

FRACTIONATION AND TANTALUM-TIN MINERALIZATION IN THE ARCHAEOAN WODGINA PEGMATITE DISTRICT, NORTH PILBARA CRATON, WESTERN AUSTRALIA.

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Synopsis

The late Archaean Wodgina pegmatite district comprises two main pegmatite groups, the Wodgina pegmatite group and the Mt. Cassiterite pegmatite group. The Mt. Cassiterite pegmatite group hosts the world's second largest tantalum resource. Both pegmatite groups are peraluminous LCT petrogenetic family, and belong to the albite and albite-spodumene pegmatite types, respectively. Distribution of the different pegmatite types is controlled by host rock type. Crystallization of primary tantalum minerals in both pegmatite groups occurs early in the paragenesis of each pegmatite group. Field and geochemical relationships suggest that the Wodgina pegmatite group has been derived from the Mt. Cassiterite pegmatite group as a residual sodic volatile melt, enriched in niobium and depleted in tin with respect to the Mt. Cassiterite group. This is reflected in changes in tantalum mineral composition and species. Fractionation within the pegmatite district attains a maxima in the Mt. Cassiterite pegmatite group, and is not influenced by the separation of the residual sodic melt.

INTRODUCTION

The Wodgina pegmatite district is located 130 km south of Port Hedland, near the north-western coast of Western Australia (Fig.1). This pegmatite district is located in the Wodgina greenstone belt, which lies in the centre of the Archaean north Pilbara granite-greenstone terrane. This pegmatite district for the purposes of this paper (Fig. 2) contains three pegmatite groups, classified by the schema of Cerny (1993):

- i) Wodgina pegmatite group of layered albite-type pegmatites hosted in metakomatiite.
- ii) Mt. Cassiterite pegmatite group of weakly layered to homogenous albite-spodumene pegmatites hosted in a psammo-pelitic sequence.
- iii) Beryl pegmatite group of simple zoned pegmatites with minor beryl and columbite mineralization, hosted in a sheared mafic schist unit.

Changes in distribution of pegmatite type appear to be directly controlled by host rock type, and have different structural controls. These changes are probably due to variations in rheology and deformation of the host rocks, and possibly thermal properties. The first two pegmatite groups show clear evidence of having been emplaced under compressional conditions into favourable structures, where magma pressure exceeded host rock strength.

Columbite-tantalite from the Wodgina pit has been dated directly using a SIMS technique at 2829 ± 11 Ma (Kinny, 2000). This age together with geochemical evidence and field relationships indicates a petrogenetic link to the 2830-2890 Ma suite of 'younger' granites that represent the culmination of magmatic evolution in the Pilbara Craton.

ECONOMIC SIGNIFICANCE

Tin and tantalum have been mined from the area since 1902. Currently, the Mt. Cassiterite pegmatite group contains the world's second largest tantalum resource of 84 million tonnes at 324 g/t Ta_2O_5 (combined resource plus reserve); second to the Greenbushes pegmatite in the Yilgarn Craton, Western Australia. The Wodgina mainlode pegmatite of the Wodgina pegmatite group supplied up to 80% of the world's tantalum requirements prior to World War 2. Minor amounts of cesian beryl were also mined from this body. In addition, the Wodgina area has a number of rare mineral species of scientific, as well as economic interest,

including the type locality for the manganese end-member of the wodginite series ($\text{Mn}_4\text{Sn}_4\text{Ta}_8\text{O}_{32}$).

WODGINA MAINLODE PEGMATITE

This pegmatite body is approximately 1 km long by 5-40 metres thick. It is characterized by a well-developed layered structure, which is best developed at the southern end of the open pit, where hanging wall and footwall cleavandite units embrace a central unit of banded to near-massive aplitic to granitic textured albite-quartz-muscovite pegmatite, with inclusions of coarse to megacrystic microcline. This central unit has been variably overprinted by sugary albite and lepidolite/lithian muscovite units. A large quartz core was mined from the northern end of the lode.

Most primary tantalum minerals (Table-1) are disseminated within the cleavandite units, frequently occurring as coarse skeletal to graphic textured crystals, commonly at the base of the cleavandite units and at the core of radial orbicular aggregates of cleavandite, suggesting an early paragenesis. Volumetrically minor secondary tantalum minerals such as microlite have a wider ranging paragenesis, but appear to have crystallized dominantly under subsolidus conditions. Micro-porous textures of microlite suggest a hydrothermal origin.

MT. CASSITERITE PEGMATITE GROUP

This pegmatite group covers a surface area of approximately 1.1 x 0.8 km, with pegmatite sheets being up to 400 m below surface. Individual pegmatite sheets range in thickness from 2-100 metres; sheets generally increase in thickness with depth. There are three principal groups of pegmatite sheets identified as the upper sheets, the main sheet and the basal sheet. Textural features of the sheets vary widely, with the varying influence of primary pegmatitic textures, late-stage overprinting/alteration and syntectonic deformation. Both primary pegmatitic banding and syntectonic foliation have been identified in the pegmatites. The upper sheet is dominated by megacrystic comb-texture spodumene, with pull-apart structures, and subordinate megacrystic microcline in a fine-grained quartz-albite-muscovite matrix. This texture is characteristic of albite-spodumene pegmatites worldwide (eg. Cerny, 1992). The main sheet tends to have a massive to foliated medium to coarse grained granitic texture, with megacrystic microcline porphyroclasts, with the micaceous component often being Rb-rich lepidolite/lithian muscovite. The basal sheet has a fine to medium grained texture dominated either by marbled albite or decussate spodumene.

Fine-grained tantalum mineralization is distributed throughout the pegmatite sheets and rarely appears to be influenced by internal changes in host mineralogy or texture. Tantalum is invariably present at levels above 40 ppm Ta_2O_5 throughout the sheets. Secondary tantalum minerals have a similar paragenesis and occurrence to that described for the Wodgina mainlobe pegmatite. Tantalum grade broadly decreases with depth, and appears to be inversely proportional to thickness in the upper sheets.

PETROGENESIS AND FRACTIONATION

Whole rock geochemistry of the Wodgina and Mt. Cassiterite pegmatite groups indicates that both have a geochemical signature typical of the peraluminous LCT (Li-Cs-Ta) petrogenetic family of Cerny (1993).

The Mt. Cassiterite pegmatite group has a bulk geochemistry similar to that of many other rare metal pegmatites, which typically approximate a granitic ternary minimum-melt composition (eg., Cerny 1992, 1993). However the Wodgina mainlobe pegmatite has a bulk composition close to that of the mineral albite which is reflected by the sugary albite and cleavandite units comprising up to 79% of the surface area as exposed in the open pit. Field and geochemical relationships indicate that the Wodgina pegmatite group has been derived by extraction of a residual sodic melt from the Mt. Cassiterite pegmatite group, while the latter was in a semi-consolidated state, consistent with the model of London (1990). The composition of the residual melt is pushed toward a sodic composition as a result of a concentration of volatile components such as H_2O , B, P and F.

In terms of the ore-forming elements tantalum, niobium and tin the Wodgina mainlobe pegmatite has undergone a depletion in tin and an enrichment of niobium relative to the upper sheets of the Mt. Cassiterite pegmatite. It appears likely that tantalum and tin were jointly crystallized from the pegmatite magma in a relatively homogenous fashion to form wodginite dominated mineralization, in addition to losing tin into exomorphic hydrothermal tourmaline-

mica veins, leaving a residual sodic melt enriched in niobium and tantalum. Changes in bulk geochemistry between the pegmatite groups are reflected in changes in ore mineral species (Table-1).

Both the Wodgina and Mt. Cassiterite pegmatite groups have the same degree of extreme fractionation which is manifest in low K/Cs and K/Rb values measured both in whole rock geochemistry as well as in microprobe analyses of muscovite. Only the beryl pegmatite group shows less fractionation. This suggests that the mineral chemistry is more important in controlling the concentration of Rb and Cs than bulk composition, as suggested by London's (1996) experimental studies.

The Mn/Mn+Fe ratio obtained by microprobe analyses of spessartine garnet has a similar relationship between the three pegmatite groups. These values also serve as an indicator of fractionation, and may exert a broad control on this ratio in columbite-tantalite group minerals, as garnet also appears to be early in the paragenesis of both pegmatite groups. A quadrilateral plot of Ta/Ta+Nb against Mn/Mn+Fe for columbite-tantalite and wodginite group minerals suggests that the highest degree of fractionation and tantalum content was attained in the Mt. Cassiterite pegmatite, which underwent only a slight change to more iron and niobium rich compositions with separation of the residual sodic melt.

CONCLUSIONS

1. Regional zonation within the Wodgina pegmatite district is principally controlled by host rock type, and is independent of changes in fractionation of rare alkali elements.
2. The albite type Wodgina pegmatite group has been derived directly from the albite-spodumene type Mt. Cassiterite pegmatite group, due to the separation of a sodic volatile enriched melt fraction.
3. Primary tantalum mineralization occurs early in the paragenesis of both major pegmatite groups, having a primary magmatic origin, although the pattern of internal distribution of tantalum mineralization is different.
4. Changes in tantalum mineral composition takes place with changes in bulk pegmatite composition, and is independent of changes in fractionation of K/Rb and K/Cs ratios.

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Table-1: Tantalum-tin-niobium mineral assemblages of pegmatite groups at Wodgina. The Ta minerals from the Wodgina and Mt. Cassiterite pegmatite groups commonly have high Mn and Ta contents, which is typical of highly fractionated pegmatites.

Pegmatite Group	Primary mineralogy	Alteration mineralogy
Wodgina	Mn-tantalite, Mn-columbite, minor wodginite and cassiterite?	defect microlite (high Ca), microlite?, fersmite (CaNb ₂ O ₆), rynersonite (CaTa ₂ O ₆)?
Mt. Cassiterite	Mn-tantalite, Mn-columbite, wodginite, cassiterite	microlite, defect microlite? (high Ca), calciotantite (CaTa ₄ O ₁₁)?
Beryl pegmatite	Mn-columbite, microlite?, cheralite?	microlite, defect microlite (high Ca), plumbomicrolite, uranomicrolite

General formula of microlite ((Na,Ca)_{2-m}(Ta,Nb,Ti)₂O₆(F,OH,O)_{1-n}.pH₂O. Defect microlite refers to microlite with a significant amount of A-site vacancies.

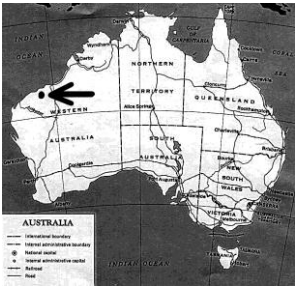


Figure-1 Location of the Wodgina pegmatite district.

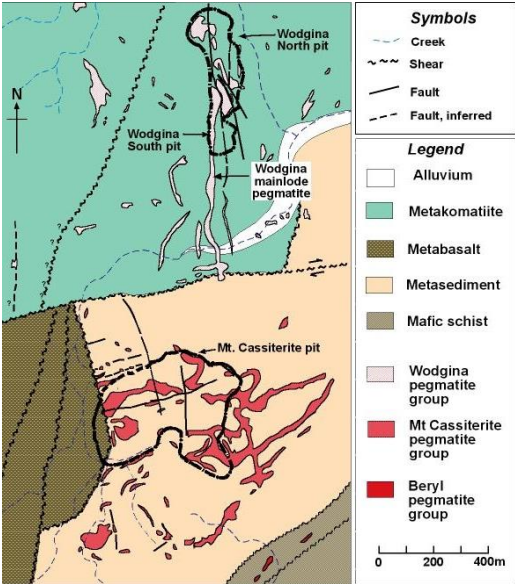


Figure-2 Distribution of pegmatite units within the Wodgina pegmatite district, showing outlines of the open pit mining operations. Mining of the Wodgina pit ceased in 1994.