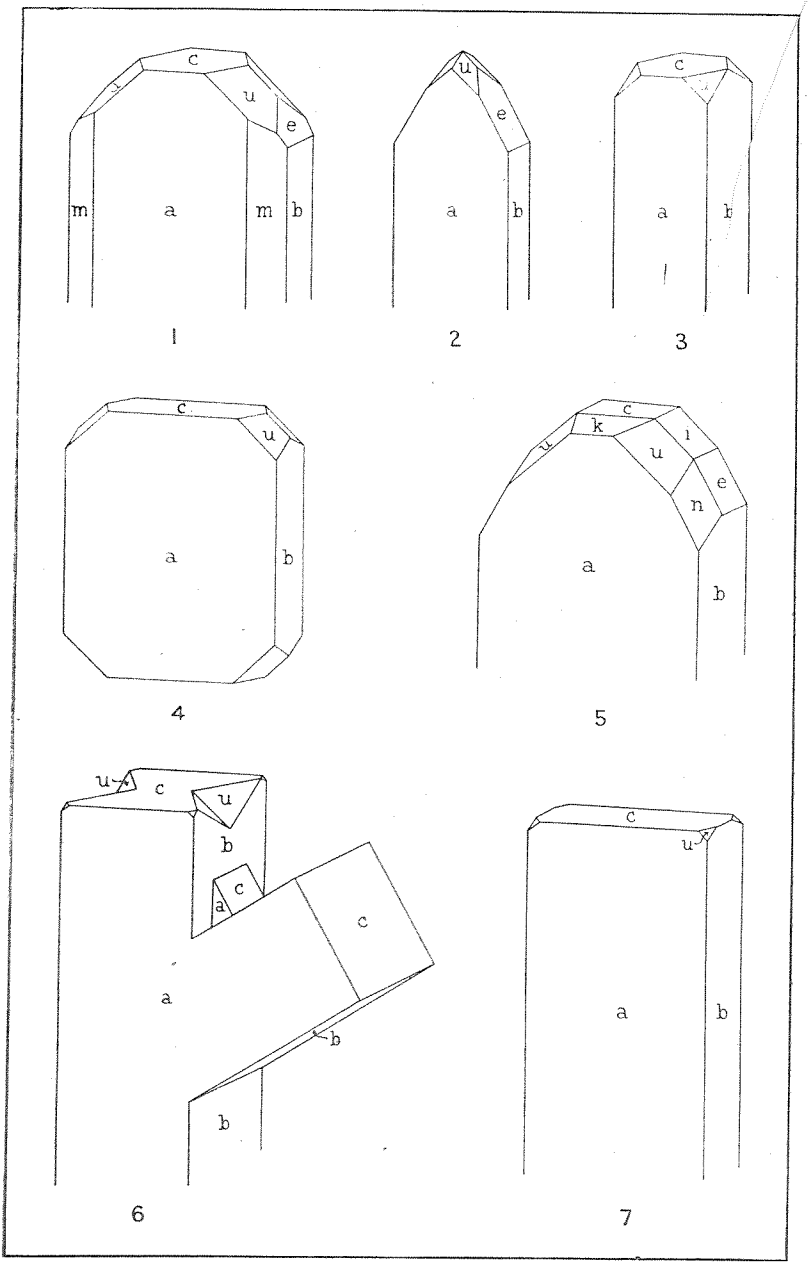

Fig. 8.—Manganocolumbite-tantalite Crystals. 1. Manganocolumbite Pilgangoora, G. 5.77. Similar crystals occur at Strelley, Wodgina and Mt. Francisco. 2. Manganocolumbite, Poona. 3. Manganocolumbite, Londonderry. G. 6.10. 4. Manganocolumbite. This form occurs at Pilgangoora, Moolyella, Mt. Francisco and Tabba Tabba. 5. Manganocolumbite, Wodgina. Crystal wt. 9 grams, G. 6.33. 6. Manganotantalite, Wodgina. Complex crystal showing twinning on (100) and (021). 7. Manganotantalite, Wodgina. The typical form. (After E. S. Simpson. All figures drawn to scale.)

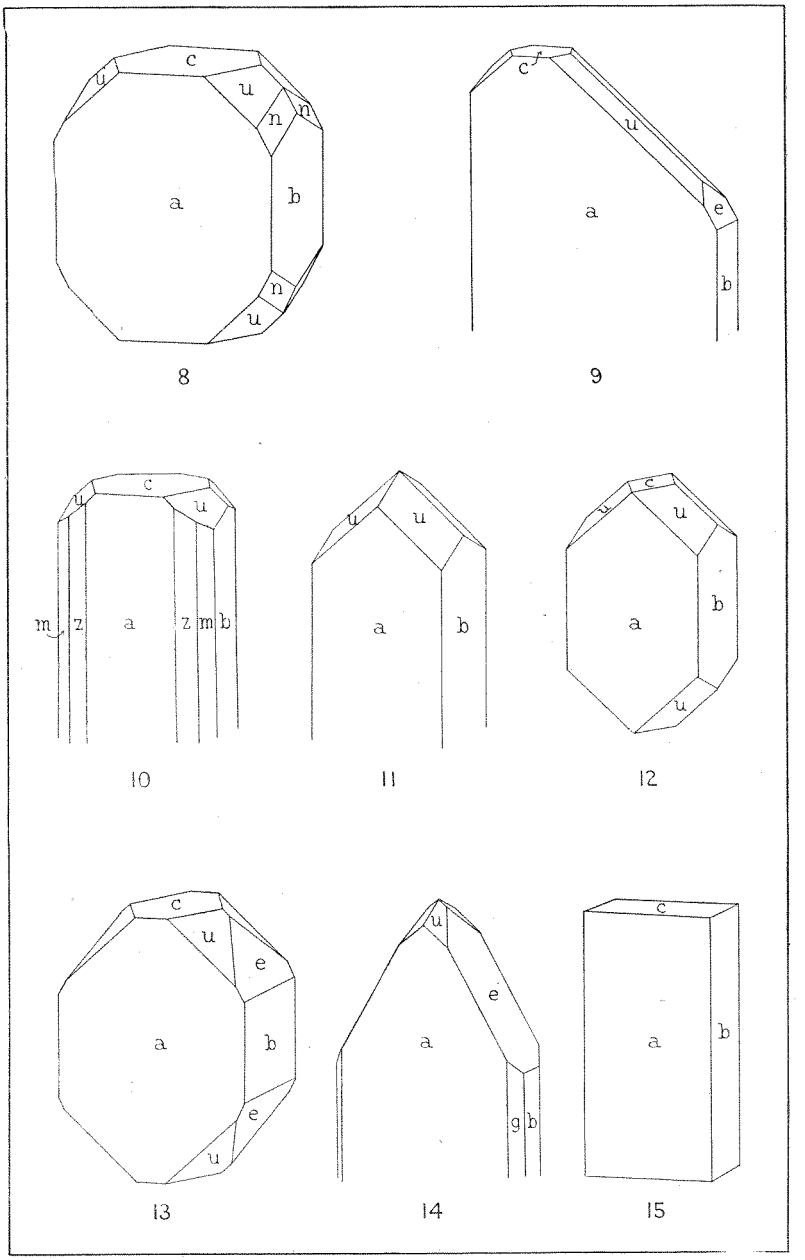

Fig. 9.—Manganocolumbite Crystals.—8. Manganocolumbite, Pilgangoora. 9. Manganocolumbite, Poona. G. 5.90. 10. Manganocolumbite, Londonderry. G. 5.47. 11. Manganocolumbite, Mt. Francisco. Typical also of ferrocolumbite from Woodstock. G. 5.72. 12. Manganocolumbite, Pilgangoora. G. 6.05. 13. Manganocolumbite, Pilgangoora, Wodgina, Mt. Francisco. 14. Manganocolumbite, Gibraltar. 15. Manganocolumbite, Pilgangoora. (After E. S. Simpson. All figures drawn to scale.)

It is stated that prior to 1942 about 10 tons of tantalite carrying 80% Ta_2O_5 and 2% Nb_2O_5 have been raised, principally from M.C. 1 (or earlier leases covering the same area) and further small parcels are being produced from time to time.

Generally the tantalite contains a high percentage of Ta_2O_5 as shown by the following analyses:—

	A. G.S.L. 2573/23 Enterprise	B. G.S.M 2025 Enterprise	C. Galt's Claim 1933.
	%	%	%
Ta_2O_5	75.87	80.61	73.30
Nb_2O_5	2.89	2.50	4.60
TiO_2	0.27	0.71	0.82
SnO_2	4.96	1.51	4.67
FeO	9.53	10.89	7.72
MnO	3.51	3.78	5.44
CaO	nil	nil	0.40
MgO	nil	0.19	0.08
Sb_2O_3	trace	—	0.71
Al_2O_3	1·00	—	0·87
WO_3	—	0.13	—
Fe_2O_3	1.28	—	—
SiO_2	0.64	nil	1.39
NiO	—	0.02	—
$CeYO_3$	—	nil	—
H_2O+	0.59	0.14	—
	100.54	100.48	100.00
S.G.	7.47	7.74	
Analyst	D.G.M.	E.S.S.	

A. Analysis of bulk sample of 1 cwt. gravel and boulder alluvial sent to the British Empire Exhibition in 1924. (Fragments showing stibiotantalite were removed.)

B. Analysis of clean picked fragments of tantalite from the 1 cwt. sample.

C. Analysis of parcel shipped by G. A. Galt from leases now covered by M.C.1 to America in 1933. (From a kaolin lode on the west side of the Bridgetown road about 1 mile south of Greenbushes.)

Various concentrates have assayed as follows:—

Sample No.	Description.	Ta_2O_5	Nb_2O_5	SnO_2
		%	%	%
1404/05	Alluvial tantalite	68·50	5·46	...
1405/05	Lode tantalite	66·86	10·00	...
1423/26	Alluvial tantalite, ½-mile south of Greenbushes	73·13	2·30	...
1958/29	Concentrate from 59 tons of lode (Barrymore and Huitson's M.L.)	41·47	15·40	26·01
3918C	Battery concentrate, Enterprise Mine ...	53·80	4·38	18·53

A concentrate from the wash near a pegmatite on Barrymore and Huitson's M.L. in 1928 consisted of cassiterite, tantalite, stibiotantalite, quartz, gahnite, and kyanite. It contained $Ta_2O_5+Nb_2O_5$, 25·25%; Sb_2O_3, 1.06%; SnO_2, 54.90%.

Odd pieces of tantalite have been found within half a mile of the railway station at North Greenbushes. One 10 gram pebble had S. G. 7·50. It is massive, black, worn and has a somewhat tetragonal appearance.

In 1936 alluvial and lode columbite was found two miles north of Greenbushes associated with some cassiterite and a little tantalite. The specific gravity of the alluvial tantalite is 7·02, 6·95, 6·76, and of the lode, 6·94. The tantalite is black, opaque, massive and shows worn crystal faces and occasional traces of orthorhombic crystallisation.

A concentrate from a lode at Greenbushes examined in 1937 contained: Ta_2O_5, 28.4%; Nb_2O_5, 22.1%; SnO_2, 35.7%. An appreciable quantity of antimony was also present.

In 1938 W. L. Griffiths sent in some worn crystal aggregates of tantalite which formed slightly barrel-shaped masses. Definite a faces are present, with vestiges of b and c.

Four samples of material obtained by boring on M.C. 6 in 1939 gave the following assays:—

No.	Bore.	Depth.	SnO_2.	$(Ta,Nb)_2O_5$	Description.
		ft.	%	%	
4976/39	68	0–10	70·6	8·5	Cassiterite, ilmenite, tantalite, magnetite, quartz, stibiotantalite.
4977/39	70	0–20	57·2	6·1	Cassiterite, magnetite, ilmenite, tantalite, limonite, biotite, quartz stibiotantalite.
4978/39	71	0–30	80·9	9·9	Cassiterite, tantalite, stibiotantalite, limonite, ilmenite, quartz.
4979/39	72	0–25	79·2	9·1	Cassiterite, tantalite, stibiotantalite, ilmenite, quartz.

The tantalite in grains under the microscope is a reddish-brown powder with a high refractive index and a fairly high birefringence. It is strongly pleochroic from a pale yellow to a deep reddish-brown which is almost black. Straight extinction; uniaxial.

Taken in conjunction with the extremely low niobium content the optical data indicate that the mineral which has been called tantalite actually is tapiolite. The analyses agree fairly well with that of tapiolite from Strelley except that the niobium content is somewhat higher in the Greenbushes mineral.

Tantalite also occurs, as noted above, but it appears to be only present in the alluvial and lodes to the west of the Greenbushes station. The tantalite from the old Enterprise lease, now M.C.1, is of very even grade and is probably all tapiolite. No specimens with a high niobium content have been recorded from this lease. (7,9,11,16,17,19, 23,24,33,58,67,68,77).

Holleton.—Very small quantities of a mineral of the tantalite group have been identified in a concentrate from an albite pegmatite. The tantalum mineral is associated with garnet. (55.)

Logan's Find.—A few small grains of tantalite were found in a lepidolite-bearing pegmatite at Logan's Find. It was not associated with cassiterite.

Bellinger.—In a mica vein prospected by T. Trott in 1907 near the Bellinger Sand Patch a few fragments of tantalite were obtained. The tantalite ranges in composition from tantalite and manganotantalite

to manganocolumbite. The tantalite has S.G. 7·6, 7·6, 7.1, and 7.1 for different fragments. The iron is more abundant than manganese and the tantalite is associated with rutile and tourmaline. (23, 28.)

Dundas.—Tantalite carrying about 70% Ta_2O_5 occurs as small masses up to half an inch in length in a four-foot albite pegmatite seven miles north of Dundas. An albite-microcline-biotite pegmatite from about 12 miles south-south-east of Dundas contains a small amount of tantalite which is associated with a little garnet. (43, 46.)

Israelite Bay.—Rolled pebbles of tantalite with specific gravity 7·1 and 7·6 were obtained here many years ago. (16.)

Manganotantalite.

Collier Bay.—Saleable tantalum ore assaying 68% Ta_2O_5, 13·69% Nb_2O_5 has been reported as coming from the vicinity of Collier Bay, but the exact locality has not been fixed. (56.)

Moolyella.—This locality is chiefly of importance for its tin ores, but manganocolumbite and sometimes a little manganotantalite, is present in all stream tin concentrates. Quantities recorded are: 8·5, 13·5, 15·5 and 46·5% respectively.

A single fragment of manganotantalite with a radiating crystalline structure was found in a parcel of tin ore. It has an intense black colour, with a metallic lustre, and S.G. 7·3. It is an aggregate of a number of wedge-shaped crystals.

In 1930 a new find of marketable tantalum ore was made at the Two Sisters Hills on Brockman Creek, six miles north-north-west of Moolyella. Several parcels of coarse detrital manganotantalite and manganocolumbite were examined and showed:—

		Ta_2O_5 %	Nb_2O_5 %	SnO_2 %
896/30	Detrital	67·79	4·51	5·96
2489/30	,,	63·31	9·61	Present
2488/30	,,	56·14	12·62	
2490/30	,,	62·55	4·02	
2495/30	Lode close to 2489/30	57·5	25·5	

In 1935 F. G. Forman collected three detrital pieces of tantalite weighing 84 to 110 grams. The two largest pieces have S.G. 6·82 and are manganotantalite. The largest piece consists of a large flat rosette made up of six twinned crystals, greyish black in colour. The S.G. of this piece is 6·75, equal to Ta_2O_5, 57·8%. Nb_2O_5, 25·9% (16, 17, 23, 33, 57).

Mt. Francisco.—Manganotantalite occurs in a six-foot pegmatite about two miles east of the Frisco Tin Mine. It is present in a highly micaceous part of the pegmatite, and the tantalite is in small sheaves of tabular crystals, which when concentrated assay, Ta_2O_5, 61·0%; Nb_2O_5 19·6%; SnO_2, 1·8%. Another concentrate from this pegmatite had a specific gravity of 6·63, equal to 53·3% Ta_2O_5. A concentrate containing Ta_2O_5, 50%; Nb_2O_5, 31%; SnO_2, 1%, came from 24 miles south of Mt. Francisco. This locality is more important for columbite than for tantalite. The tantalite from G. Hall's P.A. is in typical small black orthorhombic crystals with a, b and c faces and pyramids. (30.)

Pilgangoora (McPhee's Range).—Tantalite and columbite were discovered near Mt. York in 1904. There has been some confusion of material from this locality as different parts of it have been variously known as McPhee's Range, Green's Well, Mt. York (or Chingamong). For the earlier samples examined the localities are not definite (see Part 1, p. 35).

The minerals associated with the tantalite and columbite in the pegmatites of this area are quartz, albite, muscovite, lepidolite, cassiterite, spodumene, spessartite, and beryl. Microcline is present in some of the pegmatites, but in those containing tantalite and columbite the felspar is usually albite. Spodumene appears to be fairly plentiful in the district and is closely associated with the tantalite and columbite. It occurs as pale greyish mauve crystallised plates, and at Gilbert and Houston's workings it is in greyish green columnar bands.

The main part of the ore raised has been from the detritus shed from the pegmatites. The tantalite varies from a columbite with S.G. 5·35 to a tantalite with S.G. 6·84. Generally it has a dull rusty black surface but occasional crystals exhibit brilliant black metallic faces, especially a. This face and b are often striated vertically. The ore from here is characterised by the very variable extent to which Ta and Nb replace one another, the richest ores found at Pilgangoora have been nearly pure manganotantalite with S.G. 7·80 and 7·74. A sample of dressed ore from Green's Well brought to Perth many years ago by A. Gibb Maitland consisted of both alluvial and lode ore in angular fragments from 1 to 20 mm. in diameter. A few excellent crystals occurred in it of which the following details are available:—

No.	Size in mms.	S.G.	Faces Present
1	6 × 9 × 16	6·31	a, b, c, u.
2	3 × 10 × 11	5·50	a, b, c, u, e, y, m, g.
3	6 × 10 × 13	6·49	a, b, c, q, p. (?)
4	7 × 9 × 18	6·05	a, b, c, u.
5	7 × 7 × 12	6·32	a, b, c, u, k.
6	11 × 19 × 26	5·77	a, b, c, u, e, m.

Parcels of ore with a wide range of specific gravity in the pebbles of one parcel are:—

Locality.	S.G.	Ta_2O_5%	Nb_2O_5%
1½ miles north-east of M.L. 80	6·05 — 7·69 M/7 = 6·73	35·4 — 81·5 M = 57·2	46·4 — 4·2 M = 26·4
Bell's M.L. 100, Green's Well	5·35 — 6·84 M/8 = 6·45	7·1 — 60·3 M = 48·8	23·5 — 72·3 M = 34·1

These parcels are mixtures of manganocolumbite and manganotantalite. Both alluvial and lode concentrates contain a little cassiterite.

A number of alluvial fragments partly crystalline, obtained at Green's Well in 1929 had an average density of 6·65 (M/15), with a range from 6·12 – 7·19. This is equal to Ta_2O_5, 54·9%; Nb_2O_5, 28·5%.

The following analyses have been made of manganotantalite from Pilgangoora.

	A. 1286E (S404 ×).	B. 317E
	%	%
Ta_2O_5	60·15	56·08
Nb_2O_5	22·68	25·85
TiO_2	0·36	0·25
SiO_2	0·30	
SnO_2	0·22	0·06
MnO	15·90	16·82
FeO	0·48	0·89
Fe_2O_3	*Nil*	
Al_2O_3	0·08	
CaO	*Nil*	
MgO	*Nil*	
H_2O+	*Nil*	
Total	100·17	99·95
S.G.	6·69	6·75
Analyst	D.G.M.	H.B.

A. is a single crystal weighing 9·5 grams from the outcrop of the second lode north of the McPhees old workings 9 miles east of Gillam's Well.

B. is a rhombic detrital crystal from east of Wodgina. The common forms of this and other crystals in the sample are a, b, c, u, with sometimes k.

The largest crystals of A (S404) showed a, b, c, u(133), s(263) and q(023) faces. A number of flattish twinned crystals were also present in this sample.

The following partial analyses of concentrates consisting principally of tantalite from Pilgangoora show the variation in composition.

TABLE IV.

PARTIAL ANALYSES OF TANTALUM CONCENTRATES FROM PILGANGOORA.

No.	Locality.	S.G.	Ta_2O_5.	Nb_2O_5.	FeO.	MnO.
			%	%	%	%
1386E	Green's Well, gravelly, well-crystallised	6·73	57·0	26·7	...	...
860E	20 miles east of Wodgina ...	6·42 (bulk)	48·3	33·8	6·3	10·7
861E	do. do. ...	6·46	49·2	33·0	...	...
859E	20 miles east of Wodgina (crystal)	6·70	56·3	26·5	1·2	15·1
1949/28	5 miles north of Green's Tank and 3 miles south of Hooley's Find (alluvial)	...	52·89	22·78	3·53	...
426/30	Pilgangoora	6·21–7·19	67·19	4·13	7·22	...
429/30	do.	5·90–6·04	51·67	16·92	...	...
2402/31	Theleman's Claim, Pilgangoora	7·24 (average)	70·01	5·46	...	...
5858/37	14 miles north-east of Pilgangoora	6·685	55·9	27·6	...	...
5779/37	14 miles north-east of Pilgangoora (8 gram piece)	6·73	57·2	26·4	...	...
5852/37	do. do. do.	6·70	56·3	27·2	...	...

The following are assays of commercial parcels of tantalite ore produced at Pilgangoora.

TABLE V.

ASSAYS OF COMMERCIAL PARCELS OF TANTALUM ORE, PILGANGOORA.

No.	Description.	S.G.	Ta_2O_5.	Nb_2O_5.	SnO_2.	Weight of Parcel.
			%	%	%	tons.
4372/30	Theleman's Claim, Pilgangoora	6·47–7·10	56·26	12·18	...	1
2726/31	Houston and Gilbert's Claim	n.d.	70·56	2·84	7·60	1
2727/31	Theleman's Claim ...	n.d.	69·27	2·96	11·60	1
						lbs.
4879/31	Houston and Gilbert's Claim	6·78	58·3	16·7	6·5	2,000
4880/31	Theleman's Claim ...	6·86	57·4	14·3	8·7	2,000
456/32	do. do. ...	n.d.	56·2	16·7	8·5	2,000
1247/32	Houston and Gilbert's Claim	6·68–7·40	59·4	15·3	6·6	2,000
3000/32	C. Hausler's Claim ...	...	57·4	20·7	4·5	400
3583/32	Houston and Gilbert's Claim	...	55·29	17·76	6·51	2,000
3972/32	A. Fisher's Claim ...	...	64·2	12·3	4·0	1,100
4352/32	Theleman's Claim ...	...	60·9	13·6	7·2	400

Specimens sent in from W. E. Griffiths' lode in 1937 consisted of albite, quartz, muscovite, spodumene, beryl, spessartite, lepidolite, manganotantalite and manganocolumbite. The manganotantalite is associated largely with the spodumene, and has crystallised in small rather granular masses around the edges of the large spodumene crystals.

Concentrates from this lode gave:—

	Concentrate.	SnO_2.	Ta_2O_5, Nb_2O_5 (in concentrate).	Ta_2O_5, Nb_2O_5 (in ore).
	%	%	%	%
A.	13·45	27·54	54·84	7·38
B.	16·37	5·00	71·54	11·71
C.	4·25	4·92	69·42	2·90

Considerable detail of the crystalline form and habit is given under manganocolumbite. (12, 16, 17, 59, 68)

Stannum.—Tantalum ore from 15 miles south of Wodgina (? Stannum) consisted of manganotantalite with some albite, quartz and mica. Specimens in the Simpson collection are massive irregular crystals containing a little intergrown felspar and quartz and are apparently from a pegmatite. The largest weighs about half a pound. This ore assayed Ta_2O_5, 53·7% Nb_2O_5, 23·6%, and an individual fragment with specific gravity 6·82 gave Ta_2O_5, 59·8%; Nb_2O_5 24·0%; FeO, 2·45%.

Strelley.—Lode and alluvial tantalum ores consisting principally of manganotantalite occur at Strelley, and between 1930 and 1940 this place was, next to Wodgina, the largest producer of ore. It is probable that about a quarter of the ore raised by the Tantalite Company and mixed with the ore from Wodgina and other sources came from Strelley. The ore is high grade, manganotantalite being associated with tapiolite and microlite rather than with columbite. Both lode and detrital ore have been worked. Some of the latter is massive and a specimen from Moore's first find weighed two pounds. Detrital manganotantalite from J. Russell's 1938 find was in somewhat worn tabular crystals with S.G. ranging from 6·47 – 6·80, M/9, 6·67 which is equal to Ta_2O_5, 55·5%. The mineral is in simple tabular crystals, interpenetration twins and radiating aggregates, all worn and detrital and sometimes with a little embedded felspar.

The following are analyses of parcels of ore:—

TABLE VI.
ASSAYS OF PARCELS OF TANTALUM ORE, STRELLEY.

No.	Locality and Description.	S.G.*	Ta_2O_5. %	Nb_2O_5. %	SnO_2. %
3830/27	1 mile north of railway ...	...	68·39	9·16	...
1094/28	P.A. 636, 3 miles north of M.L. 321	M/7, 7·53	61·72	1·72	19·23
3110/28	Young's Option	...	66·09	1·49	16·22
1050/27	Moore's Claim, 4 miles from 30 mile Siding	...	42·49	3·40	40·67
1820/27	do. do. do.	...	74·55	0·46	4·57
1947/27	do. do. do.	...	50·3	4·0	42·7
1948/27	Moore's Claim, 4 miles from 30 mile Siding (31·6% conc. from mica-pegmatite)	...	69·0	...	...
4519/31	2½ miles from M.L. 321, 4 miles north of Strelley homestead (from micaceous lode)	6·99	67·3	6·8	7·5
4520/31	2½ miles from M.L. 321, 4 miles north of Strelley homestead (alluvial and detrital)	7·32, 7·22	70·6	6·1	6·8
4521/31	2½ miles from M.L. 321, 4 miles north of Strelley homestead (from lode)	7·47	74·4	4·3	5·8

A tantalum ore obtained from M.C. 355 in 1937 consisted of tapiolite and manganotantalite. After removing a small amount of limonite, quartz and felspar the clean mineral averaged: Ta_2O_5, 80·0%; Nb_2O_5, 5·5%. The crude ore (allowing for 5% gangue) averaged Ta_2O_5, 76%; Nb_2O_5, 5·2%. Another sample from this claim consisted of manganotantalite intergrown with microlite and a little quartz (47, 49, 58, 59, 68).

Tabba Tabba.—This tin and tantalum field is about eight miles south-south-west of the 35-mile post on the Marble Bar railway. Pegmatite veins just north-east of the Tabba Tin Mine have shed abundant gravelly tantalite which has been recovered by sieving. The soil is only a foot or two thick but tantalite has been obtained over almost every square yard of the lease. This ore invariably showed a low niobium content, the average figures for several parcels being: Ta_2O_5, 69·2%; Nb_2O_5, 2·9%; SnO_2, 9·9%. The ore consisted of manganotantalite, microlite, simpsonite and cassiterite.

On Young and Moulden's M.L. 312 there is a prominent pegmatite vein and the soft detritus carrying tantalite alongside this vein was concentrated by sieving. Streaks of fine tantalite are sometimes visible in albite in the pegmatite, which carried in addition quartz, microcline, lepidolite, muscovite and beryl, some of which is white with good crystal faces and some yellowish-brown in well-shaped crystals with perfect basal cleavage.

* S.G. figures are for individual fragments in the parcels.

In 1933 A. L. Kennedy collected a specimen of coarsely crystalline vitreous quartz with embedded masses of manganotantalite which was crystalline and showed a, b, and c faces. Manganotantalite occurs as a thin selvage (⅛ inch) to a 4-inch vein of white beryl (see Part I., p. 33) in the Tantalite Company's mine; it is finely granular and associated with a little greenish mica.

Tabba Tabba has been the third most important producer of tantalum ore in the North-West but the returns have been credited to the Pilbara field generally.

The following are details of concentrates and specimens examined from Tabba:—

TABLE VII.
TANTALUM CONCENTRATES FROM TABBA TABBA.

No.	Locality and Description.	Ta_2O_5. %	Nb_2O_5. %	SnO_2. %
1989/25	M.L. 317 ; ...	50·9	27·5	4·0
1990/25	M.L. 317 ; sample from 5½ cwt.	49·0	25·9	6·08
2840/25	M.L. 317	69·87	2·70	8·25
2513/26	M.L. 317 ; 17% conc. from cap of lode ...	51·01	25·95	6·90
2193/27	M.L. 317 ; manganotantalite with cassiterite quartz, muscovite, and limonite	71·0	10·5	·14
546/29	M.L. 317 ; cassiterite, 21·5%	57·92	2·10	...
1532/29	M.L. 317	58·36	5·45	...
4834/29	M.L. 317	65·51	0·77	...
4835/29	M.L. 317	66·31	2·87	...
4007/29	Theleman's New Find, ¾ mile south-west of Main Camp	60·17	2·73	11·68
2006/33	M.L. 312 ; mixed lode alluvial	72·4	4·0	8·7
2658/34	M.L. 312	66·6	5·1	11·8
6339/35	Tantalite leases, 1,000 lb. parcel	67·3	3·7	10·1
5630/35	Tantalite leases	67·1	3·1	11·6
4194/35	Tantalite leases ; dollied from mica pegmatite	65·1	7·1	14·5
4193/35	Tantalite leases, 1,100 lbs.; manganotantalite with simpsonite	68·8	2·4	11·3
3527/35	Tantalite leases, 1,100 lbs. (averaged 7·14 S.G.) ; manganotantalite with some simpsonite	71·7	2·5	8·8
2647/36	Tantalite leases, 1,100 lbs. ; manganotantalite and simpsonite	63·8	3·3	13·2
2112/36	Tantalite leases, 1,100 lbs. ; manganotantalite and simpsonite	65·6	3·4	13·2
1217/36	Tantalite leases, 1,000 lb. parcel	71·8	2·8	8·2

A sample of weathered, fine gravelly concentrate from M.L. 312 consisted of some typical small crystals and grains. The larger fragments show many small pyramid faces and the pinacoids are well developed. A little mica and ferruginous material is associated with it. Another sample from the same lease has an average S.G. of 7·27 and the tantalite is coarse and intergrown with felspar and mica. Some consist of an irregular plumose intergrowth (47, 49, 58, 64, 65, 71).

Wodgina.—The most important tantalite deposit in Western Australia is at Wodgina (Lat. 21° 15′ S; Long. 118° 40′ E). It is stated that F. H. and W. A. Mitchell of the Mons Cupri Copper Mine first found tantalite here in 1901, and in 1905 a mild rush set in and 21 leases for tin and tantalum were applied for. About 70 tons of tantalum ore were raised.

The tantalite lode is a pegmatite vein (fully described in Part I., p. 30) consisting of coarsely crystalline albite through which are distributed irregularly masses of quartz, microcline, muscovite, and lepidolite with some spessartite. Manganotantalite occurs in pieces of all sizes up to a single mass weighing 5 cwt. The original leases, M.L. 86 and 87, are now included in M.C. 107 and 109 which embrace all the tantalite occurrences in the vicinity of Wodgina.

Practically the whole tantalite yield has come from this lode or from detritus weathered from it. The tantalite occurs in the walls of the lode in bunches or large splashes which have crystallised after the quartz and felspar. Appreciable quantities are only found near the contact zone of the greenstone schist. Many tons (over 70 between 1930 and 1940) of tantalite have been produced at Wodgina from detritus and from the lode.

The tantalite from the lode is often well crystallised (p. 80) and is very even in composition, averaging: Ta_2O_5, 67%; Nb_2O_5, 15%; MnO, 13%; FeO, 2%.

The following are analyses of manganotantalite from Wodgina:—

TABLE VIII.

ANALYSES OF MANGANOTANTALITE, WODGINA.

	A. Single Crystal Detrital, M.L. 86, 1734B.	B. 95 lb. Sample, M.L. 86, 87.	C. 1st Specimen received from N.W. M5664.	D. 8 gram Crystal 1299B.	E. Lode, North End, M.L. 86, 3146/38.	F. Lode, South End, M.L. 87, 3147/38.	G. Lode, South End, M.L. 87, 3215/31.	H. M.L. 86, 3298/31.
	%	%	%	%	%	%	%	%
Ta_2O_5	68·65	69·63	72·46	69·95	69·53	67·35	66·02	69·07
Nb_2O_5	15·11	12·38	6·80	14·47	11·85	16·47	14·56	14·38
TiO_2	0·40	0·25	....	....	....	....	....	....
SnO_2	0·48	0·90	1·10	0·36	2·45	0·47	2·40	trace
SiO_2	....	0·36	....	....	0·38	0·21	....	....
MnO	14·15	12·71	16·67	12·54	12·35	13·27	12·84	†14·32
FeO	1·63	2·05	3·01	2·68	0·70	1·54	0·70	1·52
Fe_2O_3	....	0·04	....	....	....	....	....	....
Al_2O_3	....	0·01	....	....	....	....	....	....
CaO	trace	1·63	0·52	....	1·73	0·71	0·68	....
MgO	0·15	0·10	....	....	....	....	....	....
H_2O	0·07	0·31	trace	....	....	....	*0·45	0·18
Na_2O	*Nil*	trace	....	....	....	....	....	....
NiO	trace	....	....	....	....	....	....	....
Rare Earths	*Nil*	....	....	*Nil*	....	....	....	....
NaF (Calc.)	....	....	....	....	1·29	0·53	....	....
Total	100·64	100·37	100·56	100·00	100·28	100·55	97·65	99·47
S.G.	7·03	6·83 –7·01	7·15	7·09	7·00	7·07	6·96	M/6 = 7·30
Analyst	E.S.S., 1906	E.S.S., 1916	C.G.G.	E.S.S.	C.R.LeM.	C.R.LeM.	C.R.LeM.	H.B.

* $H_2O \pm$. † About 1·20% Mn. is present as psilomelane.

The tantalite is black on a fresh fracture and has a metallic lustre. Weathered surfaces are a rusty brown colour, due largely to a thin adhering film of ferruginous clay. The mineral from the lode often has a dull greyish black appearance. The masses, whether of lode or detrital ore, frequently consist of a number of intergrown parallel prismatic crystals in which the faces a, b, and c are freely represented, and, less commonly u (133). These prismatic masses are inclined at times to be wedge-shaped and, rarely, small masses are seen to be part of a spherical rosette or radiated crystal group. The faces are frequently indented by actual tabular crystals of albite, or by hollows from which albite has evidently weathered out. Twinning about the plane e has been observed in several instances. The macropinacoid, a, is often vertically striated, and at times has a very brilliant lustre. In size the masses vary from many pounds in weight down to a few grains only and in alluvial are often associated with cassiterite, although cassiterite does not appear to be present in the tantalite-bearing pegmatites.

In the Simpson collection there is a large twin of manganotantalite which weights 8 lbs. 2 ozs. (see Frontispiece). The individuals are massive, showing a, b, c in rectangular prisms with the pinacoids. The twin plane is e, but there are also interpenetration twins in the same specimen. The whole is detrital and somewhat worn.

Some well-shaped detrital crystals have been obtained at Wodgina. The following particulars are of five of these:—

S.G.	Faces present.
6·60	a, b, c, u, k, h; a penetration twin.
6·67	a, b, u, o and another face bevelling o.
6·71	a, b, and several pyramids bevelling o; penetration twin.
6·76	a, b, c, k, rectangular crystal.
6·55	a, b, c, k, o, u and another face; penetration twin.

Fine granular tantalite occurs in a micaceous pegmatite north of the north boundary of the tantalite lease. At the southern end of the lode manganotantalite is greyish black in colour and has an apparently massive form but is intergrown with felspar. Tantalite also occurs occasionally as a thin smear on the faces of felspar veinlets. Pebbles of tantalite showing an intergrowth of microlite are grey with lighter grey patches, and where broken show a dense black metallic part, tantalite, with lighter grey microlite.

Small black tabular crystals are fairly abundant at the north end of Lewis' Rockhole lode, embedded in albite and quartz, minute veins and grains of which penetrate the crystals in all directions. The

common form of these crystals is combination of a, b, and c. Small faces of f are not rare, and twins on e and parallel intergrowths are very common.

Associated with manganotantalite in the pegmatite, mainly at its northern end, are a number of rare minerals. Four radium-bearing

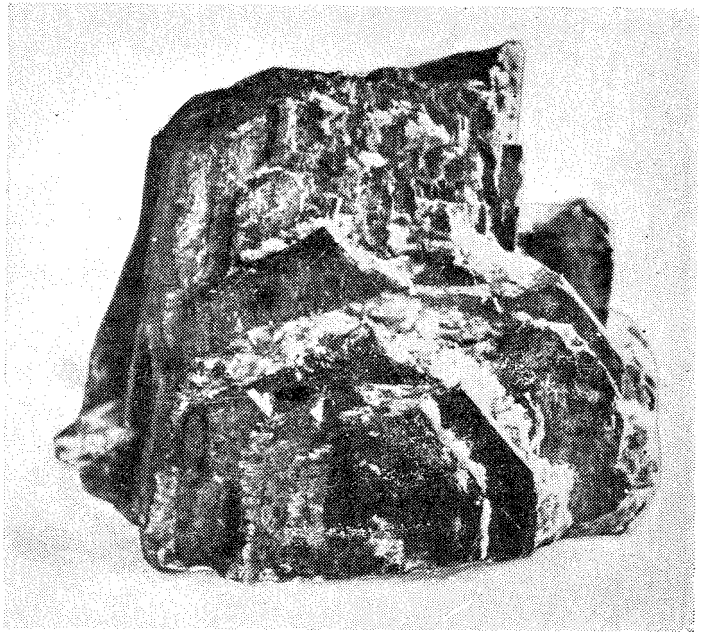

Fig. 10.—Group of Parallel Crystals of Manganotantalite, Wodgina, N.W. Natural scale.
G.S.W.A. Neg. 509.

minerals, maitlandite, nicolayite, pilbarite and hydrothorite occur associated with large masses of lithiophilite, a phosphate of manganese and lithium carrying 8 – 9% of lithia. A little apatite is associated with the lithiophilite. An intergrowth of manganotantalite, microlite, hydrothorite and altered lithiophilite collected in 1926 from a 20ft. adit on M.L. 86 gave the following analysis:—

Ta_2O_5.	Nb_2O_5.	TiO_2.	SnO_2.	SiO_2.	MnO.	MgO.	FeO.	Fe_2O_3.
70·47	8·28	0·25	*Nil*	0·58	12·25	*Nil*	1·26	0·69
Al_2O_3.	CaO.	PbO.	$H_2O.+$	$H_2O.-$	Na_2O.	ThO_2.	UO_3.	Y_2O_3.
0·87	1·65	0·52	1·20	trace	trace	1·47	*Nil*	*Nil*
P_2O_5.	Li_2O.	Total.	S.G.					
0·38	spec. deter.	99·87	6·00					

The pegmatite also carries large masses of a white caesium-bearing beryl several hundred tons of which have been exported to America.

Other pegmatites at Wodgina also carry tantalite, e.g., at Lewis' Rockhole nearly a mile west of Wodgina; 2 miles west of Wodgina; north of the main workings at Wodgina. Some columbite occurs in these places, but it does not appear to be in the main lode. Detrital and alluvial tantalite generally carries a little cassiterite, although cassiterite does not appear to be present in the tantalite-bearing pegmatites which are probably of a different age from the tin-bearing pegmatites.

A large number of parcels and samples of tantalum ore from Wodgina have been assayed. The following illustrate the type of ore and its occurrence:—

TABLE IX.

ASSAYS OF TANTALUM ORE, WODGINA.

No.	Locality and Description.	S.G.†	Ta_2O_5.	Nb_2O_5.	SnO_2.
			%	%	%
352/31	1 mile north of M.L. 86, gravelly alluvial (manganotantalite)	6·0–6·89	56·08	7·74	13·22
351/31	1 mile north-east of M.L. 86 ...	...	63·72	5·15	7·31
409/31	5 miles north-east of M.L. 86, gravelly, alluvial manganotantalite, and cassiterite	...	52·92	17·58	5·41
1387/32	M.L. 86, 87; 2,000 lb. lode and alluvial	...	62·6	14·0	n.d.
1119/32	Gully 1 mile south-east of M.L. 87; 2,000 lb. detrital	7·43, 7·09 6·20, 6·00 5·60, 5·40	57·7	12·3	15·3
2359/32	Rew's P.A. and M.L's. 86, 87; 600 lbs.	...	65·61	14·66	2·67
3584/32	M.L., 86, 87; 2,000 lbs. lode and alluvial	...	66·88	12·79	3·11
3585/32	Rew's Claim, adj. M.L. 87; 2,000 lb. alluvial	...	64·77	15·28	3·99
3586/32	M.L. 86, 87; 500 lb. alluvial shed from main tantalite lode and adj. tin lode	...	59·19	14·41	9·99
4357/32	M.L. 86, 87; 2,000 lb. lode and alluvial	...	66·6	14·5	2·2
4358/32	Gullies 1 mile south-east of M.L. 87; 900 lb. alluvial	...	54·8	9·8	20·9
5022/32	Rew's alluvial claim; 2,000 lb.	...	66·5	15·1	2·5
3962/33	Gullies ½-mile south of M.L. 87; 2,470 lbs.	...	59·0	10·9	13·0
862E/17	6 miles west of Wodgina ...	6·74	57·5	26·1*	...

† S.G. is for individual fragments in the parcels.

* MnO, 15·3; FeO, 0·9.

(10, 11, 12, 15, 16, 17, 18, 20, 22, 29, 30, 33, 47, 50, 58, 59, 61, 68, 71).

Woodstock.—A number of samples of detrital tantalum ore were obtained 23 miles south of Tambourah in 1936 at the head of the Western Shaw River. These consisted of manganotantalite and manganocolumbite with a little tapiolite, microlite, cassiterite, etc. One sample (1971/36) assayed: Ta_2O_5, 49·5%; Nb_2O_5, 15·6%; SnO_2, 8·6%; and consisted of tantalite with a little columbite, cassiterite, limonite, etc. Specific gravities obtained for a number of fragments ranged from 5·96 to 7·43. The manganotantalite is typical detrital material in fine to coarse gravel size, the larger pieces of which show the following crystal faces: a, b, c, u, g, m, y and twins.

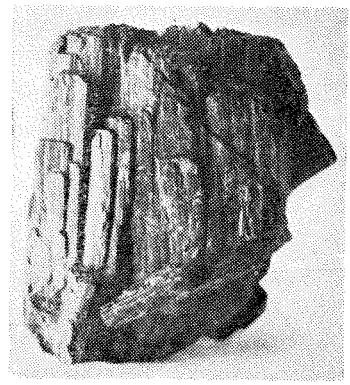

Fig. 11.—Group of Parallel Crystals of Manganotantalite, Wodgina, N.W. Two-thirds natural scale.
G.S.W.A. Neg. No. 508.

Poona.—A parcel of rejects from the second dressing of tin ore from the Great Eastern Mine contained 6·4% manganotantalite with 64·2% manganocolumbite. The specific gravity of the manganotantalite ranges from 6·71 – 6·84; it is in worn black detrital fragments. (34)

Melville.—A vein carrying topaz just south of "The Basin" at Melville contains a little green beryl and manganotantalite, but none has been found in two other veins carrying topaz at the same place. Gravelly manganotantalite is rare on the ridge south of "The Basin" near the emerald workings, where it was found by O. Drew in 1932. An approximate analysis gave:—

Ta_2O_5.	Nb_2O_5.	SnO_2.	MnO.	FeO.	TiO_2.	S.G.
64·7	18·8	0·2	14·0	1·4	0·2	M/3, 7·01

The manganotantalite is in greyish black irregular fragments in places coated with a pale yellow or grey mineral. It is black on a freshly broken face. Crystal forms are rare but a few faces can be recognised, e.g. a. Some fragments tend towards "rosettes." (61, 63)

Gibraltar.—A sample of tantalum ore from Gibraltar examined in 1929 contained 60% Ta_2O_5 and two other samples, 59·7 and 52·8% Ta_2O_5 respectively. Manganocolumbite had previously been recorded from Gibraltar but it apparently occurs in a different locality from the manganotantalite and has probably been shed from a different pegmatite. The main occurrence is stated to be about half a mile south of Clayton's battery.

The manganotantalite is glassy with a vitreous to resinous lustre. It occurs as small orthorhombic crystals with a and b faces and occasionally small pyramid faces. All the crystals appear simple and not intergrown or twinned. Both the specific gravity and composition vary for different specimens as shown by the following analyses:—

	1308/29— Single Pebble from south of Clayton's Battery.	788/29— Three Pebbles from south of Clayton's Battery.	726/37— Glassy Piece near Gibraltar.
	%	%	%
Ta_2O_5	59·71	69·88	} 82·33
Nb_2O_5	22·67	11·92	} ...
TiO_2	...	1·41	1·53
SnO_2	0·14	0·16	...
SiO_2	...	*Nil*	0·10
Al_2O_3	...	...	0·26
MnO	12·52	12·18	12·24
FeO	2·99	2·81	2·68
CaO	...	0·68	0·16
MgO	...	*Nil*	*Nil*
$H_2O\pm$	...	0·91	0·45
UO_2	...	...	0·36
RE(Y)	...	...	0·12
	98·03	99·95	100·23
S.G.	6·44	6·60	6·91
Analyst ...	E.S.S. & H.P.R.	E.S.S. & H.P.R.	H.P.R.

Various other samples of alluvial manganotantalite gave the following figures:—

No.	Locality and Description.	S.G.	Ta_2O_5. %	Nb_2O_5. %	SnO_2. %
1279/29	½ mile south of Clayton's Battery, glassy fragments	6·14–7·06	60·37	17·45	...
3317/34	Lady Moulden's Option, glassy alluvial	6·24, 6·07, 6·05	58·2	21·4	*Nil*

Kathleen Valley.—Tantalite has recently been found about two miles south or south-east of Kathleen Valley. The original specimen is a small worn pebble which on breaking is black with a sub-metallic lustre. This specimen has S.G. 6·82 equal to Ta_2O_5, 59·8%; Nb_2O_5, 24·0%. A qualitative examination showed: Fe, trace; MnO, much; CaO, nil; Sn, little; Sb, nil. The powder is light grey, translucent and anisotropic with a high birefringence. Subsequently a sample of detrital manganotantalite, stated to have come from 2½ miles south of Kathleen Valley, was sent in. Many of these pieces are worn crystals with typical orthorhombic habit; some are made up of radiating crystals. The faces recognisable are: a, b, m, u, e, c.

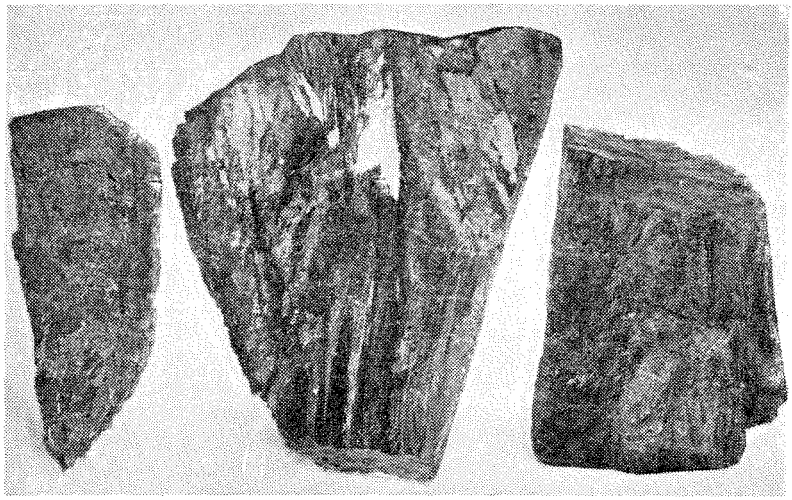

Fig. 12.—Typical Fragments of Manganotantalite, Wodgina, N.W. Two-thirds natural scale.

A little tantalite has been found in a pegmatite near this locality. The principal mineral in the pegmatite is albite; a little fluorite is also present.

Londonderry.—The first discovery of tantalum ore in this locality was made by Hugh Fraser in 1909. This discovery was probably on what was later known as Fraser's Find, now included in M.L. 80, Marshall Haig, four miles south-south-west of Londonderry townsite. Fraser also appears to have discovered what is now known as Mercer's Find, one and a half miles north of M.L. 80. The two largest pieces of tantalite found by Fraser on the Marshall Haig weighed 4 and 2 ozs. respectively and were manganocolumbite with S.G. 6·43. A much smaller fragment was manganotantalite with S.G. 7·35 (Ta_2O_5,

73·6%; Nb_2O_5, 11·4%). All these were detrital. The largest fragment is a broken top half of a much larger crystal showing a, b, c and a smoothed dome face. It is twinned and intergrown.

In 1909 C. G. Gibson collected a number of fragments of tantalite ranging in S.G. from 7·87-5·55, indicating a percentage of Ta_2O_5 ranging from 85·4-15·7%. The few fragments assayed gave: Ta_2O_5, 47·0%; Nb_2O_5, 32·3%; tin, free, nil; tin, combined, 2·8%.

When this lease was inspected by E. S. Simpson in 1928 the pegmatite vein had been opened up in several places, but no sign of tin or tantalum ore could be seen in this vein, nor in a second just east of it. A careful search of the surface over several acres near these veins yielded only a single piece of tantalite weighing about an ounce and assaying Ta_2O_5, 64·5%; Nb_2O_5, 19·1%.

More tantalite occurs at Mercer's Find near the outcrops of several pegmatite veins on old M.L. 61. Among the detrital fragments collected by E. S. Simpson on old M.L. 61 is a large one weighing 2½ ozs. and with S.G. 7·38. It is worn and has the typical form, and is intergrown with quartz or felspar. It is black with a submetallic lustre. Other specimens from the same area are shiny and black with orthorhombic crystallisation; some pieces have an almost vitreous lustre.

Three samples of clean ore collected by C. G. Gibson from the surface gave the following assays:—

	Conigrave's M.L.	Mercer's M.L. (West End).	Mercer's M.L. (East End).
	%	%	%
Ta_2O_5 (average)	51	56	37
Ta_2O_5 (range)	56–44	74–46	52–12
Nb_2O_5	29	24	43
Sn, free	*Nil*	*Nil*	*Nil*
Sn, combined	0·4	4·1	1·8
	Columbite and Tantalite	Columbite and Tantalite	Columbite

Between 1909 and 1928 no further work was done on these deposits, but they were taken up by H. Hewitt in June, 1928. A small sample of concentrates obtained by Hewitt assayed: Ta_2O_5, 70·76%; Nb_2O_5, 1·13%; SnO_2, 13·16%.

E. S. Simpson inspected these areas in 1928 and found that the vein in workings on Hewitt's P.A. 2423 contained several small pieces of embedded tantalite. On the slope on the north side of this vein detrital tantalite was found in pieces ranging from about ⅛-inch to 1 inch in diameter. These fragments, with the exception of a few pieces of cassiterite consisted of high grade manganotantalite with S.G. from 7·04-7·59, equal to Ta_2O_5, 65·8-79·2%, and Nb_2O_5, 18·5-6·2%.

In 1937 four samples of tantalum ore were examined from P.As. 4794 and 4795 at Mercer's Find. In two of these manganotantalite was associated with manganocolumbite. These assayed:—

No.	——	Ta_2O_5. %	Nb_2O_5. %	SnO_2. %	Specific Gravity. Range.	Specific Gravity. Average.
2924/37	Manganocolumbite and manganotantalite	43	40	*Nil*	5·63–7·49	6·27
2925/37	do. do.	50	33	*Nil*	5·83–7·36	6·52

The felspar vein carrying a little tantalite at Mercer's Find was worked by the British Tantalite Company in 1939 and 1940 and concentrates obtained by them gave the following figures:—

		Ta_2O_5. %	Nb_2O_5. %	SnO_2. %
5923/39	Mercer's Find ... ... Tantalite concentrate	46·5	5·2	14·9
854/40	do. do.	40·7	7·9	8·1

It is stated that this company produced 0·625 tons of concentrates from 252 tons of ore.

Tantalite collected at Scahill's felspar quarry (M.L. 80, late 72) in 1935 was black to bluish-black in colour, with a sub-metallic lustre and a radiating plumose structure made up of plates of orthorhombic crystals with prominent a, small b and c, faces. It is intergrown with felspar. One specimen contains a number of these rosettes in felspar, the tantalite having crystallised just prior to the felspar. The specific gravity of these fragments is about 7·35, equal to Ta_2O_5, 73·6%.

Tantalite from half a mile north-west of M.L. 72 is high grade, the specific gravities of detrital fragments being 7·31, 7·43, 7·44, 7·52, 7·53, 7·59, average 7·47, which is equal to Ta_2O_5, 76·5%. It is massive and black with a general tendency to plumose structure but there are some crystals which are combinations of a, b and c faces. (24, 31, 33, 51, 65.)

Logan's Find.—One fragment of manganotantalite was found with manganocolumbite in a felspar vein about three miles from Spargoville near the Norseman-Coolgardie road. The specimen had S.G. 6·97 and contained Ta_2O_5, 63·9%; Nb_2O_5, 20·3%.

Ubini.—A very small quantity of manganotantalite has been found in the pegmatite which contains tin, amblygonite, and felspar three miles north of west of the railway at Ubini. When worked for tin

ore, less than 1 cwt. of which was obtained, a few fragments of tantalite of good commercial quality were found. One of the fragments gave the following analysis:—

Ta_2O_5.	Nb_2O_5.	TiO_2.	SnO_2.	MnO.	FeO.	H_2O.	Total.	S.G.
68·24	14·38	*Nil*	0·26	15·19	2·02	0·28	100·37	6·82

A translucent portion of the fragments gave: Ta_2O_5, Nb_2O_5, 82·16%; SnO_2, 0·30%.

In 1918 a few further pieces of manganotantalite were found, the largest weighing 2 ozs. This had S.G. 6·53, corresponding to Ta_2O_5, 51.3%, Nb_2O_5, 31.8%.

E. S. Simpson inspected this place in 1928 and the only tantalum ore seen was a few specks in a large block of amblygonite and no detrital fragments were obtained (51, 53.)

Victoria Rocks.—A little manganotantalite was found many years ago at this place which is about 16 to 17 miles south-west of Londonderry. Specimens from the east side of the ridge had S.G. 7·49, 7·44, 7·41, 7·40, 7·37, and 6·87, average 7·35, equalling about 74% Ta_2O_5 and about 86% of mixed oxides. The range is Ta_2O_5, 77-61%. The specimens from the west side of the ridge had S.G. 7·17 and 6·69, equalling Ta_2O_5, 69% and 56% respectively. Manganocolumbite was also found.

In appearance this tantalite is similar to that from Londonderry and occurs in worn detrital fragments with radiating to plumose structures. The fragments are rather massive and some show typical tantalite faces, whereas others have a more tetragonal appearance with a, b and c faces. (33.)

Bellinger.—In a mica-bearing pegmatite at this locality a little tantalite occurs ranging from ferrotantalite to manganocolumbite in composition. The S.G. is 7·6, 7·1, 6·6, 5·59, indicating percentages of Ta_2O_5 from 79-16%. Most of the tantalite is in irregular, broken fragments, but a few imperfect tabular crystals were found in which the faces a and b were prominently developed, whilst traces of u were also seen. (23, 33.)

Columbite.

This is the orthorhombic iron-bearing niobate, and includes the minerals which contain a molecularly greater proportion of iron than manganese.

Abydos.—At Leeds Tin Find near the south-west corner of Abydos Station several specimens of detrital columbite were obtained in 1927 and one large sample consisted of angular fragments from 0·5 to 85 grams in weight. When cleaned the surface was black, often

flecked with small scales of mica. About 10% of the pieces showed one or two crystal faces, apparently a, b, c, with q (023) or some other dome or pyramid, but the faces are too corroded and fragmentary to be measured even approximately. The specific gravity of nine fragments ranged from 5·32 to 5·61, with mean 5·42, indicating a mean content of 69% Nb_2O_5 and 10% Ta_2O_5 with a range of 6-18% Ta_2O_5. The iron content is 12·92. Two determinations of TiO_2 gave 5·45 and 3·63% respectively, and this taken in conjunction with the subvitreous lustre of the mineral, indicates a transition towards ilmenorutile.

Carlindi.—An alluvial tantalum ore stated to have come from south of Strelley on Carlindi Station was obtained in 1931 and consisted of columbite pebbles with a mean weight of 15 grams. The specific gravity ranged from 5·38 to 5·75 and averaged on 16 pebbles, 5·54. This indicated 15% Ta_2O_5 and 65% Nb_2O_5. The predominant base is iron, one fragment with S.G. 5·57 containing 12·06% FeO. On one piece the forms a, b, c, u, k, m, z, were recognisable.

Hillside.—In 1931 a few detrital pebbles of columbite ranging from 0·5 to 3 cms. in length, were found. Some are fairly well-crystallised in combinations of a, b, c, i, m, the u faces in each case being very unevenly developed, and m only just visible as a narrow bevel. The specific gravity ranged from 5·35 to 5·90, and the amount of FeO in a crystal with S.G. 5·30 was 11·42%.

Pilgangoora.—Most of the columbite obtained here has been manganocolumbite. The only true columbite analysed contained 15·99% FeO, whilst other parcels of manganocolumbite carried FeO 3·26, 3·53, 5·22, 5·80 and 6·39% respectively. Details of the crystallography are given under manganocolumbite. Goniometer measurements were made of a crystal of columbite with S.G. 5·55. The faces measured were a^1, z^1, m^1, g^1, b^1, m^2, z^2, a^2, z^3, m^3, g^3, b^2, g^4, m^4, z^4, and c^1. No sharp readings could be obtained for the forms u and e. From the mean reading for az, the ratio a : b was calculated to be 0·82976. (17, 69)

Pinnacle Hill (The Pinnacles).—A small parcel of heavy alluvial gravel examined in 1927 was found to be columbite with:—Ta_2O_5, 25·14%; Nb_2O_5, 51·91; SnO_2, nil; FeO, 14·83. S.G. (average) 5·72.

Columbite in 0·5 to 1 cm. fragments was obtained one mile west of the Hill in 1930. The specific gravities ranged from 5·32 to 5·81, M/12 = 5.58. This indicates Nb_2O_5, 63%; Ta_2O_5, 17%. FeO is 14.54%. Broken crystals were plentiful in the parcel examined, the faces recognisable being a, b, c, u, e, m, y.

Stannum.—Columbite on the borderline between columbite and manganocolumbite has been obtained here (see details under manganocolumbite).

Strelley.—A single sample of columbite has been obtained from Orr's Find, two miles south of the 37 mile-post on the railway. This was in angular fragments 1 – 3 cm. in length, all showing signs of crystal form and some exhibiting a fair number of faces including a, b, c, u, m, e. Other faces which could not be determined with certainty are n, y and (012). The mineral is jet black on fresh fracture. The S.G. ranged from 5·52 to 6·07 with a mean of 5·62, indicating Nb_2O_5, 61·6%; Ta_2O_5, 18·8%. The FeO is 11·05%.

Tabba Tabba.—A well crystallised sample of columbite obtained in 1906 "16 miles north-west of Lalla Rookh" may have come from here, but practically all the columbite is manganocolumbite associated with manganotantalite. The faces a, b, c, u, e, m, g, and y were recognisable in the original specimens. (17, 47, 53)

Wodgina.—Columbite has been found 2½ miles north of M.L. 86 where some large detrital crystals have been obtained (FeO, 11·64%). One, consisting of a, b, c, u, e, faces weighed 105 grams though one half is missing. Others are combinations of a, b, c, u, m and are tabular parallel to a(100). Traces of a parallel parting are seen in some pieces. The specific gravity is very uniform ranging from 5·51 to 5·65, with a mean of 5·56, indicating Nb_2O_5, 64%; Ta_2O_5, 16%. Another parcel obtained near here in 1936 had S.G. from 6·07 to 6·69, with an average of 6·36 corresponding to Nb_2O_5, 37%; Ta_2O_5 46% (17, 47).

Woodstock.—In 1936 tantalite and columbite were found in three places within two miles of one another near the head of the Western Shaw River, probably on Pastoral lease 2591. In one detrital concentrate all the fragments over ½ inch gauge were columbite, with S.G. from 5·97 – 6·44. The columbite is in more or less well-crystallised fragments from one to 90 grams in weight. A determination of iron in a crystal of S.G. 5·98 showed 10·84% FeO, suggesting a ratio of Fe to Mn of 3 to 2. The mineral is jet black and opaque on a fresh fracture. The common combination of forms is a, b, c, u, but one crystal had a, b, u without any c faces. More complex combinations were: a, b, u, k, m, g, y; a, b, c, u, s, k, m, y; a, b, c, u, i, s, e. A slightly radiating structure is to be seen in some of the masses, and a common feature is a multitude of smaller parallel crystals forming a bas relief on the a(100) faces.

Balingup.—A few ounces of columbite were obtained from the felspar vein at Ferndale. The columbite is intergrown with the other minerals in small angular masses and very imperfect crystals, the largest weighing 25 grams. Some pieces were found embedded in beryl. The mineral is pure black and opaque, with S.G. ranging from 5·40 to 6·40 with an average of 5·69, indicating Nb_2O_5, 59·0%; Ta_2O_5, 21·7%. The FeO is 10·98%, indicating a ratio of Fe to Mn of 4 : 3. The forms observed were a, b, c, u, m, z. (64)

Greenbushes.—Columbite is of rare occurrence in this field. A concentrate from Barrymore and Huitson's claim in 1929 yielded SnO_2 16·06%; Nb_2O_5, 26·63 and Ta_2O_5, 37·42%. The ratio of Nb to Ta in this is 1·2 to 1 and iron predominates over manganese. In 1936 some alluvial and lode columbite was found 2 miles north of Greenbushes associated with cassiterite and a little tantalite. The columbite is in black imperfect crystals up to 10 grams in weight with S.G. 5·5 – 6·1. (73)

Jimperding.—A little gravelly columbite has been obtained associated with a little tapiolite in alluvial gold washings on Yinnerding Creek. The fragments of columbite are 3 to 10 mm. in length and tabular in habit. The heaviest piece weighs a little less than a gram. The forms present are a, b, c, u, with rarely e, m, z. Groups occur in which (a), all faces are parallel; (b), the (010) face is common to all subdivisions, or parallel throughout, whilst the (100) faces differ in orientation by successive amounts of about 10°, giving a fan-shaped group. The colour is black and the S.G. 6·29 to 6·33. An analysis (see Table X) of a small crystal proved the molecular ratio of iron to manganese to be 3·4 to 1, that of niobium to tantalum to be 1·4 to 1. (60)

Lake Moore (*Lake Monger*).—At an unrecorded locality between Lake Moore and Lake Monger a number of detrital pieces of ilmenorutile were found by a prospector in 1912 and with them were four pieces of columbite, ranging in weight between 12 and 43 grams. The S.G. ranged from 5·70 to 5·78. An analysis of a typical piece is given in the Table and the figures give a ratio of Fe to Mn, 2·5 to 1·0 and of Nb to Ta of 5·0 to 1·0. The mineral is jet black, sub-metallic in lustre and no crystal faces were present. (28, 33)

Smithfield.—Near Loc. 11472 at Smithfield, south-west of Bridgetown, a few hundredweights of alluvial tin ore were obtained in 1931. One parcel consisted of cassiterite, 90%; columbite, 10%. The latter had S.G. 5·66 indicating Nb_2O_5 60·1%; Ta_2O_5 20·5%. In the vicinity a little struverite and gahnite have been found with cassiterite and much tourmaline.

A typical orthorhombic crystal is black and opaque and weighs 6·98 grams. It consists of a, which is rather uneven and vertically striated, possibly due to twinning; b, pyramid faces, and u (?). The specific gravity is 6·02 equal to Ta_2O_5, 34·3%; Nb_2O_5, 47·4%. Two other fragments weigh 30·97 and 5·32 gms. respectively. The specific gravity of both is 5·54 equal to Ta_2O_5, 15·4%; Nb_2O_5, 64·7%. They have no crystal faces, but show good cleavage, (?) parallel to a.

Logan's Find.—In 1931 detrital columbite was found when dry-blowing for gold 3 miles south of Spargoville, and 50 to 60 lbs. were collected. The specific gravity ranged from 5·48 to 5·63, the mean of a

large number of fragments being 5·54, indicating Nb_2O_5 64·7%; Ta_2O_5 15·4%. The FeO content of a crystal with S.G. 5·49 was 12.81%. The columbite is jet-black and opaque, with an unusually bright lustre, especially on some of the crystal faces. Broken fragments of crystals are numerous and the following are recognisable, a, b, c, l, u, n, y, z, m, g, s, π , e; y, z, m are often quite well-developed broad faces. The largest fragment weighing 96 grams with S.G. 5·48, showed the forms a, b, u, y and z. One unusual crystal fragment of 23 grams (S.G. 5·51) shows a very unsymmetrical development with large faces of a^1, c^1, z^4, z^1, smaller faces of b^1, u^2, u^3, s^1 and still smaller ones of z^2, g^2, m^4, u^1, u^4, π^4. Other combinations are a, b, c, u, z (all large); a, b, c, u, z, m, e; a, b, c, u, n, z, m; a, c, u, y; a, b, y, m; a, b, c, u, m, g.

Manganocolumbite.

Mt. Dockrell.—In 1927 a little alluvial tin and tantalum ore was found at the head of Willy Willy Creek. The concentrates consisted of pebbly cassiterite with some tantalite and a little manganocolumbite and spessartite. The manganocolumbite is in well developed but broken crystals from 0·5—2·5 cms. in length; the common habit is a combination of a, b, c, u, m, flattened considerably parallel to a(100), the larger ones about 25 x 15 x 3 or 4 mm. Many crystals exhibited parallel overgrowths and in some cases several crystals were combined in fan-shaped groups in which the b(010) faces were parallel but the a(100) faces made a series of small angles with one another. Specific gravities determined were 6·16 to 6·34 with a mean of 6·21. A crystal with S.G. 6·19 (Nb_2O_5, 41.9%, Ta_2O_5, 40.2%) was found to contain FeO, 6·82, indicating that the species is manganocolumbite. An alluvial concentrate collected 8 miles east of Mt. Dockrell by the Northern Australian Survey in 1937 consisted of manganocolumbite with a little intergrown microlite, 25.8%; cassiterite 48.1%. Four other samples contained 24-87% manganocolumbite in the purified concentrates, the balance being cassiterite. (70)

Cooglegong.—Manganocolumbite is quite rare in distribution and quantity at Cooglegong where it occurs in alluvial tin ore with rare earth tantalates and monazite.

Lalla Rookh.—A black gravelly alluvial concentrate said to have come from the vicinity of Pinpin Creek on Lalla Rookh Station in 1935 consisted of a mixture of magnetite and manganocolumbite with quartz and muscovite. The manganocolumbite had S.G. 6·00 equal to 48·1% Nb_2O_5 and 33·6% Ta_2O_5.

Moolyella-Talga.—A little manganocolumbite occurs with alluvial cassiterite in this district. One parcel of residues from tin sluicing from MacDonald's lead was found to consist of:—manganocolumbite, 46.5%; cassiterite, 26.3; monazite, 26.2 and spessartite, 1.0%.

The manganocolumbite in this parcel is pure black in colour and opaque and occurs in small (3-5mm), angular and often tabular pieces, the latter being fractured and water-worn crystals with a(100) well preserved, b, c, u much less so, and y(210) occasionally recognisable. The average specific gravity is 6·1. Four lots of these fragments had S.G. 5·61, 5·70, 5·76, 5·80. One lot with an average S.G. of 5·655 had approximately Nb_2O_5, 60·2%; Ta_2O_5, 20·2%; FeO, 8·5%; MnO, 11.1%.

Much coarser grained manganocolumbite was found at the Two Sisters Hills near Talga. One fragment of a crystal, showing the faces a(striated), b, e, u, y, weighed 84 grams and had S.G. 5·90, indicating Nb_2O_5, 51·4%; Ta_2O_5, 29·9%. Others ranging from 1-15 grams had S.G. 5·97-6.28, with a mean (8), 6·13, indicating Nb_2O_5, 43·8%; Ta_2O_5, 38·2%. This parcel contained FeO, 5·67%, thus MnO was greatly in excess of FeO. The only form observed besides a, b, c, u, y were doubtful faces of n(163). (23,47).

Mt. Francisco.—Manganocolumbite was first discovered *in situ* in a pegmatite in 1917 and the outcrop was pegged out as the Congo M.L. one mile north of the Government Well. Much later it was found in other veins, and two tons were taken from outcrop and adjacent soil on Hooley's M.L. about 1928 and sold abroad for experimental purposes.

In the vein on the Congo M.L. shapeless masses of manganocolumbite up to 2 lbs. in weight can be seen embedded in albite and quartz. Good single-ended crystals several centimeters in length have also been found growing in parallel position from the sides of a narrow (4cm.) fissure, which has been finally filled with secondary albite. The forms present are a, b, u. On the face of a large mass of the mineral are many almost parallel crystals standing out in low relief. One imperfect crystal appears to be a combination of a, b, c, e with small faces of m and n.

On a fresh fracture the mineral from the Congo M.L. is greyish black, with a submetallic lustre and is quite opaque even in fine powder under the microscope. The analysis of a typical specimen is given in Table X. The figures show a ratio of MnO to FeO of 5·7 to 1 and of Nb_2O_5 to Ta_2O_5 of 2·6 to 1. The crystal analysed had S.G. 5·87. Others examined had S.G. 5·73, 5·75, 5·86. The last contained 4.86% of FeO.

A mineral obtained about a mile north of the Congo M.L. had S.G. 6·53 and is on the border line between manganocolumbite and manganotantalite. Manganocolumbite from 2-5cm. in diameter and 5-60 grams in weight was abundant along the outcrop when seen by E. S. Simpson in 1927. The S.G. of individual fragments ranged from

from 5·32 to 5·94, the average of 21 being 5·64 indicating Nb_2O_5, 61%; Ta_2O_5, 19%. The bulk parcel of concentrates sold contained 41.30% Ta_2O_5 and 30.84% Nb_2O_5. The lowest S.G. noted was 5.32 indicating 73·6% Nb_2O_5 and 5·7% Ta_2O_5.

A number of fragmentary crystals were collected on Hooleys' M.L. One has large a, b, c faces and small u and m. In several, e(021) is prominent. The crystals are mostly tabular parallel to a, with small c face, small to moderately large u and rarely small n faces. One fragment is a mass of radiating prisms forming a low conical segment of a sphere. A single twin on e(021) has been recorded. (23,47,53.)

Pilgangoora.—This is the most important locality in the State for crystallised manganocolumbite (see Fig. 4 and Fig. 9) which is associated with manganotantalite of commercial grade. The ore, with which is invariably associated a few per cent. of cassiterite, varies greatly in the relative proportions of tantalum and niobium, even at times in the same vein or deposit. Manganotantalite is somewhat more plentiful than manganocolumbite whilst only rare crystals or pebbles of tantalite or columbite have been found. Determination of iron on picked crystals from different veins of ore have given FeO, 3·26-15.99%., but the figure is usually under 9%. The only other tantalum and niobium minerals associated with them are tapiolite and microlite, both of which are very rare. The main quantity of ore has been alluvial and eluvial material shed from pegmatite dykes. The lowest specific gravities recorded from this area are 5·21, 5·35 and 5·42, representing 99·5, 94·2 and 88.4% by weight of (Mn, Fe) Nb_2O_6. The first came from 2 miles north of M.C. 80, the other two were amongst the earliest samples from Bell's and Macbeth's claims "near Green's Well."

Examples of uniform grade in parcels of columbite from here are the following:—

	Locality.	S.G. Range.	S.G. Mean.	Nb_2O_5. Range.	Nb_2O_5. Mean.	Ta_2O_5. Mean.	FeO.
				%	%	%	%
1.	5 miles north of Green's Tank	6·18–6·47	6·33 (m/8)	42·25–33·5	37·6	44·9	3·53
2.	Pilgangoora	5·90–6·04	6·01 (m/7)	51·4–46·7	47·7	33·9	5·80
3.	Do.	5·77–6·31	5·98 (m/17)	56·0–38·2	48·7	32·8	6·39
4.	Hooley's M.L. Pilgangoora	5·58–5·79	5·70 (m/4)	63·1–55·3	58·6	22·1	15·99

Nos. 1, 2 and 3 are manganocolumbite; No. 4 is columbite.

The following are examples of a wide range in composition:—

	Range.	Mean.	FeO. %
1½ miles north-east of M.L. 80	S.G. 6·05– 7·69 Nb_2O_5% 46·4 – 4·2 Ta_2O_5% 35·4 –81·5	6·73 (m/7) 26·4 57·2	3·38
Bell's M.L., Green's Well	S.G. 5·35– 6·84 Nb_2O_5% 72·3 –23·5 Ta_2O_5% 7·1 –60·3	6·45 (m/8) 34·1 48·8	<MnO
Griffith's M.C., Pilgangoora	S.G. 5·95– 7·34 Nb_2O_5% 49·7 –15·0 Ta_2O_5% 31·7 –73·4	6·54 (m/13) 31·6 51·6	<MnO

These are mixtures of manganocolumbite and manganotantalite.

Both alluvial and lode concentrates contain a little cassiterite ranging from less than 0·5% up to 20%; the majority carry less than 10%.

The fragments of columbite examined by E. S. Simpson ranged in weight from about 0·1 gram to 165 grams. A fairly typical alluvial parcel gave the following grades: +4 mesh, 11.6%; —4 +10, 80.7%; —10, 7.7%.

On a fresh fracture the columbite is opaque and pure black in colour, but the surface is usually stained red or brown by ferruginous soil and possibly at times by decomposition products of the mineral itself.

Much of the manganocolumbite and ferrocolumbite from Pilgangoora is well-crystallised but usually single-ended. The forms noted are, in approximate order of frequency:—a(100), b(010), c(001), u(133), m(110), k(103), e(021), y(210), g(130), z(530), q(023), f(102), n(163), o(111). Typical crystals are shown in Figures 8 and 9.

Crystals are either tabular (flattened parallel to 100) or columnar. The largest seen was much chipped, but it still weighed 165 grams. It was made up of the forms a, b, c, u, m, and had S.G. 5·95. The next largest also fragmentary, weighed 30 gms. and had S.G. 5·78. Occasionally simple combinations of a, b, c are seen, but mostly these faces are associated with u, giving forms ranging between those shown in Fig. 9. The u faces are often unevenly developed, u^1u^4 being large and u^2u^3 small, or *vice versa*. Faces m and y may be moderately broad, but usually these other prisms are only narrow chamfers on the edges of the pinacoids (Figs. 8 and 9).

Some complex forms observed were:—a, b, c, u, e, y, m, g; a, b, c, u, n, e, k, y; a, b, c, u, n, o, k, m; a, b, c, u, n, f, e. Tabular twins on e (021) are extremely rare.

The (100) faces are not uncommonly complicated by small bas-reliefs of parallel crystals. In other cases this face is striated. Fan-shaped aggregates of tabular crystals were noted, in which the individuals were attached by a face vicinal to (100), whilst all the (010) faces were in two parallel planes. Still rarer were mushroom forms, in which a large number of small prismatic individuals were combined in the form of a conical segment of a sphere. Four of these had S.G. ranging from 6·38 to 6·55 (17, 69).

Stannum.—Columbite bordering between manganocolumbite and columbite is rather abundant in alluvial tin ores in the creek on the eastern side of the Wodgina greenstone massif. Some angular pebbles of tantalum ore found in 1932 ranged in specific gravity from 5·65-6·10, with an average for eight pebbles of 5·83, corresponding to Ta_2O_5, 27·2%; Nb_2O_5, 53·9%. The FeO is 9·76%. Most of the pebbles range in weight from 5-20 gms. and show few crystal faces, but those recognisable appear to be combinations of a, b, c, e, and possibly u (133).

Tabba Tabba.—Associated with the manganotantalite there is a little manganocolumbite. In 1927 when visited by E. S. Simpson the cap of a highly micaceous pegmatite and the adjacent soil on Theleman's M.L. 317 was being concentrated for a gravelly mixture of manganocolumbite, with a little manganotantalite. Of 13 pebbles whose S.G. was taken only two were manganotantalite. Eleven were manganocolumbite with S.G. 6·07-6·41, mean, 6·25, indicating Nb_2O_5, 40·1%; Ta_2O_5, 42·3%. A complete analysis of three clean pebbles is given in the table. Many of the fragments were imperfectly crystallised, showing traces of a, b, c, u.

Another concentrate, believed to be from the same lease, contained much larger pebbles, up to 3 cm. in length and 40 grams in weight. These had S.G. 6·06 to 6·50, the mean of nine being 6·36, indicating Nb_2O_5, 36·8%; Ta_2O_5, 45·9%. Fragmentary crystals showed the faces a, b, c, u, the pyramid faces in some cases very small, in others moderately large.

Another parcel of small detrital manganocolumbite had S.G. 5·74, 6·19, 6·55 and showed the combinations a, b, c; a, b, c, u.

The manganocolumbite from Tabba is pure black to dark brown on the surface and pure black on a fresh fracture. The fine powder is opaque and black under the microscope (23, 47, 53).

Wodgina.—A little manganocolumbite has been found at Wodgina. A concentrate from an alluvial claim adjacent to the tantalite mine carried 97·2% of manganocolumbite with S.G. 6·28-6·36. It was in angular, often crystallised fragments from 3 to 30 mms. in length. Crystals show the forms a, b, c, or a, b, c, u (No. 5, Fig. 8). A pebbly detrital concentrate from half a mile north-north-east of M.L. 86 consisted chiefly of manganocolumbite, S.G. 5·27-6·08, with a little manganotantalite, S.G. 6·76-7·38, and microlite.

E. S. Simpson in 1927 found some manganocolumbite in the outcrop of a pegmatite and in the adjacent soil about two miles north 25° west of M.L. 86. The pebbles were sub-angular and crystallised, the faces recognisable being a, b, c, u. The S.G. is 6 27-6·39; (23, 47).

Yinnietharra.—Manganocolumbite of variable composition has been recorded from the Yinnietharra district. Manganocolumbite has been found in the vicinity of the bismuth show on Nardoo Creek and from an indefinite locality stated to be 30 miles north-east of Mooloo Downs Station homestead. The composition of these specimens is Ta_2O_5, 51 and 34%; Nb_2O_5, 32 and 48% respectively. Two additional specimens received from the Yinnietharra district have the typical crystalline form of columbite. One has S.G. 5·79 equal to Ta_2O_5, 26·6%; Nb_2O_5 55·3%; the other, S.G. 5·69 equal to Ta_2O_5, 21·7%; Nb_2O_5 59%. The crystal is detrital and somewhat worn; it measures 3·5 by 2 by 1·2 cm. and the faces present are: a, b, c, u, o, and h or k. The smaller piece is jet black on a fresh surface and shows only portion of a, which is striated vertically. Other specimens contained Ta_2O_5, 46%; Nb_2O_5 37%. (73, 77)

Coodardy.—Manganocolumbite constituted 29 % by weight of the heavy minerals associated with detrital tin ore collected by H. P. Woodward on M.L. 13 in 1912. The weight of individual fragments varied from 0·5 to 10·0 grams; they were all sub-angular fragments of single crystals or crystal groups, with small adherent fragments of quartz and albite. The forms present are a, b, c, u, m, k and possibly e. Parallel growths are very common. The specific gravity ranged from 5·60 to 6·00 indicating the following range in composition: Nb_2O_5, 48·1-62·3%; Ta_2O_5, 18·0-33·6%. Chips from two typical crystals were analysed and yielded the figures given in the table. Manganese is in excess of iron. The manganocolumbite is opaque and pure black in colour with a sub-metallic lustre on a freshly fractured surface. (34)

Poona.—Manganocolumbite in small quantities has been found associated with detrital tin ore shed from albite pegmatites. The mineral was first recognised in concentrates collected by A. Montgomery in 1909 and two samples carried 13 and 8% respectively of manganocolumbite. The S.G. of two pieces of manganocolumbite average 5·70 and 5·76. A crude concentrate from the main creek collected by H. P. Woodward in 1912 contained (by weight): cassiterite, 33.4%; wolfram, 26.2; magnetite, 13.8; hematite and limonite, 13.7; epidote 6.3; manganocolumbite, 4.2; tourmaline, 1·4; ilmenite and garnet 1·0%. A parcel of rejects from the second dressing of ore from the Great Eastern mine contained: Cassiterite 11.9%; manganocolumbite 64.2%; manganotantalite, 6.4; limonite, 12.9; hematite, magnetite, ilmenorutile, 4.6%. Of 72 pebbles selected from material obtained on this lease

69 had S.G. 5·30-6·50, average 5·93, and were maganocolumbite Nb_2O_5, 50·3%; Ta_2O_5, 30·8% (see Table X.). The remaining three were low grade manganotantalite with S.G. 6·71-6·84.

The manganocolumbite is in angular fragments up to 13 grams in weight. Many of the fragments show crystal faces and several are perfect single-ended crystals. The common faces present are:—a, b, c, u, e, with k and m rare. Some observed combinations are:—a, b, u, k; a, b, u, e; a, b, c, u, e. (No. 9, Figure 9.) An example of unevenly developed u faces is shown in Figure 9 (26, 34).

Mt. Dale.—On a highly weathered outcrop of a micaceous pegmatite on the right bank of the Darkan River about 5 miles north-east of Mt. Dale one large and several small pieces of manganocolumbite were found associated with a little nigrine and euxenite. The mineral is in angular fragments with small remnants of one or two crystal faces. It is black and opaque, with S.G. 5·56 indicating the presence of Nb_2O_5, 63·9%; Ta_2O_5, 16·3%. The largest crystal carried 2·5% of TiO_2, and 8.32% of FeO indicating a preponderance of manganese over iron.

Ravensthorpe.—The large spodumene-bearing pegmatite on W.R. 17 about a mile north-west of Ravensthorpe contains a fair amount of black manganocolumbite in thin tabular fragments and also in larger, more robust crystals. It generally occurs in the felspar adjacent to spodumene and quartz. The specific gravity ranges from 6·04 to 6·14, Ta_2O_5, 35-38·5%; Nb_2O_5, 46·7-43·5%. A partial analysis shows it to be manganocolumbite with Nb : Ta = 2 : 1; Mn : Fe = 1·5 : 1. Manganocolumbite from a large quartz vein on Dunn's original farm 12 miles west of Ravensthorpe is in large tabular masses showing well developed a faces and sometimes b and c. It has crystallised in numerous thin flat (100) tablets separated by quartz and associated with a little mica. It occurred in three small lenses measuring about 3 by 12 inches. The columbite is a dull greyish black, and has a dull lustre on broken surfaces. One specimen contains Nb_2O_5, 58·95%; Ta_2O_5, 21·66%. It is often intergrown with mica (zinnwaldite). A partial analysis shows:—Mn, much; Sn, trace; Fe, little. Manganocolumbite also occurs at about 14 miles south-west of Ravensthorpe where it is intergrown with felspar.

Coolgardie.—The only specimen of manganocolumbite obtained is a single 4 gram crystal said to have been found three miles south of the town in 1932 in association with a number of detrital pebbles of ilmenite and tourmaline. The S.G. is 6·20, indicating Nb_2O_5, 41·6; Ta_2O_5, 40·6% and the forms present are a, b, c, u, z.

Gibraltar.—At two places, about a mile apart, in the vicinity of the mining centre of Gibraltar, manganocolumbite and a little manganotantalite have been found in angular fragments near pegmatite outcrops. Some of the first specimens were found by C. R. LeMesurier

in 1921 on the Bendigo G.M.L. 5036, the largest weighing 1·5 kilos. This area was inspected by E. S. Simpson in 1928 and a number of small pieces of manganocolumbite were picked up on the surface, the largest weighing about 25 grams. In 1929 a new find was made on this and the adjacent De Beers G.M.L. 1854 and some angular fragments up to 250 grams were obtained. Analysis of one fragment is given in Table X, and partial analyses made of two parcels of detrital pebbles. Manganese only slightly exceeds iron. A number of specimens from this lease gave S.G. ranging from 5·54 to 6·49 (mean/ 17, 5.84), indicating a range from Nb_2O_5, 64·7 to 33·0 and Ta_2O_5, 50·0 to 15·4%. The crystalline forms observed were a, b, c, m, y, g, e, u, one habit being shown in No. 14, Fig. 9.

Goniometer readings on a somewhat corroded crystal from this lease are:—

Face	b^1	b^2	g^1	m^4	a^1	a^2	m^1	g^1	e^2?	e^1?	u^4	u^3	u^2	u^1
ϕ	0°0¹	179	155	130	87	269	61	21	176	356	151	207	331	26
δ	90°0¹	90	90	90	90	90	90	90	55	55	41½	41½	41½	41

On the Lloyd George mine near the boundaries of G.M.Ls. 4580 and 4589 only a few broken crystals have been collected, the faces represented being a, b, c, m, e, u. The S.G. of these varies from 5·48 to 6·00, indicating a range of Nb_2O_5, 48·1-67·0 and Ta_2O_5, 12·9-33·6.

The mineral is pure black and opaque even in a very fine powder (38, 42, 51, 53).

Larkinville.—Manganocolumbite stated to have come from Larkinville has the following composition:—Ta_2O_5, 13·0%; Nb_2O_5, 67%; MnO, 20%. (77.)

Londonderry.—As far back as 1900 some detrital cassiterite associated with a little manganocolumbite and manganotantalite was found at two places known as Fraser's and Mercer's Finds in the hills west of Londonderry. The tantalum and niobium-bearing minerals have been found chiefly in the soil near pegmatite outcrops but a few pieces were also got from the solid veins on M.L. 80 at Fraser's and M.L. 61 at Mercer's. In the former E. S. Simpson found a crystalline mass of manganocolumbite in 1937 which weighed 350 grams and had S.G. 6·21. A few hundredweights of manganotantalite were marketed from Mercer's Find.

Manganocolumbite has been the commoner mineral on M.L. 80 at Fraser's, a typical crystal with S.G. 6·11, containing only 6·52% FeO. The S.G. ranges from 5·55 to 6·43, mean/20, 6·08, indicating the following range of composition:—

Nb_2O_5, 34·7-64·3, mean 45·4%.

Ta_2O_5, 15·9-48·1, mean 36·4%.

The mineral is in black angular and crystallised fragments up to 350 grams (¾ lb.). It frequently exhibits a number of easily recognisable faces, a, b, c, u being prominent, and e, m, z less common and

usually only developed on a small scale (No. 3, Fig. 8). The most perfect crystal is tabular parallel to 100, weighs 1·3 gram, and has S.G. 5·69. The forms are a combination of a^1, a^2, b^1, b^2, c^1, z^1, z^2, z^3, z^4 and traces of u^1, u^2, u^3, u^4. This crystal was measured on the goniometer and the approximate angle between e and u was found to be 43° 46′.

Much more detrital manganocolumbite was got at Mercer's Find and was partly admixed with tantalite. One sample collected by C. G. Gibson in 1909 from the east end of Mercer's M.L. was manganocolumbite with S.G. ranging from 5·47 to 6·54 (mean, 6·08). On M.L. 61 the manganocolumbite appeared to be shed from a number of quartz-albite-zinnwaldite pegmatites which were opened up in 1937, but yielded only a few pounds of ore.

The Londonderry mineral varies greatly in relative proportions of tantalum and niobium but always carries a large excess of manganese over iron. Single-ended crystals are common, as also is a parallel repetition of faces. A number of vicinal faces in the zone (001), has been noted. These give rise usually to striations on the macropinacoid, less often on the brachypinacoid. One crystal with S.G. 6·1 was bounded by a^1, a^2, b^1, c^1, and a large striated curved surface made up of vicinal faces in the zone (310), of which u^1 is the typical face. It also shows distinct indications of twinning on (100), a form of twinning seen in the Wodgina manganotantalite. An 11 gram broken crystal (S.G. 5.76) from Mercer's Find is a twin on e (021); it exhibits the forms a, b, c, u, n, m, z. Two other crystals got in 1937 gave the following data:

Wt. gms.	S.G.	Nb_2O_5.%	Ta_2O_5.%	Forms Present.
13·7	5·62	61·6	18·8	a, b, y, m, g, e, u, n.
3·7	5·65	60·4	20·0	a, b, c, m, e, u.

(24,51)

Ubini.—A small quantity of detrital cassiterite was obtained near the amblygonite-bearing pegmatite on M.L. 65, about three miles northwest of the railway. Associated with it were a few pieces of manganotantalite and manganocolumbite. A single large fragmentary crystal of manganocolumbite showed the forms a, b, c, u. It had S.G. 6·53 and was black and opaque.

Victoria Rocks.—A few large fragments of manganocolumbite and manganotantalite were found here by H. Fraser in 1909. One 200 gram fragmentary black crystal has S.G. 6·53 and contains 2·05% FeO.

Bellinger.—On Mica Hill, about 12 miles inland from Point Malcolm a little prospecting was done for mica in 1907 and a few small pieces of tantalite and manganocolumbite were found. The manganocolumbite has S.G. 5·59 and was black and opaque with traces of crystal faces. (23)

TABLE X.

ANALYSES OF COLUMBITE AND MANGANOCOLUMBITE.

Locality.	1. Mt. Francisco, Congo M.L.*	2. Mt. Francisco, Congo M.L.†	3. Mt. Francisco, Lode M.L.‡	4. Tabba.§	5. Coodardy.	6. Coodardy.	7. Poona.	8. Poona.	9. Jimperding.	10. Lake Moore.	11. Ravensthorpe.	12. Gibraltar.	13. Gibraltar.	14. Gibraltar.
	%	%	%	%	%	%	%	%	%	%	%	%	%	%
Ta_2O_5	22·38	31·07	41·30	48·00	32·30	20·00	39·48	15·30	44·5	19·94	37·0	27·28	16·2	20·8
Nb_2O_5	49·76	47·90	30·84	32·74	47·40	60·10	40·74	62·30	38·0	59·88	44·2	51·17	62·9	57·0
FeO	3·27	2·66	5·58	6·21	6·04	6·77	3·07	6·08	13·5	14·36	7·1	7·87	9·7	9·3
MnO	11·89	14·88	13·28	9·96	14·24	13·24	16·00	14·73	4·0	5·75	11·2	10·16	9·8	9·4
CaO	0·68	0·34	*Nil*	0·08	...	...	...	...	...	*Nil*	...	*Nil*	...	...
MgO	1·04	0·16	*Nil*	0·08	...	...	...	...	...	*Nil*	...	*Nil*	...	...
Fe_2O_3	...	trace	6·50	0·11	...	...	...	...	...	...	...	1·70	...	...
Al_2O_3	3·47	0·35	0·20	0·23	...	...	...	...	...	...	...	...	...	...
TiO_2	...	1·62	1·32	0·91	...	...	0·48	n.d.	...	0·64	...	1·75	...	...
SnO_2	0·16	0·40	0·34	0·42	0·10	trace	0·36	0·64	...	0·18	...	0·12	...	...
SiO_2	5·70	0·28	0·40	...	...	...	...	...	...	0·22	...	0·39	...	...
$H_2O\pm$	0·50	0·42	0·41	0·72	...	...	0·20	0·47	...	*Nil*	...	0·14	...	...
Na_2O	1·22	...	...	...	...	...	...	...	...	*Nil*	...	...	...	...
K_2O	0·80	...	...	...	...	...	...	...	...	*Nil*	...	...	...	...
Total	100·87	100·08	100·17	99·46	100·08	100·11	100·33	99·52	100·00	100·97	99·5	100·58	...	...
S.G.	n.d.	5·87	5·32–5·94	6·22–6·28	5·97	5·65	6·24	5·67	6·33	5·78	6·08	5·81	5·57	5·68
Analyst ...	E.S.S.	W.W.S.	D.G.M.	H.P.R.	E.S.S.	E.S.S.	E.S.S.	E.S.S.	E.S.S.	E.S.S.	E.S.S.	H.B.	E.S.S.	E.S.S.

* Handpicked concentrate with albite, microcline, quartz, garnet, muscovite. † Clean mineral. ‡ Bulk concentrate.
§ Three pebbles.

(II) STIBIOTANTALITE.

Stibiotantalite crystallises in the hemimorphic class of the orthorhombic system, but the habit of the crystals obscures the hemimorphic character. In the only locality from which good crystals have been obtained, Mesa Grande, California (13) the crystals are generally polysynthetic twins. In habit the crystals resemble columbite, the axial ratios being very nearly the same. The forms observed are: a(100); m(110); g(130); η (209); h(203); δ (043); w(4.12.9). The twin axis is generally the vertical axis. The macropinacoid, a, predominates and the most important cleavage is parallel to a(100). The prism g(130) is a very common form as are macrodomes (η). Isomorphous replacement of tantalum and niobium give a series of minerals differing in composition and specific gravity. A graph, similar to that for tantalite and columbite, is given in Figure 13. The first appreciation of this isomorphous replacement is due to Penfield and Ford (13, p. 349) who also realised its practical use in determining the composition from the specific gravity of fragments of stibiotantalite.

Greenbushes.—The Greenbushes tinfield was discovered in 1888 and over 300 tons of ore was sold within two years of its discovery. Amongst some wash dirt examined by J. J. East there was a mineral called "pale tin" or "resin tin" by the prospectors. This had much the same specific gravity as cassiterite and caused low assay results in tin ores. This mineral varied in colour from a dirty greenish white through flesh colour to almost black, many of the specimens resembling rutile, which it was taken to be. An analysis made by G. A. Goyder showed that it was a tantalate of antimony, part of the tantalic acid being replaced by niobic acid and part of the antimony oxide by bismuth oxide. This mineral was named stibiotantalite.

East's specimens described in 1893 were somewhat water worn but the form approached that of tantalite. The specific gravity was highest in the lightest coloured specimens (7·37), and those with the lowest specific gravity (6·47) were black and gave reactions for niobic acid. When fused on a charcoal block with soda the stibiotantalite yielded a metallic button which rapidly oxidised and gave the sublimate of antimony on the charcoal. The fracture is uneven, with an adamantine lustre, the exposed surfaces being changed to resinous. The hardness is from 5 to 5·5 and the mineral is brittle.

The specific gravities of eight specimens varied from 6·145 to 7·370, which latter, a flesh-coloured specimen with easy cleavage, was the one selected for analysis.

The main source of stibiotantalite has been in alluvial tin and tantalite ores from the southern part of the field and it has so far not been found in amounts worth mining as an ore. The main source has been the Enterprise M.L. 369 (now replaced by M.C. 1), on the saddle

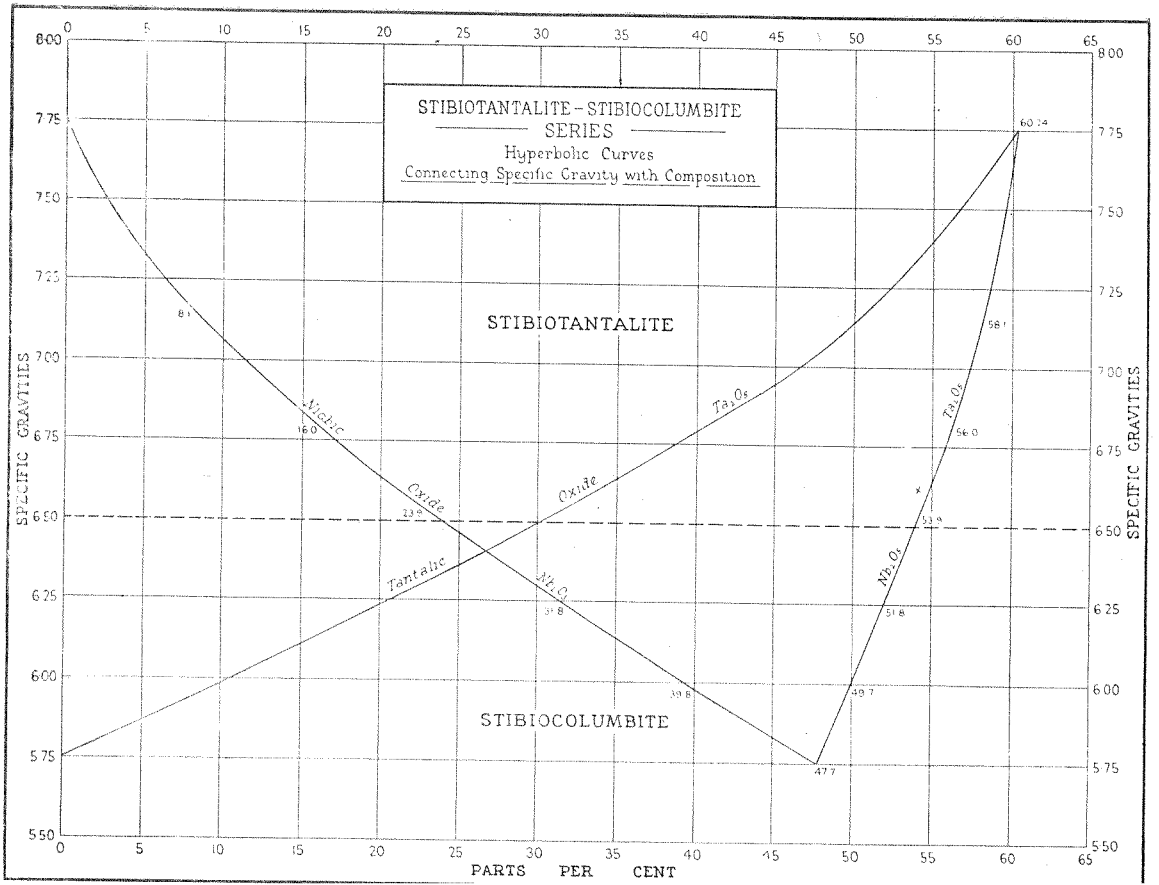

Fig. 13. Graph showing relationship of Specific Gravity to Composition in the Stibiotantalite-Stibiocolumbite Series.

between Floyd's and Bunbury gullies about a mile south-south-east of the town and in the alluvium in these gullies below this lease. A little has also been found in Boronia Gully near the Boronia, M.L. 361, 2 miles north-west of Greenbushes. Some has been found with tantalite and cassiterite in the Enterprise lode, a greisenised pegmatite, but the major quantity occurred in tin-bearing alluvium. Probably less than 1 cwt. of stibiotantalite has been obtained and most of it has been shipped away in parcels of tin or tantalum ore.

All the specimens obtained from the lode, and many of those from the alluvium have been replacements of, or fissure fillings in comparatively large pieces of tantalite and it would appear that the crystallisation of tantalite preceded that of stibiotantalite, the latter being formed by interaction between antimonial solutions and pre-existing tantalite in the later stages of pegmatite consolidation. The highly weathered nature of the whole area has made field work difficult and few fresh rocks have been obtained. No other antimony bearing minerals, such as stibnite have yet been found at Greenbushes. Polished sections of tantalite and stibiotantalite made by A. B. Edwards show that although the tantalite crystallised first, there has been a subsequent crystallisation of stibiotantalite with little marked replacement. (Crystal outlines are not broken or obliterated.) Veinlets are rare, and consist of honey-coloured translucent stibiotantalite, usually 1 mm. or less in thickness. E. S. Simpson stated that replacements are quite common and usually proceed from one side of the tantalite to an extent ranging from a thin shell about 1mm. thick to an almost complete replacement of a mass several centimetres across. The advancing face of the replacement is always uneven and often ragged, whilst completely isolated inclusions of unaltered tantalite have frequently been observed in the stibiotantalite. This pseudomorphous stibiotantalite is usually very finely granular, dull grey or yellow in colour and of low translucency.

The alluvial ground also carries small fragments, usually not over 5 m.m. in diameter, of pure stibiotantalite. Many of these have the appearance of the replacing mineral first described, others are more or less translucent, and apparently consist of a single crystal individual, in which, owing to its comparative softness and brittleness, crystal faces are not generally recognisable. Only one crystal in the Simpson collection has faces good enough for orientation and measurement, but from the descriptions of East and Goyder, several crystals were obtained in the original samples from Greenbushes. Cleavage faces are generally seen in detrital fragments and occasionally there are two adjacent faces with worn boundaries.

The largest crystalline mass recorded was about 2½ inches in diameter and is said to have been sold to the Foote Mineral Company, but there are no details of the faces present. Detrital fragments generally show a distinct cleavage parallel to the macropinacoid which has determined the shape, but there is sometimes a second cleavage which may be parallel to the base (001). Crystals are rather scarce; one of the largest found, measuring 13 x 12 x 6 m.m., was described by E. S. Simpson in 1936, who, however followed the orientation of Ungemach (25) and not that of Penfield and Ford (13), which from later work on bismutotantalite would appear to be correct. A sample of detrital stibiotantalite weighing 6lb. 4oz. recently obtained yielded 4ozs., of fragments showing crystal faces. All the crystals are worn but faces recognisable are: a, g, η , w, and several others which have not been completely identified. Many crystals are twinned and some are very similar to Penfield and Ford's original descriptions. Much of the alluvial stibiotantalite is translucent in thickness up to 4 or 5 mm. and some of it is quite transparent when 1 mm. or rarely 2 mm. thick. The colour is usually some tint of pale yellow such as sulphur, honey or lemon. Darker fragments grade towards cement grey or dark brown. Microscopic examination showed that some of the stibiotantalite has good pinacoidal cleavage, straight extinction, high refractive index and high birefringence. The interference figure is biaxial and often consists of a single bar with brushes and numerous sharply defined colored rings. Another mineral associated with stibiotantalite and labelled stibiotantalite in the Simpson Collection is yellow or brown and isotropic. It may be microlite. Specific gravities determined on a number of pebbles by E. S. Simpson were:—

6.41, 6.75, 7.05, 7.14, 7.18, 7.26, 7.27, 7.29, 7.34, 7.35, 7.36, 7.41, 7.46, 7.48.

The highest figure represents almost pure stibiotantalite, the lower ones increasing percentages of niobium grading to stibiocolumbite (see Fig. 13). There does not appear to be any correlation between specific gravity and depth of colour. The heaviest fragment (S.G. 7·48) was dark yellow, but two dark brown ones gave 7·26, 7·35 and a pale sulphur-yellow, 7.41.

In composition the Greenbushes mineral consists mainly of $Sb_2Ta_2O_8$, with minor variable amounts of $Sb_2Nb_2O_8$ and usually under 1% of $Bi_2Ta_2O_8$. Of the analyses made, two have been on the pure mineral and one on stibiotantalite intergrown with a little quartz.

TABLE XI.

ANALYSES OF STIBIOTANTALITE.

	%	%	%
Ta_2O_5	51·13	51·95	57·29
Nb_2O_5	7·56	4·49	1·79
Sb_2O_3	40·23	38·04	40·64
Bi_2O_3	0·82	0·79	0·30
NiO	0·08	trace	*Nil*
Fe_2O_3	trace	0·39	*Nil*
CuO	...	0·20	...
MnO	...	trace	...
SiO_2	...	3·14	...
H_2O	...	0·61	...
	99·82	99·61	100·02
S.G.	7·37	6·47	7·345
	G. A. Goyder	G. A. Goyder	E. S. Simpson

The fragment analysed by E. S. Simpson was dark brown in colour.

In 1904 Mawson and Laby examined specimens of a stibiotantalite for radio activity, but none was found and in 1911 W. G. Giles stated that he found traces of germanium in specimens which he analysed.

The bulk sample from which the pieces whose specific gravity was determined assayed:—Ta_2O_5, 50·7%; Nb_2O_5, 12·58%; a second bulk sample assayed Ta_2O_5, 51·15%; Nb_2O_5, 7·56%, which is almost identical with Goyder's first analysis.

In 1933 A. Galt stated that he had found stibiotantalite *in situ* in a lode on the west side of the road about a mile south of Greenbushes and a concentrate consisting of tantalite, cassiterite and stibiotantalite assayed:—Ta_2O_5, 42·15%; Nb_2O_5, 6·19%; Sb_2O_3, 2·25%; SnO_2, 30·52%. Tantalum ores from this part of the field generally contain a little stibiotantalite.

The southern limit of the occurrence of stibiotantalite appears to be the centre of the Vulcan, M.C.4, between Elliott's and Westralia Gully. It occurs there minutely intergrown with tantalite in a kaolinised greisenised lode (pegmatite) with a little cassiterite and schorl. The crystalline stibiotantalite was almost all got from M.L. 369 (now part of M.C. 1). (1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 13, 16, 17, 19, 23, 25, 33, 35, 40, 58, 67, 78).

(III) TAPIOLITE GROUP.

All the minerals in this group crystallise in the tetragonal system. In tapiolite the forms developed are a(100), m(110), e(101), s(111), c(001). The crystals are very similar to those of zircon, rutile and cassiterite, and are square octahedra, often monoclinic in appearance

by distortion. Ilmenorutile crystallises in combinations of s(111) and e(101), often with a(100) and less commonly m(110). There is very little information available concerning the forms developed by ixiolite, manganomossite and struverite, the remaining members of this group.

TAPIOLITE.

Pilgangoora.—During the period of increased production of tantalum ore prior to 1940, ore containing much tapiolite, Ta_2O_5, 75-85%, was mixed with manganotantalite from Wodgina to increase the Ta_2O_5 content of the ore exported. The first tapiolite recorded came from alluvial material at Green's Well. The crystals are small, 2·1 and 3·5 grams in weight and broken, but such faces as are preserved are very little corroded and have a brilliant lustre. In one crystal weighing 2½ grams and with S.G. of 7·839, in addition to the usual twinning on e, there is a further small inset which is a twin on (106), previously not known as a face or twinning plane in this series of minerals. The faces present are:—

Upper half of twin: a^1, a^2, r^2, r^3, s^1, s^2, e^2.
Small inset: a^3, a^4, r^6, r^7.
Low half of twin: a^3, a^4, a^1 (?), r^5 r^6, r^7, r^8, s^3.

Another crystal from the same locality is heart-shaped with a small re-entrant angle of approximately 11°. This appears to be a twin on (301). A distorted and fractured crystal shows the following faces:—a^1, a^2, r^1, r^2, s^1, s^3, s^4. Of these the most prominent are s^1 and s^4, a^1 and r^2 being moderately large, the others quite small. This crystal weighs 2·7 grams and has S.G. 7·875.

The largest crystal obtained was found in alluvial material containing microlite. It weighs 18 gms. and shows the forms (100), (001), (110), (111), the crystal being elongated parallel to the edge p^1p^2 and having a S.G. of 7·52. Two large but imperfect crystals in this parcel have portion of the surface converted into opaque, greyish-yellow microlite and the bulk S.G. is reduced to 6·95 and 6·85. Several uncrystallised pebbles show much greater replacement of tapiolite by microlite; one specimen shows on fracture a core of black tapiolite with a complete coating of light grey microlite 2-4 mm. thick.

An alluvial sample of tapiolite and microlite obtained from three miles north of Pilgangoora contained a small (0·9 gm.) crystal of tapiolite with S.G. 7·44. The forms s(111) and e(001) were present and the angle between s and e measured 43° and s∧s, 57°. A larger piece had S.G. 7·53 and was mainly tapiolite but partly altered to pale yellow microlite (37, 40, 50, 53, 69, 70).

Strelley.—In 1917 E. S. Simpson described tapiolite from Strelley, then known as Tabba Tabba north. The crystals at first sight appeared to be monoclinic, several having a distinct resemblance in form to

orthoclase. The recognisable crystals ranged in weight from about one to twenty grams. The forms developed are a, c, s, and e, whilst r is frequently present. One crystal has a prismatic habit parallel to the vertical axis.

The outline of the basal section is somewhat distorted owing to the irregular development of the faces, those present being a^1, a^2, a^3, r^1, r^2, r^3, r^4, r^5, s_3, s_4 and one small face which is probably e^4, and a second which may be d^2(058) or a^4. This fragmentary detrital crystal weighs 18½ grams and has S.G. 7·69.

A crystal of tapiolite weighing 35 grams and having S.G. 7·47 was analysed.

9178D. T. Molloy's Claim.

Ta_2O_5.	Nb_2O_5.	TiO_2.	SnO_2.	Fe_2O_3.	FeO.	MnO.	CaO.	MgO.
82·55	1·37	0·18	0·34	0·83	10·69	1·49	1·96	0·10

$H_2O.\pm$	Na_2O.	F.	Total.	S.G.	Analyst.
0·06	n.d.	n.d.	99·57	7·47	E.S.S.

The physical characteristics of the Strelley tapiolite are: form, often well-crystallised, usually in twins on (101) and elongated parallel to the edge of adjacent unit pyramid faces; in other specimens, rough fragments, water worn to various degrees—density, 7·36-7·69; H. = 6¼; brittle, no cleavage. Colour, on fresh fracture, pure black; colour of surface, black to dark brown, the brown tints being a sign of a thin surface weathering. Opaque except in fine powder, which is translucent and pleochroic from light to very dark brown. Birefringence, strong.

Some detrital pebbles obtained in 1927 showed an intergrowth of microlite with tapiolite. In one pebble only were crystal faces present and these indicated that the whole mass had the form of a complex twin of tapiolite. The major part of each pebble consists of a coating of microlite which has obviously replaced the tapiolite. A pebble weighing 85 grams was analysed (see under Microlite). Examination of the powder under the microscope indicated a relative volume of three parts of tapiolite to 10 parts of colourless isotropic microlite.

A number of mixed tantalum and tin detrital ores from Strelley contained tapiolite. One such came from 2½ miles north of M.L. 321 (four miles north of Strelley homestead); it consisted of cassiterite, tapiolite, and intergrowth of tapiolite and microlite, mica and quartz. It was made up as follows:

	Cassiterite. %	Tapiolite. %	Tapiolite and microlite. %	Mica and quartz. %
	47·7	39·7	11·3	1·3
S.G. ...	6·82–6·90	7·54–7·77	6·54–6·96	

This included a small twin weighing 11 grams having S.G. 7·77. This is a combination of a^1, a^2, a^3, s_1, s_2, r^3 (a^1, a^4, s^3, s^4). The angles between the faces measured:

$$a^2 \wedge (a^4),\ 66^\circ\ ;\ \ s^1 \wedge s^2,\ 57^\circ\ ;\ \ a^1 \wedge s^1,\ 61\tfrac{1}{2}^\circ\ ;\ \ a^2 \wedge r^3,\ 56^\circ.$$

Another sample from the same locality consisted of detrital tapiolite, partly yellow and partly black. This sample assayed:

Ta_2O_5.	Nb_2O_5.	TiO_2.	FeO.	CaO.	Fe_2O_3.	MnO.	H_2O.
82·34	1·24	0·30	7·40	3·44	2·40	n.d.	0·42

(35, 37, 40, 41, 47, 48, 49, 58, 70)

Wodgina.—A sample of tantalum ore collected in 1936 from two miles north of M.L. 86 consisted of a mixture of grey isotropic microlite with black tapiolite (?), some cassiterite, a little limonite, spessartite, quartz and kaolin. It assayed Ta_2O_5, 71·5%; Nb_2O_5, 1·4%; SnO_2, 10·7%. (68)

Woodstock.—On pastoral lease 2591/96, 23 miles south of Tambourah columbite was found in 1936 associated with tantalite in samples of tantalum ore. In one parcel there were three fragments showing tapiolite in various stages of alteration to microlite. A typical crystal elongated 111, was almost completely replaced, the broken crystal weighing 3·95 gms. and having S.G. 6·33. It showed small masses of black tapiolite embedded in light brownish microlite. Other crystals had S.G. 5·20 (6.9 gms.) and 7·4 (10·8 gms.). (68)

Greenbushes.—A broken crystal (S.G. 7·86) and a number of fragments of tapiolite with a little embedded quartz were obtained by H. S. Barrymore in 1937 from the northern end of the tinfield in greisen on old M.L. 294. The specific gravity of the fragments ranged from 7·53-7·71, mean/11, 7·63. The mineral is black, opaque, subvitreous and has a conchoidal fracture. Without testing, this tapiolite could readily be mistaken for cassiterite as the pyramid faces are well developed in a number of fragments. It is opaque except in very fine grains, when it is translucent, brown and pleochroic from pale brown to almost opaque. The birefringence is fairly high.

Two worn fragments of tapiolite were found associated with stibiotantalite in the Bunbury Gully in 1937. No crystal faces were present except a doubtful c(001). It is considered that much of the tantalite mined on M.C.1 is probably tapiolite (see description under Tantalite).

Jimperding.—Prospectors for gold on Yinnerding Creek, a branch of the Jimperding Brook, obtained a small amount of heavy black gravel in their dish concentrates. Much of this is columbite, but a single crystal of tapiolite was found in one parcel. This is 10 mm. long and weighs 0·95 gms. The ends of the crystal are broken but the faces s^1(111), s^2, s^3, s^4 are large and well-preserved, and a^1(100) and a^3

small but distinct. It is elongated parallel to the edge s^1, s^2. The measured angle between these two faces is 57° and between a and s, 61° 30′. The S.G. is 7·75. A much smaller crystal, only 3 mm. in length, is also tapiolite with $s^1 \wedge s^2$ measuring 57°.

Later a 5 gram very imperfect crystal was found in mica schist at a depth of several feet. It is black with brown veinlets. A partial analysis gave:—

$(TaNb)_2O_5$.	TiO_2.	SnO_2.	SiO_2.	WO_3.	CaO.	FeO.
79·9	trace	0·06	0·34	Nil	Nil	13·5 +
S.G.			(60, 61)			
7·2						

Ixiolite.

Wodgina.—Ixiolite was found *in situ* in the main tantalite lode. It occurred in rudely prismatic forms with but little evidence of crystallisation except complication by the oscillary development of adjacent faces. Most of the Wodgina ixiolite is cinnamon brown in colour but occasionally ranges to black. An analysis gave:—

Ta_2O_5.	Nb_2O_5.	TiO_2.	SnO_2.	MnO.	FeO.	CaO.	MgO.	Ign. loss.
70·49	7·63	*Nil*	8·92	10·87	1·34	0·42	0·37	0·18
Total.	S.G.							
100·22	7·36							

Intergrown cassiterite is absent and the SnO_2 is considered to be present as a homogenous mixture and to be part of the molecular constitution of the mineral. In thin slices it is subtranslucent and apparently homogenous except for gradual slight variations in depth of colour (23, 29, 33, 50).

Londonderry.—Tantalum ores collected by C. G. Gibson at the tin find at Londonderry in 1909 consisted mainly of normal columbite with ixiolite and a little tantalite. The ixiolite was first recognised as several detrital fragments with high S.G. and indeterminate crystallisation, composed mainly of manganese and tantalum oxides. The largest piece found weighed 37 grams and has S.G. 7·44. It is pure black in colour, opaque and possesses a brilliant lustre. It is wedge-shaped, growing outwards from a small starting point. The outward end is terminated by a fracture surface and one of the sides is chamfered by repetitions of many vicinal faces further complicated by twinning. An analysis gave:—

Ta_2O_5.	Nb_2O_5.	TiO_2.	SnO_2.	MnO.	FeO.	CaO.	MgO.	Ign. loss.
74·39	3·18	0·12	10·04	12·04	0·59	*Nil*	*Nil*	0·18
NiO.	Total.	S.G.						
trace	100·54	7·50						

The SnO_2 is apparently in solid solution in the mineral (24, 33, 58).

Manganomossite.

Yinnietharra.—A black opaque mineral occurring in rounded detrital masses on the western boundary of the Mica Queen M.L. four miles west of Morrissey Hill has been tentatively identified as manganomossite, the tetragonal niobium-bearing mineral corresponding to the orthorhombic manganocolumbite. An analysis of this mineral gave:—

Ta_2O_5.	Nb_2O_5.	SnO_2.	TiO_2.	FeO.	MnO.	H_2O.	Total.	S.G.
44·53	34·64	*Nil*	3·92	4·64	12·02	0·26	100·01	6.21

About 8 cwt. of manganomossite was sold in 1938 for approximately £170 a ton. Specimens examined had the following specific gravity and composition:—

S.G.		Ta_2O_5 %	Nb_2O_5 %
6·42	indicating	48	35
6·34	,,	45	37.5
5·72	,,	23	58
5·70	,,	22	58.5

Several specimens occur in vitreous quartz with a little microcline. No good crystal faces were present.

Manganocolumbite has since been obtained from the vicinity of Yinnietharra. Specimens show definite orthorhombic crystallisation. (39, 44, 45, 78.)

Ilmenorutile.

Globe Hill.—A number of good crystals and small angular pebbles of ilmenorutile, associated with a little cassiterite and possibly struverite and nigrine have been obtained on the south side of the Ashburton River, one and a half miles from the old Globe Hill Station homestead. Individual fragments, all single crystal individuals, range from a little under 1 gram up to 35 grams in weight. The crystals are combinations usually of s(111) and e(101), often with a(100), and less commonly m(110). The crystals are rarely symmetrically developed, being mostly greatly distorted by unequal development of the faces, elongation (sometimes extreme), and flattening parallel to the edge s^1s^2 and twinning on e (101). The various habits are similar to many of the crystals of tapiolite found at Strelley.

A large number of crystals which are twinned on e(101) have been collected. These are identical with several of the ilmenorutile crystals from Madagascar figured by Lacroix (Mineralogie de Madagascar. Tome I, pp. 227-232), and of those of tapiolite from Pilbara figured by E. S. Simpson. (37)

The specific gravity of a number of crystals and angular pebbles has been determined. The figures for one parcel ranged from 4·66 to 4·82, with a mean of 4·76 for 14 pieces from 0·2 to 20·6 grams in weight. A correlation of specific gravity with TiO_2 and Fe content has been made for three crystals.

	S.G.	TiO_2 %	Fe %
P_1	4·77	48·6	6.1
P_2	4·70	51·5	n.d.
P_3	4.82	59·0	6·2

These figures are plotted on the graph, Figure 14 showing the relationship between specific gravity and composition in this group of minerals. Specimens P_1, and P_2 are ilmenorutile; P_3 is close to the borderline between ilmenorutile and struverite, as is also a further specimen with higher TiO_2 content.

In another parcel of sheddings from the same or a nearby pegmatite a black mineral, possibly referable to nigrine, was found. Several specimens had S.G. 4·27 to 4·36 with TiO_2 86·3% in one with S.G. 4·29. There are other fragments intermediate between this and the more typical ilmenorutile. Three pieces had S.G. 4·52, one with TiO_2 79·7% and FeO 4·7%, which is therefore close to a highly rutiliferous struverite. All crystal faces were missing from this, but several sectors with different reflecting angles on a fractured face indicate a complex twin.

In another parcel there were angular black opaque fragments of ilmenorutile up to 35 grams, all with S.G. 4·31-4·36. One had TiO_2 80%. Almost all were multiply twinned on e(101) and possibly (106), in radiating sectors, and two or three had recognisable faces of s, a, e, and sometimes m.

An analysis of ilmenorutile from Globe Hill gave:—

TiO_2.	Ta_2O_5.	Nb_2O_5.	FeO.	SnO_2.	SiO_2.	MnO.	H_2O. +	H_2O—
66·28	15·44	8·64	8·00	1·24	0·32	trace	0·18	*Nil*

Total.	S.G.
100·10	4·833

The hardness is 6 on all the specimens measured (78).

Dalgety Downs.—Black, angular, detrital fragments referable to ilmenorutile have been collected from about 10 miles east of the homestead on this station. It has a hardness of 6¼, a conchoidal fracture and brilliant resinous lustre. The S.G. is 4·42-4·48 and the principal constituents are TiO_2 and FeO. The presence of Nb_2O_5 has not been established (37).

Lake Moore.—The first specimens found in the State were picked up somewhere between Lakes Monger and Moore, possibly near Payne's Find in 1913. One consisted of a mass of parallel crystals weighing 50 grams and having S.G. 4·98, with the faces s(111) and a(100) prominently developed. Another weighed 7·5 grams with S.G. 5·05, and is perfectly formed single-ended combination of a and s with a small bevel of m(110), the whole twinned on e(101). Both specimens are black and opaque. The larger mass gave the following analysis:—

Ta_2O_5.	Nb_2O_5.	SnO_2.	TiO_2.	FeO.	MnO.	Ca, Mg, Ce, Y.	H_2O.	Total.
10·08	33·47	0·04	45·85	10·15	0·41	*Nil*	*Nil*	100·00

The metallic bases almost exactly balance the metallic acids, and the analysis is therefore interpreted as:—

Mossite	$FeNb_2O_6$	2·02	54·01
Group	$MnNb_2O_6$	40·18	
	$FeTa_2O_6$	11·81	
Rutile,	TiO_2		45·85
			99·86

It is a typical ilmenorutile and is plotted on the graph at point S.

Melville.—In a vein containing manganocolumbite on the west side of Harrison's Reward claim near "the Basin" a number of angular pebbles and crystals of ilmenorutile were found; the largest fragment weighed 240 grams and consisted almost wholly of a single imperfectly formed and probably chipped crystal. The forms recognisable on it are s(111) and c(001). Most of the crystals are difficult to interpret, owing to their fragmentary state, the unequal development of faces, the twinning, and the similarity of several interfacial angles. The following combinations of forms have been recognised:—

Simple combination of s(111) and a(100).
Simple combination of s and c(001).
Simple combination of s, a, and c.
Combination s, a, m(110) twinned on e(101).
s only, with twice repeated twinning on e.

The specific gravity was determined on 10 fragments and found to range from 4·80 to 5·01, with an average of 4·90. The specimen analysed had this average S.G.

Ta_2O_5.	Nb_2O_5.	SnO_2.	TiO_2.	SiO_2.	FeO.	MnO.
7·61	33·31	0·39	43·20	0·60	10·81	3·61

Ca, Mg, Ce, Y.	H_2O.	Total.
Nil	0·16	99·69

There is an excess of (Fe,Mn)O in this analysis over that required to combine with $(Ta,Nb)_2O_5$. A micrographic examination was made by A. B. Edwards in 1938, who found that the SnO_2 was present as minute inclusions of cassiterite, and that ilmenite as well as ilmenorutile was present. The analysis may therefore be interpreted as:—

			Per cent. by Weight.
Mossite Group	$FeNb_2O_6$	30·93	51·10
	$MnNb_2O_6$	11·35	
	$MnTa_2O_6$	8·82	
Rutile, TiO_2			38·50
Ilmenite, $FeTiO_3$			8·94
Cassiterite, SnO_2			0·39
Quartz, SiO_2			0·60
Water, H_2O			0·16
			99·69

Two other angular fragments of uncertain locality but possibly from Melville were examined by E. S. Simpson in 1916. The larger weighed 24 grams and the smaller 8 grams. They had the following chemical composition:

	TiO_2	$(Nb,Ta)_2O_5$	FeO	MnO	SnO_2	S.G.
Larger	54·27	27·70	13·89	1·26	n.d.	4·76
Smaller	50·46	32·24	13·11	n.d.	1·48	4·85

When plotted on the graph (Figure 14) these are seen to be typical ilmenorutile. (63, 78)

Mt. Dale.—A little ilmenorutile was found with euxenite and beryl in a pegmatite in the vicinity of Mt. Dale, about 12 miles south-west of Sawyers' Valley. There are no mineralogical details available, but ilmenorutile is present in two parcels of minerals collected from this pegmatite.

Struverite.

Globe Hill.—Some of the ilmenorutile from Globe Hill is on the borderline between ilmenorutile and struverite, or a highly rutiliferous struverite, with TiO_2, 79·7% and FeO 4·7% described above.

Smithfield.—In 1933 H. Bowley found some small fragments of struverite in a supposed tin-bearing ferruginous conglomerate from near the southern end of Loc. 11472, about nine miles south-west of Bridgetown. The clean mineral separated had S.G. 5·83 and contained TiO_2, 25·5%. A qualitative analysis showed much Ta, Nb, Ti, Fe, with a little Mn. In 1937 a tin concentrate from Donovan's Find,

not far from the previous find, was found to consist of 70% struverite, 20% cassiterite, 5% quartz, and 5% tourmaline. This struverite is greyish black, opaque and in angular fragments up to about 2 grams in weight. One piece had S.G. 5·54 with TiO_2 39·6%. another had S.G. 5·77. When plotted on the graph the Smithfield specimens lie well within the struverite field. (62,70,78).

TABLE XII.

KEY TO GRAPH SHOWING RELATIONSHIP BETWEEN RUTILE, TAPIOLITE, AND MOSSITE, AND THEIR ISOMORPHOUS REPLACEMENTS.

Point.	Mineral.	TiO_2. %	S.G.
A	Tapiolite (pure $FeTa_2O_6$), Green's Well ...	...	7·90
B	Mossite (pure $FeNb_2O_6$)	...	5·20
C	Rutile (pure $TiTi_2O_6$)	100	4·20
D	$FeTa_2O_6$. $FeNb_2O_6$	...	6·55
E	$9FeTa_2O_6$. $TiTi_2O_6$	4·93	7·57
F	$FeTa_2O_6$. $9TiTi_2O_6$	80·81	4·62
G	$9FeNb_2O_6$. $TiTi_2O_6$	7·31	5·11
H	$FeNb_2O_6$. $9TiTi_2O_6$	86·45	4·31
J	Type Tapiolite, Tammela	...	7·50
K	Type Mossite, Moss	...	6·45
L	Type Struverite, Craveggia	41·20	5·57
M	Abandoned type Ilmenorutile (= Struverite) Miask	53·04	5·14
N	Type Ilmenorutile, Ireland	54·57	4·64
P^1	Ilmenorutile, Globe Hill	48·6	4·77
P^2	do. do.	51·5	4·70
P^3	do. do.	59·0	4·82
P^4	do. do.	79·7	4·52
P^5	do. do.	80·0	4·35
PH	Ilmenorutile or Nigrine, Globe Hill ...	86·3	4·29
Q	Ilmenorutile, Poona	43·8	4·95
R	Ilmenorutile, Melville	43·2	4·90
S	Ilmenorutile, Lake Moore	45·8	4·98
T	Struverite, Smithfield	25·5	5·83
T^1	do. do.	39·6	5·54

IV. RARE EARTH TANTALATES.

The minerals described in this group crystallise in the orthorhombic system and the forms developed are as follows:—a(100), b(010), c(001), m(110), p(120), p(111), q(150), q(301), s(201), β (011), e(101), d(201), h(120), v(231), u(101), l(011), s(111), z(121), r(131), o(210). These have not been recorded for each mineral, but b, c, a, m, p, d appear to be common to the group as a whole.

YTTROTANTALITE.

Cooglegong.—The mineral from here first described as fergusonite has since been proved to be yttrotantalite being orthorhombic in

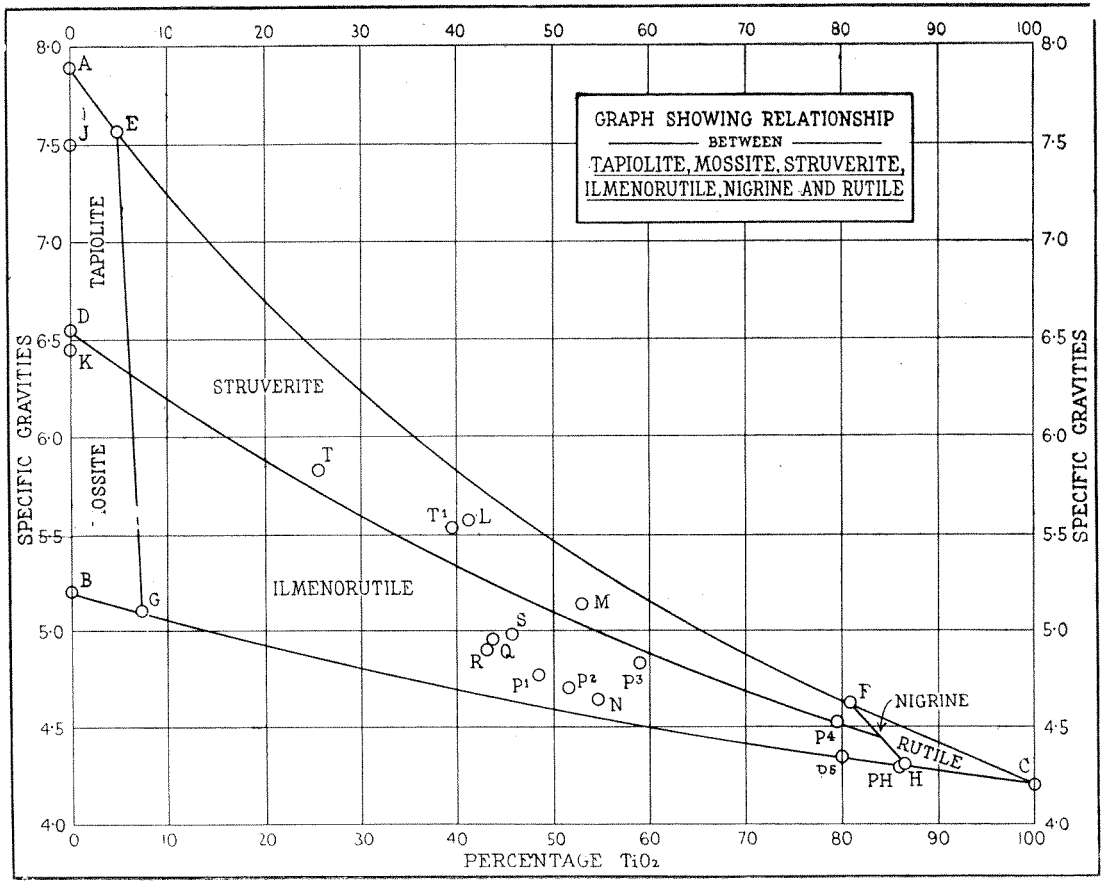

Fig. 14.—Graph showing relationships of the members of the Tapiolite-Rutile Series.

(After E. S. Simpson, 1939.)

crystallisation and containing much more tantalum than niobium. The first sample, discovered in 1906, came from a gully on the side of Trig. Hill, but the locality is not very definite. In 1913 a small sample was got from a pegmatite outcrop. The alluvial sample consisted wholly of clean yttrotantalite in subangular fragments up to 20 grams in weight. Many consist of single tabular crystals, or fan-shaped groups of such crystals, too imperfect for accurate determination of the forms. It is probable however, that a(100), b(010), c(001), m(110) and d(011) are represented. Externally the pebbles are dull and coated with a reddish yellow ochreous film of decomposition products. On a fresh fracture, which is conchoidal, the mineral is brownish black and brilliantly resinous. It is opaque except in very thin splinters under the microscope, when it is transparent, colourless to pale olive-brown, and isotropic. This indicates that the mineral is a hydrated pseudomorph after the original anisotropic yttrotantalite. Many other rare earth compounds pass thus readily into isotropic hydrous forms.

The following specific gravities were obtained:—5·79, 5·82, 5·88, 6·01, 6·03, 6·24, 6·39, 6·42, 6·48, 6·65, 6·68, 6·72, 6·76. These differences are due to variations in the ratio of Ta to Nb and in the proportions of water present. The hardness is 6 to 6½.

Two complete analyses were made of carefully cleaned material (see Table XIII). A bulk sample of several pounds weight of concentrates gave the following figures:

Ta_2O_5.	Nb_2O_5.	ThO_2.	$(Y, Er)_2O_3$.	Ce_2O_3.
54·22	1·80	0·36	27·73	3·20

In three other specimens the percentage of TiO_2 was 0·26 (S.G.6·76); 1·98(S.G.5·88); and 2·26 (S.G.6·01). The radium present in the alluvial mineral analysed is calculated to be 3·5mg. per ton, that in the lode mineral, 7mg. per ton.

When heated in a closed tube the mineral decrepitates slightly and turns a paler yellow colour, but does not glow. It is infusible and yields a sublimate of water.

A parcel of alluvial concentrates examined in 1926 consisted of yttrotantalite, 89%; cassiterite, 10%; monazite, 1%; columbite and ilmenite, traces.

Heavy minerals concentrated by E. S. Simpson in 1927 from a creek bed alongside Angelo's gadolinite vein, half a mile west of the Black Ridge consisted of cassiterite, 30%. magnetite, 25%; yttrotantalite, 10%; monazite, garnet and limonite, 5%. The largest fragment of yttrotantalite in this weighed 18 grams and contained well under 1% TiO_2, thus distinguishing it from tanteuxenite.

Another alluvial concentrate obtained in 1937 from four miles east of Cooglegong Creek Tin workings consisted of gadolinite, 42%; garnet, 30%; allanite, 20%; yttrotantalite, 6%; monazite or xenotime, 2%; besides two small pieces of hydrothorite (?). The yttrotantalite is intimately intergrown with the monazite in angular pebbles up to 10 grams in weight. It is brownish-black, with resinous lustre and has S.G. 6·02 to 6·14. The densest piece contained 0·80% TiO_2, with abundant Y_2O_3 and Ta_2O_5. (23, 27, 32, 33, 43, 47).

Split Rock Station.—Fourteen miles north-north-east of Eleys Well yttrotantalite was found in 1936. It was associated with coarse detrital cassiterite in the following proportions:—yttrotantalite, 15%; cassiterite, 60%; monazite, 22%; quartz, biotite, etc., 3%.

The yttrotantalite is in angular pebbles up to 20 grams in weight, brownish black in colour with a resinous lustre on a fresh conchoidal fracture. It is coated more or less heavily with brown yellow or greyish white decomposition products. No crystals were found. The hardness is 6¼, and S.G. 5·21, 5·53, 5·65, 5·78. The mineral contains much Ta, Nb, rare earths and water, with a little Ca and Ti. The TiO_2 determined on two fragments is 1·4 and 1·3%, respectively.

Tantalopolycrase.

Abydos.—At Hall's Tin Find about eight miles south-west of Abydos Station homestead there is a mineral associated with tanteuxenite that bears the same relationship to polycrase that tanteuxenite does to euxenite. This mineral has been called tantalopolycrase; it has the composition $YTaTi_2O_8$ with some niobium replacing tantalum and was first collected, examined and named by E. S. Simpson in 1927.

Tantalopolycrase occurs with detrital cassiterite in angular and often tabular fragments up to several grams in weight. The crystals seen were too much fractured and worn to permit of the forms being determined, other than the often striated tabular faces which are a(100).

Two slightly different types have been observed: one is brownish black and heavy; the other lighter both in colour and weight, the colour being bronze or slightly darker. Both have a conchoidal fracture, and a resinous lustre.

Pieces of the darker variety had S.G. 5·41, 5·46, 5·65, 5·88. The piece with S.G. 5·46 had H 5½ and contained 34·25% TiO_2. Pieces of the paler variety had S.G. 5·04, 5·09, 5·18, 5·20, 5·23, 5·32. The piece with S.G. 5·18 contained 26·4% TiO_2, with H 5½, was transparent and isotropic under the microscope and colourless to pale yellowish green. It showed an ignition loss of 2·64%.

A small parcel of tantalopolycrase obtained in the same district in 1934 is of the paler variety, but in much smaller (0·2-3·0gm.) grains, is more worn, and has a continuous and rather thick coat of a cinnamon brown decomposition product. Two cleaned fragments have S.G. 5·00 and 5·19, the latter containing 33·6% TiO_2. (47).

Cooglegong.—Some specimens of tantalopolycrase from Cooglegong associated with a little gadolinite were described by E. S. Simpson (1907 and 1909) as euxenite. Analytical data, in the light of more recent theory, indicate that this mineral is tantalopolycrase conforming closely to the standard formula, when allowance is made for Ta being replaced by Nb, Y by Er, and TiO_2 by autoxidised UO_2. The proportions of uranium and radium present are higher than in any other local mineral of this series, being UO_3, 6·69%, and Ra, 0·02 grams per ton, with protoactinium, 0·016 grams.

The mineral is in angular pieces with traces of orthorhombic crystallisation, and weighing from half a gram up to 57 grams. The surface is dull and brown in colour, but on a fresh fracture there is a brilliant resinous lustre and the colour is a mottled olive-brown. The fine powder under the microscope is transparent, isotropic and light brown. The hardness is 6·5 and S.G. 5·1-5·4. (17, 23, 33).

White Springs Station.—A mineral found in alluvium eight miles south-east of the homestead appears to be on the border-line between polycrase and tantalopolycrase. It is a titanotantalate and niobate of the yttrium earths with S.G. 5·17, and TiO_2 28·1%. The colour is very dark brown, lustre resinous, fracture conchoidal and hardness 5½.

Greenbushes.—Small fragments of an isotropic mineral resembling tantalopolycrase or pyrochlore have been observed in the stanniferous albite pegmatites in the Cornwall and South Cornwall mineral leases. As the local tantalite has a very much larger proportion of tantalum than niobium, the mineral is more likely to be tantalopolycrase than normal polycrase. (49)

Tanteuxenite.

Abydos.—A little tanteuxenite has been found in a range of hills about eight miles S.W. of Abydos Station homestead, in gravelly pieces 3-4 mm. in diameter associated with alluvial cassiterite. The colour is brownish black, lustre resinous, fracture conchoidal, and the fine powder is translucent to transparent and isotropic. The mineral contains 20·5% TiO_2 and has S.G. 5·3 to 5·9. (50).

Cooglegong.—This tin-mining area was the first place in Western Australia where compounds of yttrium with titanium, niobium and

tantalum were found. In the absence of complete analyses and measurable crystals considerable confusion arose in regard to the early naming of the minerals, to which the names euxenite and fergusonite were applied. It is now known that the minerals so named belong properly to the species *tanteuxenite*, *tantalopolycrase* and *yttrotantalite*.

In 1913 a specimen of true tanteuxenite was sent in to the Government Laboratory for examination. It was a large brownish black mass weighing about half a pound (200 grams) and having about 10% of adherent quartz. It was found in a quartz floater shed from a pegmatite vein. A similar fragment was obtained several years later. The masses are traversed by numerous minute cracks, more or less parallel, giving them a roughly foliated appearance. On either side of the cracks there was an extremely thin film of grey or brown decomposition product, which could not be separated completely from the pure mineral selected for analysis. (See Table XIII.) The radium content is calculated to be 9·6 mg. per ton, and the protoactinium content 7·7 mg. The comparatively low percentage of TiO_2, 14·17 and 16·1% respectively, distinguished this mineral from tantalopolycrase and indicates the presence of the $Y_2Ta_2O_8$ molecule. The high specific gravity, 5·77, and ratio of Ta to Nb (7 to 1) distinguished this mineral from euxenite.

The *Cooglegong mineral*, which is the type specimen, is almost black in colour when in mass, with a brilliant resinous lustre and subconchoidal fracture. The powder is dull brown in colour and under the microscope is isotropic (? because of hydration), olive-yellow in colour, and translucent up to 0·5 mm. in thickness. Before the blowpipe it is infusible, glows only slightly, decrepitates slightly, and yields water. It is slowly attacked by hot strong HCl or H_2SO_4 but most readily dissolved by a mixture of HF and H_2SO_4.

Tanteuxenite is plentiful in alluvial tin rejects from M.C. 15 on Eleys Creek between the old and new Government wells. A parcel of heavy minerals rejected on a second concentration of tin ore from M.C. 15 and collected by E. S. Simpson in 1927 contained 27% tanteuxenite, 69% monazite, 4% garnet, iron oxides and quartz. The tanteuxenite is in subangular to well rounded pebbles weighing from ½ to 4 grams each. On the exposed surface it is brown or brownish black in colour, with a dull lustre. Fresh fractures are conchoidal, with resinous lustre, and brownish black colour. Under the microscope it is transparent up to 0·5 mm, and isotropic. A number of specific gravities determined were: 5·66, 5·61, 5·58, 5·59, 5·56, 5·54, 5·52, 5·50, 5·36. The pebbles with S.G. 5·58 contained 18·07% TiO_2.

Several specimens are distinctly tabular in structure and almost certainly orthorhombic, though they are too waterworn for accurate angular measurement. The commonest forms appear to be a(100), b(010), c(001), and a first order prism (120)? making an angle of about 35° with a(100). The prism faces are vertically striated. (16, 47, 48).

Hillside.—In 1933 small quantities of tanteuxenite were found about six miles north of the old Tambourah gold diggings on the road to Hillside. It occurred in rather large pieces embedded in a microcline-albite pegmatite and was found along three parallel bands about four inches apart. Many of the pieces are well developed thin tabular crystals composed of a(100), b(010), l(120) and rarely d(201), p(111), m(110) and what are possibly (101) and (021). The (100) faces are vertically striated or covered with bas reliefs of parallel faces. The mineral is black on a fresh fracture, which is even to subconchoidal and the lustre is brilliant to resinous. The outer surfaces are more or less thinly coated with a greyish white decomposition product. Individual remnants of crystal reach 10 grams in weight. Specific gravities determined are 5·88, 5·85, 5·84, 5·83, 5·80, 5·79, 5·73. A piece with S.G. 5·83 contained 17·5% TiO_2 with abundant tantalum and yttrium. (62).

Mt. Francisco.—Alluvial tin ore from P.A. 630 six miles southeast of the Government Well contained some limonite, monazite, and tanteuxenite. Some of the pebbles collected by E. S. Simpson weighed over 2 grams. After cleaning, the specific gravities obtained were: 5·90, 5·78, 5·71, 5·59, 5·55, 5·45, 5·42. The specimen with S.G. 5·78 contained 18·16% TiO_2. Distinct traces of tabular prismatic crystallisation are visible, the face (100) being vertically striated. The fresh fracture was conchoidal, colour brownish black, and lustre resinous (47, 48).

White Springs Station.—Some alluvial cassiterite was said to have been found somewhere on this station in 1932 and with it were a few small pebbles of brownish black resinous tanteuxenite with S.G. 5·24. Considerable proportions of rare earths, tantalum, niobium and titanium were proved.

Wodgina.—A few small pebbles resembling tanteuxenite were found in 1931 in a parcel of alluvial tantalum ore from half a mile north of the Tantalite Mine. The chief constituents of the parcel were manganotantalite, microlite, cassiterite, quartz, felspar and spessartite.

Woodstock.—A few pounds of tanteuxenite in large fragments were obtained about four miles south-east of Cunagnunna Trig. Station (B4) on Woodstock Station in 1926. The mineral is similar in appearance to that occurring at Cooglegong; it has a hardness of 5½ to 6 and specific gravity 5·5-5·0. It is devoid of crystalline form or cleavage and has a subconchoidal fracture; colour, brownish black; lustre, resinous, practically opaque. The powder under the microscope is transparent, brownish-amber and isotropic. In the closed tube it glows slightly, decrepitates, and turns light greyish-yellow.

Titanium determinations on various pieces with S.G. 5·5-5·6 gave from 18 to 21% TiO_2. (Two complete analyses are given in Table XIII). The comparatively large proportion of cerium earths is noteworthy.

The radium content is 1·2 centigram per ton. As UO_3 represents autoxidised UO_2, and this and ThO_2 are isomorphous with TiO_2, the mean of the two analyses corresponds to $3Y_2O_3$. CaO. $9TiO_2$. $4(Ta, Nb)_2O_5$.

The largest (broken) fragment obtained weighed about 8 ozs. (230 grams). (47, 48).

Euxenite.

Mt. Dale.—A few small angular specimens of euxenite were found in 1932 in the outcrop of a pegmatite on the right bank of the Darkan River five miles north-east of Mt. Dale. The largest of the fragments weighed 80 grams. When freshly broken the mineral has a characteristic brownish-black colour, resinous lustre and conchoidal fracture. The specific gravity of the unaltered mineral is 5·21, which is near the upper limit for euxenite where it grades into tanteuxenite and a partial analysis show that it contains 52·0% of $Ta_2O_5+Nb_2O_5$ and 21·1% of rare earths (see Table XIII). It shows only 8·2% of TiO_2, indicating a considerable cocrystallisation of $Y_2Nb_2O_8$ with the polycrase molecule. When crushed it gives a light brown powder which under the microscope is seen to be translucent, olive-brown in colour, and isotropic. This confirms the evidence of the ignition loss that the mineral is the hydrated form of euxenite. Some fragments found a few yards away from the original specimens had a lower density (S.G 4·8) and were more granular, due apparently to intersecting films of decomposition products. (61).

Fraser Range.—When pegmatite veins were prospected early in the century for mica and other minerals, several pieces of hydroallanite were obtained, and with them two small specimens of euxenite. These are angular and slightly weathered and each weighs about one gram.

They have an earthy pale brown surface, but on a fresh fracture are dark brown with resinous lustre. The specific gravity is 4·64-4·88. Under the microscope the powdered mineral is light brown, translucent and isotropic, indicating the hydrated form of the original mineral. Before the blowpipe the mineral decrepitates slightly, but does not glow or fuse; it is slowly but completely attacked by strong HCl, with separation of a white powder. A qualitative analysis indicated the presence of abundant Nb(+Ta), and Y, and much Ti. Very little Fe and Ca were found, and PO_4, SiO_2 and Th were proved to be absent (33).

Calciosamarskite.

Hillside.—Calciosamarskite has been found in an alluvial pebbly concentrate four miles north-west of the homestead associated with microlite, an undetermined phosphate, iron ores, quartz, and microcline. In composition, physical and chemical properties, it closely approximates to calciosamarskite described from Hybla, Ontario.

The pebbles weigh up to 10 grams. On a fresh fracture the mineral is brownish black with a resinous lustre but the surface has a thin coating of light grey to brownish alteration products. It has a hardness of 5½. The specific gravity, determined on 20 more or less thinly coated pebbles, ranged from 5·73 to 5·03, with an average of 5·60. The two lightest pebbles with S.G. 5·25 and 5·03 were probably more weathered or more hydrated than the others. The piece, carefully cleaned, used for analysis, had the average specific gravity.

$(Nb, Ta)_2O_5$.	Y_2O_3.	CaO.	FeO.	MnO.	PbO.	UO_3.	TiO_2.	SnO_2.	$H_2O\pm$
58·3	16·5*	6·0	3·5	1·0	2·0	8·0†	1·0	2·6	2·0

Total.	S.G.
100·9	5·60

Under the microscope the mineral is translucent and the colour of the more transparent granules is olive-brown; it is isotropic. In a closed tube it decrepitates energetically when heated, and yields a little water without melting.

The place where calciosamarskite was found is only seven miles from Eleys where monazite, tanteuxenite, and tantalopolycrase occur; and twelve miles from Cooglegong where monazite, gadolinite, hydrogadolinite, metagadolinite, hydroallanite, tanteuxenite and yttrotantalite have been found. (70, 72).

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* Includes a little Ce_2O_3; † includes traces of BeO and UO_2.

TABLE XIII.

ANALYSES OF RARE EARTH TANTALATES.

Mineral.	Euxenite.	Tanteux-enite.	Tanteux-enite.	Tanteux-enite.	Tantalo-polycrase.	Yttrotan-talite.	Yttrotan-talite.
Locality.	Mt. Dale.	Coogle-gong.	Wood-stock.	Wood-stock.	Coogle-gong.	Coogle-gong.	Coogle-gong.
	%	%	%	%	%	%	%
Ta_2O_5 }	52·0	47·31	22·95	24·84	21·92	55·51	51·32
Nb_2O_5 }	....	3·83	15·27	13·40	5·53	2·15	4·72
TiO_2	8·2	14·17	21·05	20·71	29·95	2·20	0·31
SnO_2	trace	0·14	0·44	0·42	*nil*	*nil*	0·39
ThO_2	n.d.	tr.	2·86	3·16	1·76	1·02	0·53
UO_3	n.d.	3·35	4·16	4·04	6·69	1·18	2·38
Y_2O_3 }	21·1	17·48	11·32	11·50	15·76	23·00	18·37
Er_2O_3 }	....	....	5·04	5·12	9·27	8·38	8·98
Ce_2O_3 }	....	7·22	9·40	9·04	1·82	0·94	3·12
$(La, Di)_2O_3$ }	....	....	0·14	0·34	1·73	....	....
PbO	trace	trace	1·71	1·64	trace	trace	0·18
Fe_2O_3	n.d.	1·18	1·53	1·48	trace	trace	‡0·81
MnO	n.d.	0·35	0·28	0·28	0·34	0·87	0·74
MgO	n.d.	*nil*	*nil*	*nil*	0·35	*nil*	*nil*
CaO	3·7	2·22	0·97	0·97	1·02	2·18	4·57
Al_2O_3	n.d.	*nil*	0·31	0·61	0·76	*nil*	*nil*
Bi_2O_3	*nil*	*nil*	0·04	0·04	*nil*	*nil*	*nil*
SiO_2	n.d.	0·90	0·13	0·56	*nil*	*nil*	*nil*
Na_2O	n.d.	trace	*nil*	*nil*	trace	*nil*	*nil*
Ign. loss	3·5	2·40	2·24	2·16	2·82	3·36	3·82
Total	†	100·55	99·84	100·31	99·72	100·79	100·24
S.G.	5·21	5·77	5·55	5·55	5·37	6·24	5·79
Ra. mg per ton	....	9·6	11·9	11·5	19·1	3·4	1·8
Analyst.	....	Simpson.	Murray.	Murray.	Brooking.	Simpson.	Simpson.
						6 gram detrital fragment.	Piece from pegmatite.

* Includes H_2O-, 0·10. † Partial Analysis. ‡ (FeO)

V. MISCELLANEOUS MINERALS.

MICROLITE.

Mt. Dockrell.—An alluvial concentrate consisting mainly of cassiterite and manganocolumbite contained one or two small pebbles (up to 4 mm. in length) of pale brown isotropic microlite and the concentrate as a whole contained 25·8% of manganocolumbite intergrown with microlite. (70).

Hillside.—Detrital microlite occurs in a pebbly alluvial concentrate with calciosamarskite, iron ores, quartz, microcline and an undetermined phosphate 4 miles north-west of the Hillside homestead. (70).

Kangan.—A sample of angular pebbles from one mile north of Kangan Station homestead and 6 miles east-south-east of Womerina Pool on the Yule River consisted of a black tantalum-bearing mineral (? tapiolite) with dull yellow replacements of microlite. The

pebbles are mostly between 1 and 2 cms. in diameter, devoid of crystal faces, and having S.G. from 6·10-7·31 with an average of 6·61 for five pieces. The average S.G. of the total is 6·7. The sample contained Ta_2O_5 77·87%; Nb_2O_5 0·57%; CaO, 5·7%. (70).

Moolyella.—In 1938 a small pocket of manganotantalite was found in a pegmatite 15 miles north of Moolyella. Some of the tantalite was interlaced with a greyish to brownish alteration product which was found to be microlite. It is isotropic and contains much calcium.

Pilgangoora (including McPhees Range and Green's Well).—Microlite has been found in the alluvial tantalum ores of this district. Worn, rounded, detrital fragments of microlite from Green's Well have S.G. 5·37, 5·76, 5·61, 5·42, 5·73. Parts of the surface are covered with a very thin black coating which penetrates unevenly into the mass of the mineral. This coating, as well as more or less numerous minute black inclusions in the centre of the pebbles, appears to consist of manganotantalite. On fresh fractures the mineral is opaque and usually light pinkish-grey to liver-coloured. In thin section the mineral is seen to consist of numerous cores of clear unaltered microlite enclosed in a meshwork of the same mineral rather cloudy and altered. Throughout the section are tiny pinpoints of black manganotantalite. An analysis was made of a pale pink fragment of microlite practically free from included tantalite. (See Table XIV.)

In 1928 G. F. Hooley collected some coarse detrital black tantalite partly altered at the surface to yellowish grey microlite at a new find at Pilgangoora. Two large but imperfect crystals resemble those from Strelley (see below) and several pebbles show replacement of tapiolite by microlite, and in one specimen it is almost complete, the S.G. being 6·01, that of pure microlite being 5·70. One specimen exhibits on fracture a core of black tapiolite with a complete coating of light grey microlite 2—4 mm thick. A partial analysis of the whole parcel gave:

Ta_2O_5	Nb_2O_5	CaO	SnO_2
75·76	6·92	5·50	0·14

The fine powder consists of about 70% tapiolite and 30% colourless, transparent, isotropic microlite. Several of the larger particles of tapiolite are crossed by small veins of microlite.

Microlite also occurs in alluvium and in an albite pegmatite three miles north of Pilgangoora. A picked specimen from the alluvium had S.G. 5·88 and contains Ta_2O_5 + Nb_2O_5, 78·8%; 3A + Mn_2O_3, 3·22%; CaO, 13·22%. The detrital microlite is associated with some tapiolite, both separate and intergrown. The microlite

in the pegmatite is purplish-grey and has small cores of (?) tapiolite. Another alluvial sample, concentrated by bromoform, assayed: Ta_2O_5, 71%; Nb_2O_5 9%. (14, 16, 17, 23, 33, 50, 53, 58, 69).

Strelley.—Microlite intergrown with and replacing tapiolite has been found in samples from 2½ miles north of M.L. 321. The mixture is in coarse detrital pebbles weighing up to 100 grams. One pebble only showed crystal faces and these appeared to indicate that the whole mass has the form of a complex twin of tapiolite; the other pebbles are considerably worn. The major part of each pebble consists of a black iron tantalate, apparently tapiolite, which is replaced irregularly in parts by an opaque pale buff to cinnamon-coloured mineral. When broken this pale mineral is seen to penetrate to varying depths, forming ragged boundaries with the tapiolite and often penetrating deeply into it in minute veins. A pebble weighing 85 grams was examined in detail. It had S.G. 6·51 and was split into four pieces having S.G. 6·85, 6·50, 6·50 and 6·20 respectively. The lightest piece showed the greatest proportion of the pale-coloured mineral. It was crushed and analysed (see Table XIV). Examination of the powder analysed, under the microscope, indicates a relative volume of three parts of transparent, almost colourless isotropic microlite with a little quartz, albite and limonite. The analysis of the mixture gives the following mineral composition:—Microlite, 68·8%; tapiolite, 27·3; limonite, 1·6; albite, 1.1; quartz, 1·0; water, 0·2.

Such a mixture would have by calculation a S.G. of 6·1 against the observed density of 6·2 and it would have a volume ratio of tapiolite to microlite of 3 to 10, a ratio confirmed by several counts under the microscope.

Another pebble examined weighed 237 grams, with S.G. 6·8, and consisted of 45% of microlite with 55% of tapiolite. (48, 49, 70).

Tabba Tabba.—Grey angular alluvial fragments of microlite 2-15 mm. in diameter were found a few hundred yards north-east of the main tantalite lode of M.L. 312. The specific gravity ranged from 5·55-5·84 with an average of 5·69. The powder under the microscope is very pale yellow, transparent to translucent and isotropic. There are a few black inclusions. A qualitative analysis showed the presence of CaO, Ta_2O_5, MnO, Al_2O_3 and a trace of Fe and Mg. There was no Ce, Y, or PO_4. Greyish microlite pseudomorphous after and still enclosing granules of manganotantalite was collected two miles west of Tabba Tabba homestead. The pieces are broken and the breaks filled with albite and quartz and they are contaminated with calcite and mica. (70.)

Wodgina.—Microlite replacing manganotantalite is of fairly widespread occurrence in the vicinity of Wodgina.

Some alluvial pebbles in a stream bed less than a mile north of the tantalite mine, consisted of microlite. Beneath the surface crust the pebbles are opaque and light to dark grey, sometimes pinkish grey in colour. Under the microscope the powdered grains are colourless to pale yellow, transparent and isotropic. Individual pebbles vary in weight from 1 to 40 grams. The mean of 29 specific gravity determinations is 6·02. An analysis is given in Table XIV.

A sample from two miles north of the Tantalite Mine contained fine alluvial pebbles of microlite with S.G. 5·60, 5·76, 5·80 and 5·97 respectively. The colour is a light to medium grey and the heavier pebbles had a thin crust of black ore and sometimes black inclusions. Another sample from this locality was a coarsely crushed black tantalum ore containing a little pale grey mineral and a few composite fragments of grey black minerals. A chemical assay gave Ta_2O_5 71·5%; Nb_2O_5, 1·4; SnO_2, 10·7. The ore consisted of tapiolite (?), cassiterite and altered microlite with a little limonite, garnet, quartz, and kaolin. The greyish white mineral separated was isotropic and contained:—$(Ta, Nb)_2O_5$, 86·9%, CaO 9·8%; MnO, FeO, little.

In 1931 a sample was collected from 1½ to 2 miles north-east of the Tantalite Mine. It contained nine pieces of microlite, each averaging 1 oz. in weight. The crushed mineral was isotropic microlite with some dark fragments of tantalite, limonite, etc. This sample assayed Ta_2O_5, 72·83%; Nb_2O_5, 4·45%; SnO_2, 1·22%. An alluvial pebble from the same place weighed 59 grams and had a central core of black mineral about 1 cm. thick, covered by a layer of black mineral about 1 mm. thick. Other specimens from here are black pieces from the lode which on polishing show up greyish patches. The specific gravity varied from 6·59 to 6·83. The heaviest pebble gave the following analysis:—$(Ta, Nb)_2O_5$, 79·26%; FeO, 8·27%; MnO, 2·39%; CaO, 3·58%; SnO_2, 2·12%; Ign. loss, 1·06; total, 96·68%. These are intimate mixtures of tantalite and microlite. Alluvial pebbles from the same locality, ranging in S.G. from 5·60-5·90, consisted almost entirely of microlite, such material assaying over 72% Ta_2O_5.

A single fractured crystal weighing 28 grams was collected with alluvial manganocolumbite 10 miles south of Wodgina in 1937. The crystal, which has one or two rough unrecognisable faces, is a blotchy buff to light pinkish-brown in colour, is opaque and has S.G. 5·66.

Pebbles of a greyish-black opaque and apparently homogenous mineral were collected at Wodgina many years ago. One of these pebbles weighing 18 grams was broken in half and one half was analysed (see Table XIV). (17, 23, 49, 53, 59, 61, 68, 70).

Woodstock.—In one parcel of columbite and tantalite obtained in 1936 at the head of the Western Shaw River on Pastoral Lease 2591/96 there were three fragments showing tapiolite in various stages of alteration to microlite. A typical crystal of tapiolite, elongated (111), was almost completely replaced by microlite. This crystal weighed 3·95 gm. and had a S.G. of 6·33. It showed small masses of unaltered black tapiolite embedded in light brownish microlite. (68, 70).

TABLE XIV.

ANALYSES OF MICROLITE.

Locality.	Pilgangoora (Green's Well).	Strelley.	Tabba Tabba.	Wodgina.	Wodgina.
Lab. No. ...	...	320/28	2221/28	1077/28	1260/05
Ta_2O_5	73·54	77·96	67·03	77·00	73·82
Nb_2O_5	3·62	0·96	10·95	3·64	6·44
TiO_2	0·90	0·30	...	0·51	0·54
SnO_2	...	0·40	0·42	0·37	0·72
SiO_2	...	1·76	1·48	0·40	...
CaO	13·46	7·12	10·10	12·78	7·78
MgO	0·42	*Nil*	...	*Nil*	0·62
MnO	0·60	0·60	2·40	0·11	1·39
FeO	3·64	2·88	1·91	0·47	8·42
Fe_2O_3	...	1·78	...	0·72	...
Al_2O_3	...	0·24	1·68	6·55	...
Na_2O	1·66	3·68	...	1·18	...
K_2O	0·20	0·15	...	0·15	...
F	...	2·04	n.d.	1·09	...
H_2O+ ...	1·28	0·40	2·06	2·00	...
H_2O- ...		0·09			
Ce_2O_3	*Nil*	*Nil*	...	*Nil*	*Nil*
Y_2O_3					
Less $O=F_2$ ...	...	0·86	...	0·46	...
Total ...	99·32	99·50	...	100·51	99·73
S.G.	5·42	6·20	...	5·77	6·04
Analyst ...	E.S.S.	D.G.M.	...	E.S.S.	E.S.S.

SIMPSONITE.

Tabba Tabba.—In 1934 a few specimens of a cream-coloured crystalline detrital mineral ranging in specific gravity from 5·92—6·05 were received from M.L. 312 which was being worked for manganotantalite. The freshly fractured surfaces showed that they consisted of a transparent colorless mineral intergrown with a creamy-white translucent mineral. A preliminary chemical examination showed the presence of much tantalic oxide with some sodium and fluorine and traces only of iron and manganese.

In 1935 A. L. Kennedy sent in 8 lbs. of similar material and stated that a sample of tantalum ore from Tabba weighing about 1,450 lbs. contained from 50-100 lbs. of simpsonite which was subsequently described by H. Bowley and named simpsonite in honour of the late Dr. E. S. Simpson, mineralogist to the W.A. Government from 1897 to 1939.

Simpsonite occurs as flat tabular crystals in a quartz biotite pegmatite outcropping a little to the north of the tantalite workings on the M.L. 312.

All the specimens examined showed evidence of crystal development many of them having a pronounced tabular habit with a somewhat hexagonal outline. No complete crystals were found; they ranged in size from 0·5 cm. to 2·4 cm. maximum dimensions. Parallel crystal growths and penetration twins are common. Owing to the matt surface and to the development of many small vicinal faces goniometric measurements were not satisfactory, although the strongly developed basal plane and prisms were recognised. An X-ray examination subsequently showed that simpsonite belongs to the hexagonal class of the hexagonal system.

Under the microscope with reflected light simpsonite appears as colorless masses intergrown with a pale cream alteration product. With transmitted light a section of a crystal showed irregular cores of a transparent, colorless, anisotropic mineral bounded by interlacing veinlets of a small amount of a colorless isotropic mineral which is intergrown with a pale cream, almost opaque, granular mineral without any crystal habit whatever. Narrow veins of muscovite and quartz cut across the crystals in places. The anisotropic colorless mineral is simpsonite.

Complete analyses were made of two selected crystals.

	A.	B.
	%	%
Ta_2O_5	72·31	71·48
Nb_2O_5	0·33	0·32
SnO_2	2·00	1·19
FeO	0·16	0·44
MnO	0·08	0·04
CaO	3·40	3·19
Fe_2O_3	0·14	0·48
Al_2O_3	16·75	18·64
K_2O	0·24	0·42
Na_2O	1·16	0·68
PbO	0·42	*nil*
F*	0·21	0·38
H_2O+	1·35	1·39
H_2O-	0·20	0·03
SiO_2	1·78	2·34
Total	100·53	101·02
$O=F_2$	0·09	0·16
	100·44	100·86
S.G.	6·525	6·27
Analyst	D.G.M.	J.N.A.G.

(*) This figure is probably low as determinations of F. by an improved method on other specimens have invariably given higher results.

TiO_2, BeO, UO_2, ZrO_2 and rare earths have been proved absent in Specimen A.

Partial analyses have been made of three crystals the figures being:—

Specimen	C.	D.	E.
	%	%	%
3A (mainly Al_2O_3) ..	15·50	16·00	18·14
CaO	4·48	4·46	4·12
Na_2O	1·09	1·13	1·02
F	0·86	0·89	0·81

The fluorine figures in these partial analyses were obtained by H. P. Rowledge by an improved method.

All the specimens examined showed intergrowths of quartz and mica. The alumina, silica and water necessary to form these minerals has been deducted from the analyses, leaving tantalic and niobic oxides,

lime, sodium, aluminium, fluorine and water, which form two distinct minerals. The alteration product of simpsonite is considered to be microlite, which is a common alteration product of manganotantalite and tapiolite as noted above. The formula for simpsonite, after deducting the constituents from the analyses to form microlite, quartz, and muscovite, is:—

$$2H_2O.CaO.5Al_2O_3.4Ta_2O_5.$$

The alteration product, now known to be microlite, was previously given the name metasimpsonite. (64, 70, 74, 75).

Ainalite.

Greenbushes.—Two fairly large detrital fragments of what appeared to be typical cassiterite were found on analysis to contain a little tantalum. Partial analyses showed:

	Smaller %	Larger %
SnO_2	94·60	96·86
$(Ta,Nb)_2O_5$	3·86	2·54
FeO	1·57	1·10
	100·03	100·50
S.G.	6·86	6·77

A polished section of the smaller fragment which was examined by A. B. Edwards showed that it was a mixture of cassiterite and tantalite or tapiolite. (78.)

Ubini.—A number of fragments of a black mineral with an appearance somewhat like cassiterite were found somewhere near the amblygonite-bearing pegmatite three miles north-west of Ubini Siding. The mineral is dense and appears to be finely crystalline but has no external crystal faces. A partial analysis gave:

SnO_2, 79·2%; $(Ta,Nb)_2O_5$, 17·5%; FeO, 2·7%

Specimens did not respond readily to the test for cassiterite with hydrochloric acid on metallic zinc, some parts being coated only after prolonged treatment. In a polished section described by A. B. Edwards both tantalite and cassiterite are visible, but there is not sufficient tantalite showing in the slice to account for the tantalum present, which indicates that the cassiterite is saturated with the tapiolite molecule. (77, 78.)

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INDEX.

Where a number of references are given the more important ones are printed in heavy type.

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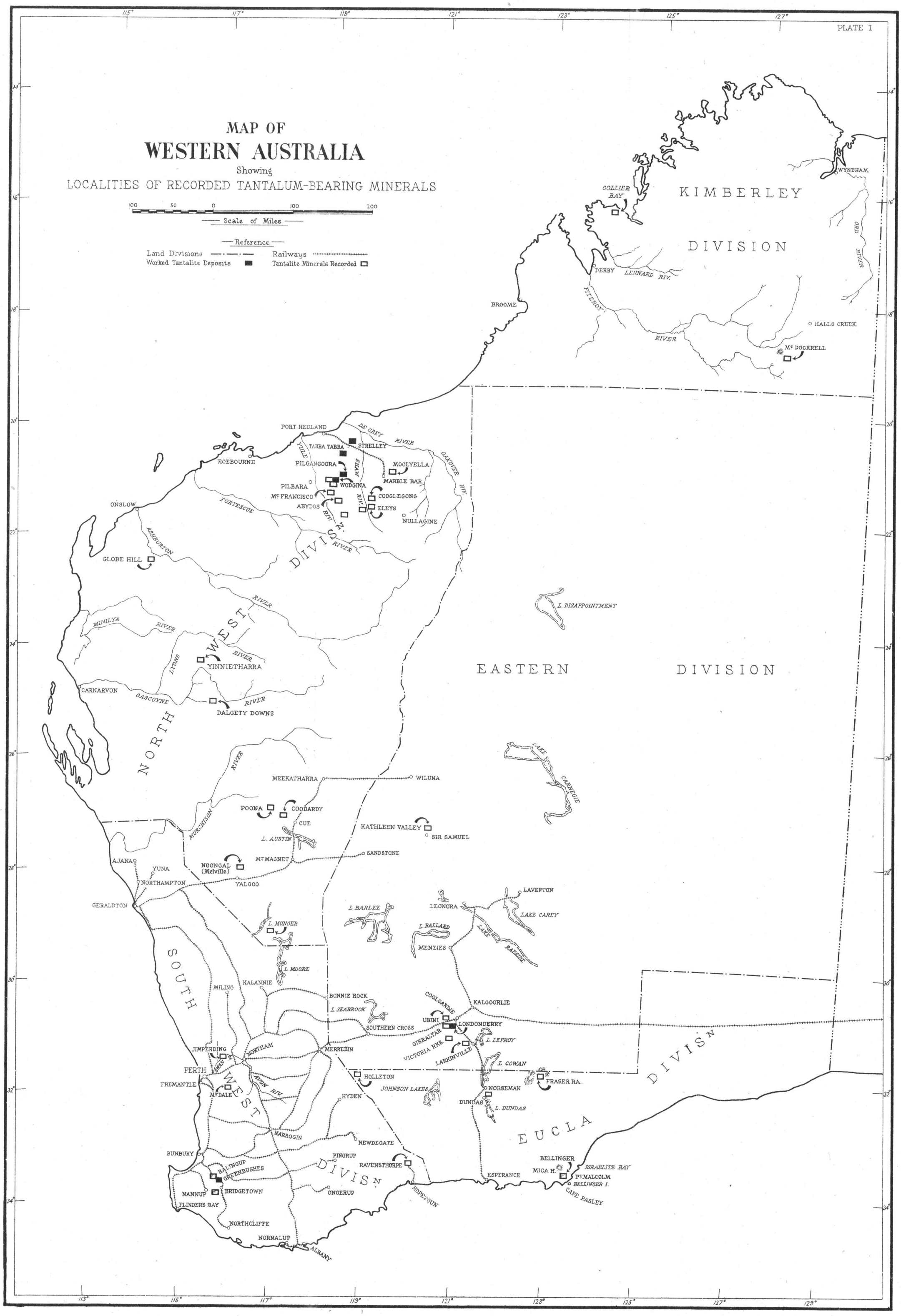


PLATE I
MAP OF
WESTERN AUSTRALIA
Showing
LOCALITIES OF RECORDED TANTALUM-BEARING MINERALS
Scale of Miles
Reference
Land Divisions
Railways
Worked Tantalite Deposits
Tantalite Minerals Recorded
KIMBERLEY DIVISION
EASTERN DIVISION
NORTH WEST DIVISN.
SOUTH WEST DIVISN.
EUCLA DIVISN.
WYNDHAM
COLLIER BAY
DERBY
LENNARD RIV.
FITZROY RIVER
BROOME
HALLS CREEK
Mt DOCKRELL
OLD RIVER
PORT HEDLAND
DE GREY RIVER
TABBA TABBA
STRELLEY
YULE
STAW
OAKOVER RIV.
ROEBOURNE
PILGANGOORA
MOOLYELLA
MARBLE BAR
PILBARA
WODGINA
Mt FRANCISCO
COOGLEGONG
ABYDOS
ELEYS
NULLAGINE
ONSLOW
FORTESCUE
ASHBURTON
GLOBE HILL
L. DISAPPOINTMENT
MINILYA RIVER
LYONS
YINNIETHARRA
CARNARVON
GASCOYNE
DALGETY DOWNS
LAKE CARNEGIE
MEEKATHARRA
WILUNA
POONA
COODARDY
CUE
MURCHISON
L. AUSTIN
KATHLEEN VALLEY
SIR SAMUEL
SANDSTONE
AJANA
YUNA
NOONGAL (Melville)
Mt MAGNET
NORTHAMPTON
YALGOO
GERALDTON
L. BARLEE
LEONORA
LAVERTON
LAKE CAREY
L. MONGER
L. BALLARD
LAKE RAESIDE
MENZIES
L. MOORE
MILING
KALANNIE
BONNIE ROCK
L. SEABROOK
COOLGARDIE
KALGOORLIE
UBINI
LONDONDERRY
SOUTHERN CROSS
GIBRALTAR
L. LEFROY
VICTORIA RKS.
LARKINVILLE
JIMPERDING
NORTHAM
MERREDIN
PERTH
SWAN R.
L. COWAN
FREMANTLE
Mt DALE
AVON RIV.
HOLLETON
FRASER RA.
JOHNSON LAKES
NORSEMAN
HYDEN
DUNDAS
L. DUNDAS
NARROGIN
NEWDEGATE
BUNBURY
PINGRUP
RAVENSTHORPE
BELLINGER
BALINGUP
GREENBUSHES
MICA H.
ISRAELITE BAY
ESPERANCE
Pt MALCOLM
BELLINGER I.
NANNUP
BRIDGETOWN
ONGERUP
HOPETOUN
CAPE PASLEY
FLINDERS BAY
NORTHCLIFFE
NORNALUP
ALBANY
113°
115°
117°
119°
121°
123°
125°
127°
129°
14°
16°
18°
20°
22°
24°
26°
28°
30°
32°
34°

PLAN SHOWING

LOCATION OF TANTALITE-COLUMBITE OCCURRENCES

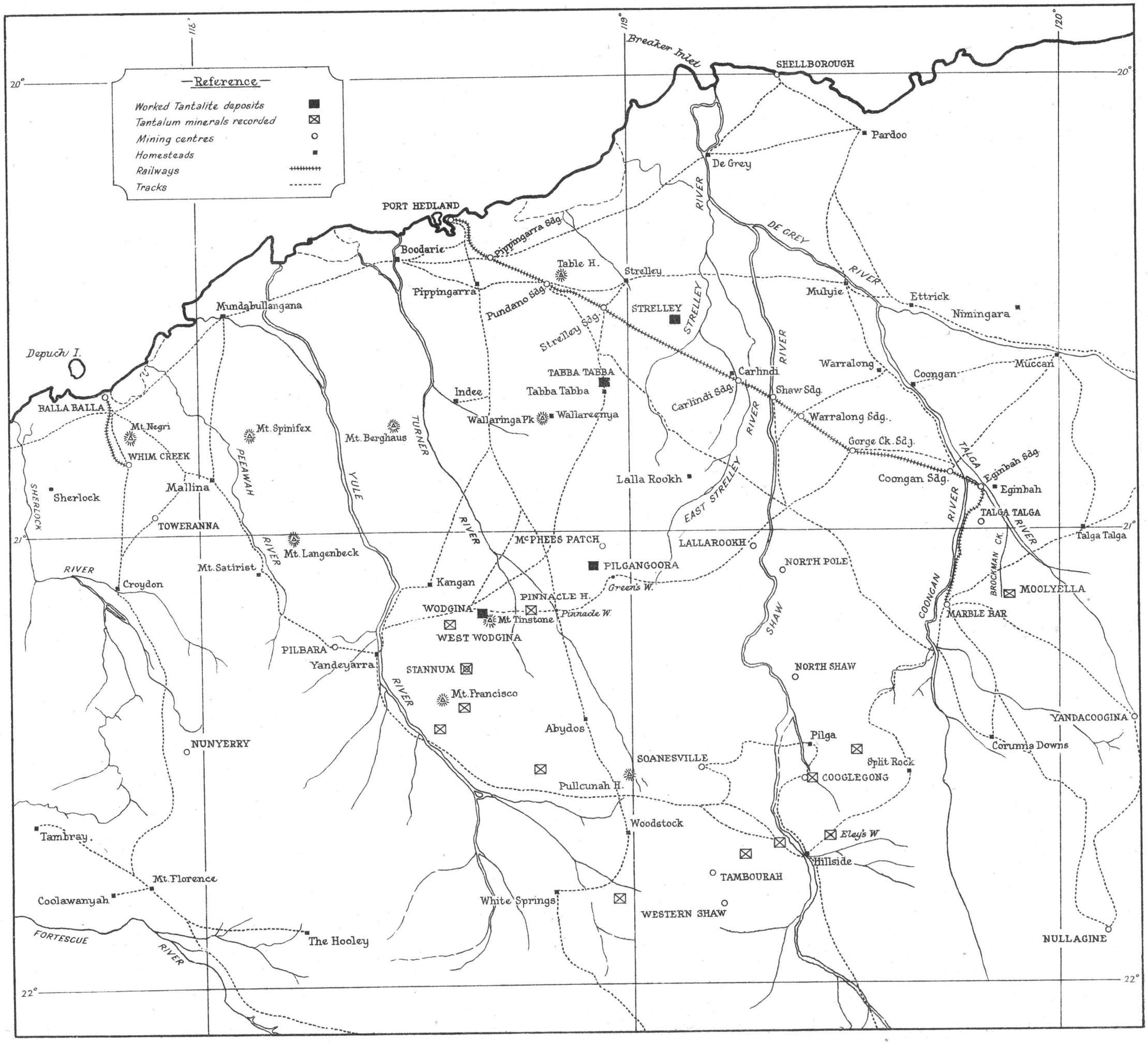
PILBARA DISTRICT

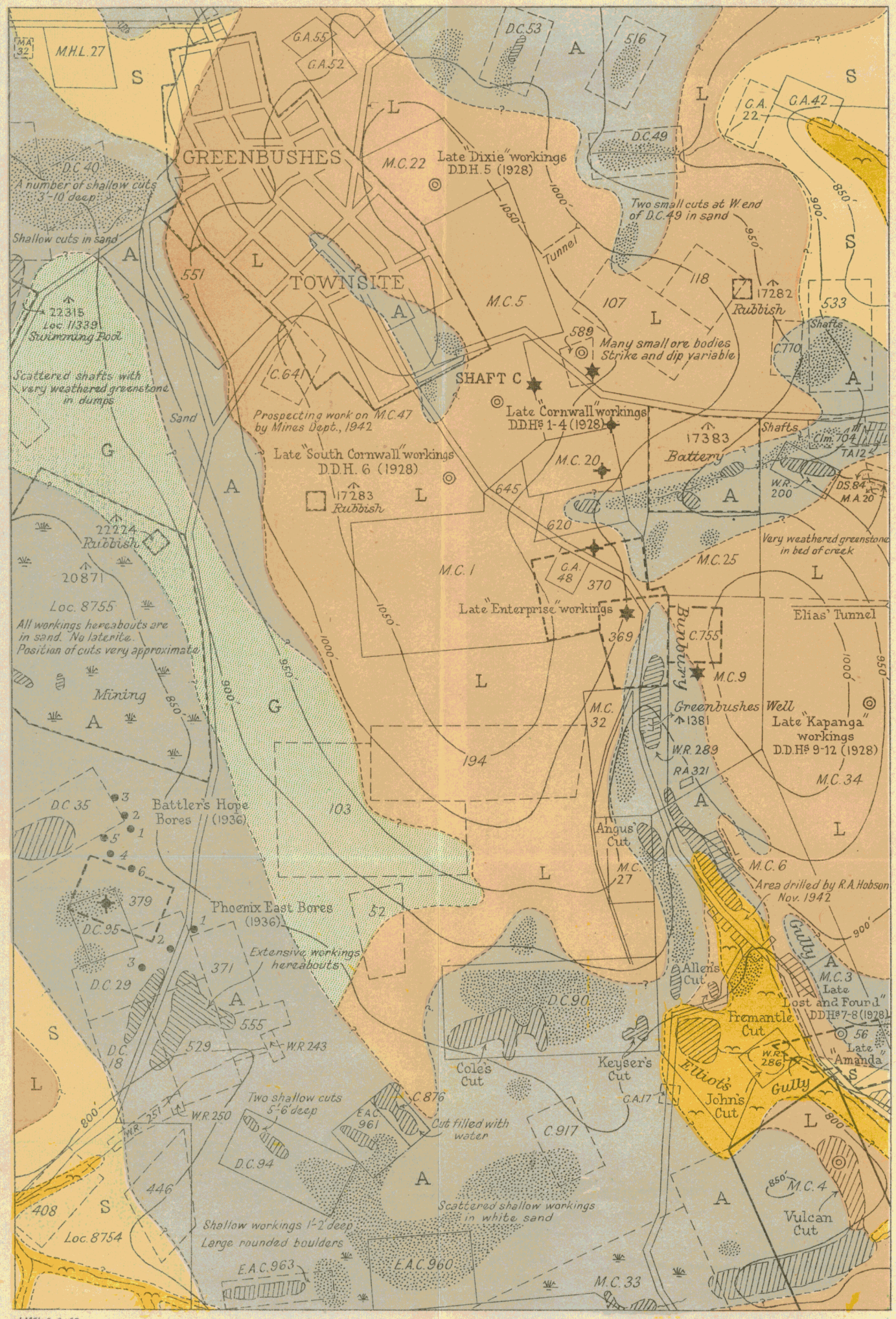
NORTHWEST DIVISION

Scale of Miles

15 0 15 30 45

PLATE II





LEGEND

Recent Alluvium	⌒
Areas covered with clayey soil and laterite rubble. Underlying rocks unknown.	S
Laterite – ferruginous	L
Old Alluvium	A
Clayey soil with laterite rubble. Fairly frequent shafts with very weathered greenstone in dumps. Underlying rock greenstone, probably of varying types.	G

REFERENCE TO SIGNS

Mining holding existing	M.C. 9
Mining holding void	M.C. 33
Mineral Lease	194
Mineral Claim	M.C. 5
Claim	C.755
Dredging Claim	D.C. 90
Extended Alluvial Claim	E.A.C. 960
Garden Area	G.A. 22
Tailings Area	T.A. 12
Machine Area	M.A. 32
Water Right	W.R. 250
Dam Site	D.S. 84
Miners Homestead Lease	M.H.L. 27
Open cuts formed as a result of sluicing	
Alluvial workings. May be shallow workings in creeks or deep workings by shafts. Individual shafts too numerous to be shown.	
Geological boundaries – approximate	----?----
Swamps	
Lode workings. Only principal lode workings are shown.	◎
Known production or reported production of tantalite	✱
Reported occurrence of tantalite	✦
Diamond drill hole, number, year drilled	D.D.H. 6 (1928)

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

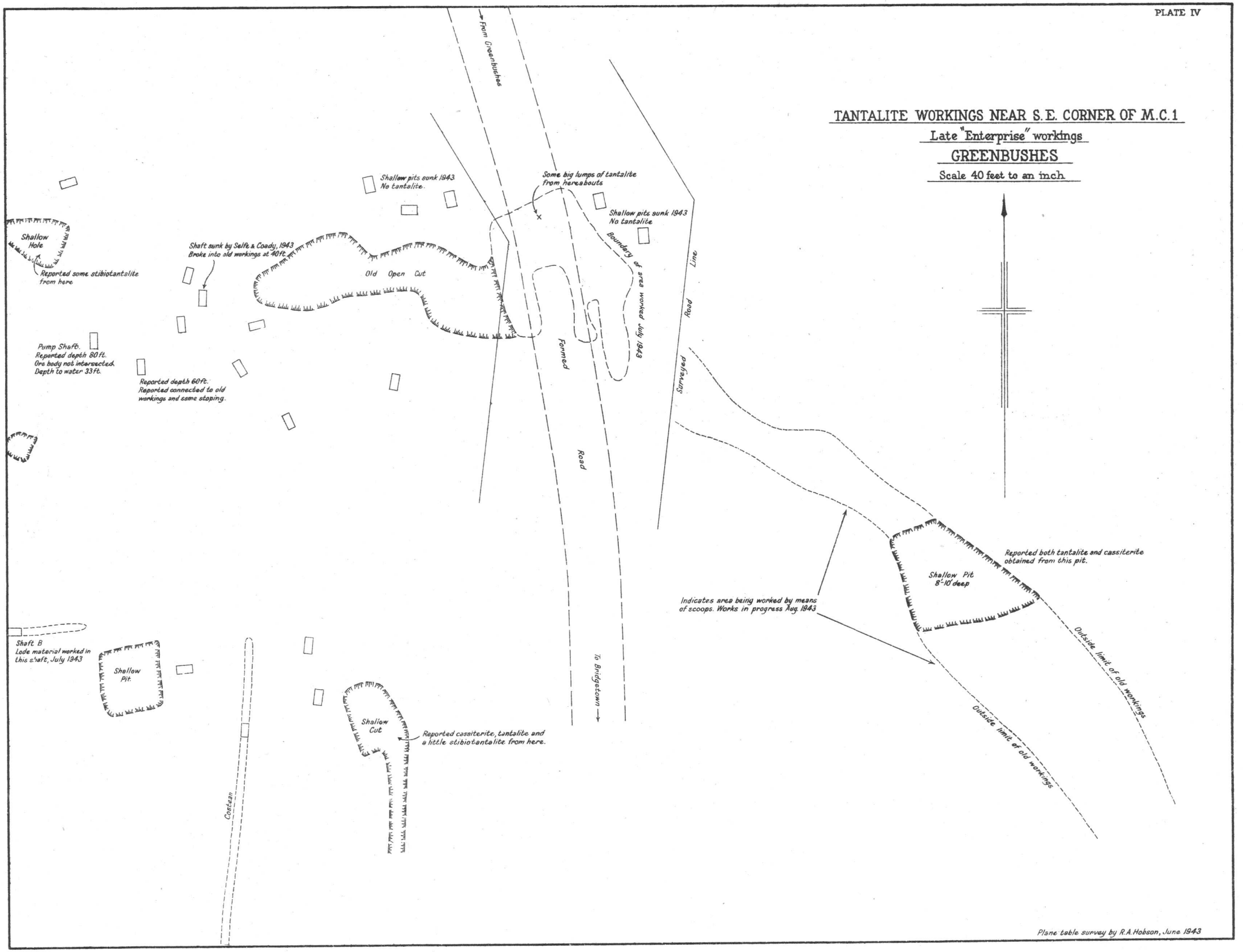
GEOLOGICAL SKETCH MAP
OF
PORTION OF GREENBUSHES MINING DISTRICT

Scale 20 chains to an inch

20 15 10 5 0 20 40

The localities indicated on this map are those at which tantalite is the principal economic mineral. Reference has been made in the text to other localities where tantalite is associated with cassiterite.

Geology by R.A. Hobson and R.S. Matheson, 1942


TANTALITE WORKINGS NEAR S.E. CORNER OF M.C.1
Late "Enterprise" workings
GREENBUSHES
Scale 40 feet to an inch
From Greenbushes
Shallow pits sunk 1943
No tantalite.
Some big lumps of tantalite
from hereabouts
Shallow pits sunk 1943
No tantalite
Boundary of area worked July 1943
Surveyed Road Line
Shallow
Hole
Reported some stibiotantalite
from here
Shaft sunk by Selfe & Coady, 1943
Broke into old workings at 40ft.
Old Open Cut
Formed Road
Pump Shaft.
Reported depth 80ft.
Ore body not intersected.
Depth to water 33ft.
Reported depth 60ft.
Reported connected to old
workings and same stoping.
Reported both tantalite and cassiterite
obtained from this pit.
Shallow Pit
8'-10' deep
Indicates area being worked by means
of scoops. Works in progress Aug. 1943
Outside limit of old workings
Outside limit of old workings
Shaft B
Lode material worked in
this shaft, July 1943
Shallow
Pit
Shallow
Cut
Reported cassiterite, tantalite and
a little stibiotantalite from here.
Costean
To Bridgetown
Plane table survey by R.A. Hobson, June 1943