Tasmania

Tasmanian Geological Survey
Record 2001/07

Rare earth, tantalum and niobium minerals reported in Tasmania

by R. S. Bottrill

Abstract

There are numerous occurrences of rare earth minerals in Tasmania. Some small alluvial monazite deposits have been mined in the past, and other small resources have been defined. One poorly understood primary REE occurrence in Cambrian rocks in the Huon Valley may be of potential economic interest, but most other significant occurrences are in beach sands or tin-bearing placer deposits. There are no significant deposits of Ta, Nb or Sc known, but it is considered that a few rock or deposit types in Tasmania would have some potential, although there has been little or no significant exploration directed at these valuable metals.

Introduction and nature

These commodities are all relatively rare but highly valuable metals. There is considered to be a small potential for all of these commodities to occur in Tasmania, although known resources are small and sparse (excepting monazite).

Mineral Resources Tasmania recently granted an exploration licence for tantalum in the Blue Tier tin district, although this has lapsed and no resources are currently identified.

Rare Earths (REE)

Rare earth metals are usually considered to comprise the periodic row of lanthanides ranging from atomic numbers 57 to 71, but some definitions include other rare elements like scandium (Sc) and yttrium (Y). Generally soft, malleable and usually reactive, especially at high temperatures, the rare earth metals range in colour from iron-gray to silvery-white, and have melting points which range from 789° to 1663°C. The elements range in crustal abundance from cerium (Ce), the 25th most abundant element of the 78 common elements in the Earth's crust (at 60 parts per million), to thulium and lutetium, the least abundant rare-earth elements at about 0.5 parts per million. Lanthanum (La) and niobium (Nb) are also important.

Tantalum (Ta)

Tantalum is a rare, hard, blue-gray refractory metal with chemical characteristics resembling those of niobium, the element above it in the periodic table. It is easily fabricated, has a high melting point, and is a good conductor of heat and electricity. Pure tantalum is extremely ductile and can be drawn into a very thin wire. It is malleable and highly resistant to common acids and to corrosion at temperatures below about 150°C.

Niobium (Nb)

Niobium and columbium are synonymous names for the chemical element with atomic number 41; despite the adoption of the name niobium by the International Union of Pure and Applied Chemistry, the alternative name columbium is still used by metallurgists in the United States of America. Niobium (symbol Nb) is a shiny-white, soft, refractory metallic chemical element. In its physical and chemical properties niobium resembles tantalum, the element below it in the periodic table, and separating niobium from tantalum is difficult. At normal temperatures niobium is insoluble in most acids and alkalis. It reacts readily at high temperatures with oxygen, carbon, the halogens, nitrogen and sulphur, and must be placed in a protective atmosphere when processed. Niobium looks like steel or platinum.

Yttrium (Y)

Yttrium is a highly crystalline iron-gray metal. Usually considered a rare-earth metal, it is found above lanthanum in group IIIb of the periodic table. Yttrium is fairly stable in air but oxidises readily when heated, and reacts with water and mineral acids.

Scandium (Sc)

Scandium is a silver-white metal which develops a slightly yellowish or pinkish cast upon exposure to air. It is relatively soft, and resembles yttrium and the rare-earth metals more than it resembles aluminium or titanium. Scandium is a very light metal and has a much higher melting point than aluminium, making it of interest to designers of spacecraft. Scandium is not attacked by a 1:1 mixture of HNO_3 and 48% HF.

Uses

REE and Y

Mixed rare earths are used in glass making, ceramic glazes, glass-polishing abrasives, carbon arc-light electrode cores, catalysts for petroleum refining (catalytic crackers and converters), metallurgy, permanent magnets, nickel hydride batteries, and X-ray intensifying phosphors. Individual purified rare earths have many uses, for example in lasers and as colour television picture tube phosphors. The largest use of the element Y is as its oxide yttria (Y_2O_3), which is used in making red phosphors for colour television picture tubes; it also has other uses. Yttrium metal has found some use alloyed in small amounts with other metals.

Ta

Major uses of tantalum include electrolytic capacitors, chemical equipment, and parts for vacuum furnaces, aircraft and missiles. Tantalum was used in the filaments of electric light bulbs and electronic tubes but has been largely replaced by tungsten. It is often alloyed with other metals where it imparts strength, ductility, corrosion resistance and a high melting point. In particular, since the 1960s, tantalum has been added to nickel-based superalloys (mostly for jet engine components) at levels of up to 4%. Because it is unaffected by body fluids and causes no adverse tissue reactions, tantalum is used in dental and surgical instruments and prostheses. Useful tantalum compounds include the carbide TaC_2, an abrasive that is almost as hard as diamond; and the oxide Ta_2O_5, used in making special highly refractive glass. The major use for tantalum, as tantalum metal powder, is in the production of electronic components, mainly tantalum capacitors. Major end uses for tantalum capacitors include portable telephones, pagers, personal computers, and automotive electronics.

Nb

Uses of Nb range from electronic components to transportation, metal-working machinery, and chemical equipment. In the form of ferrocolumbium, niobium is used as an alloying element in steels and in nickel, cobalt, and iron-base superalloys and special stainless steels for such applications as jet engine components, rocket subassemblies, and heat-resisting and combustion equipment. Large amounts of niobium have been used in the US space program.

Niobium resists corrosion, is a good shock absorber, and can withstand very high temperatures. The presence of niobium makes hot-pressing dies and cutting tools resistant to shock and wear. Its conductivity makes niobium useful in electronic devices and superconductive magnets. Combined with nickel, niobium makes a high-temperature alloy; added with iron to stainless steel, it offers stability on welding or heating. Niobium is also used in high-strength structural steel. Nuclear reactor cores are constructed with niobium alloys because niobium does not react chemically with uranium and because it is resistant to corrosion. Niobium is totally hypo-allergenic, so it is frequently used in artificial joints, plates, pacemakers and dental implants.

Sc

Scandium is used increasingly in aluminium alloys, where it has the effect of refining grain size, inhibiting recrystallisation, increasing plasticity, enhancing fatigue resistance and increasing the strength of aluminium. As a component of welding wire, it produces stronger welds without heat cracking. Scandium iodide added to mercury vapour lamps produces a highly efficient light source resembling sunlight, which is important for indoor or night-time colour television. The radioactive isotope ^{46}Sc is used as a tracing agent in refinery crackers for crude oil.

Economics and Production

The information in this section is largely sourced from the United States Geological Survey mineral reports (http://minerals.usgs.gov/minerals/pubs/commodity/niobium/).

REE and Y

Most rare earth metals are derived from the minerals bastnaesite, monazite, xenotime and 'ion-adsorption clay'. Bastnaesite is the world's principal REE source, and is produced mostly in China and the United States of America. Significant quantities are also recovered from the mineral monazite. Xenotime and ion-adsorption clays account for a much smaller part of the total production but are important sources of yttrium and other heavy rare earths. The major producers are China, the USA, India, Brazil and the countries of the former Soviet Union. USA prices for bastnaesite concentrate (rare earth oxide basis) remained at the 1997 level of $2.87 per kilogram, according to United States Geological Survey estimates. Likewise, on the same basis, monazite concentrate prices were also flat, remaining at 73 cents (US) per kilogram.

Ta

Tantalum is primarily found in columbite-tantalite, although it also occurs in euxenite, samarskite, and some other rare minerals. Tantalum is almost always found in association with niobium. The major sources of tantalum ore are Africa, Australia, Brazil, and Canada. The published spot price for tantalite ore ranged from $32 to $35 per pound in 1998.

Nb

Principal commercial sources of niobium are niobite (columbite), niobiotantalite, pyrochlore, tantalite and euxenite. Major niobium producers are Brazil, Canada, Nigeria and Zaire. Nb resources are largely in Australia, Brazil, Canada, Congo (Kinshasa) and Nigeria. The price for columbite ore in late 1998 was between $2.80 and $3.20 per pound of contained columbium and tantalum pentoxides.

Sc

Most scandium is currently being recovered from thortveitite or is extracted as a by-product from uranium mill tailings. The major suppliers are China and the Soviet-block countries. The cost of bulk scandium was $100/g.

Geological factors

REE and Y

Rare earths are widely distributed in the Earth's crust and some are moderately abundant in most rocks (Ce averages about 60 ppm, and Y and La about 30 ppm each in the Earth's crust). Important rare-earth minerals include the bastnaesite group (a group of rare earth or Y-rich fluorocarbonates), cerite, euxenite, gadolinite, monazite, xenotime, allanite, loparite, florenceite, samarskite and the lateritic ion-adsorption clays. They occur most abundantly in alkaline igneous rocks, including syenite, granite, alkaline ultramafic rocks, lamprophyre and carbonatite. Some rich deposits may form in altered dolostones, breccias and skarns. During weathering these minerals are released as alluvial minerals or remobilised into phosphate and carbonate minerals in clays.

Ta and Nb

Niobium is widely distributed in nature; the average crust contains about 20 ppm of niobium, making it about one and a half times as abundant as lead. Tantalum, at about 2 ppm, is rarer.

Tantalum and niobium are primarily found in tantalite and other complex oxides (usually with Fe, Mn, Ca, Sb, Sn and other metals), mostly of the columbite, polycrase, tapiolite, ixiolite, fergusonite and euxenite groups. These minerals are characteristic of some complex granitic pegmatites and greisens, usually associated with Sn, Li and/or Be. Niobium also occurs in many silicate minerals (e.g. låvenite and wöhlerite), especially in alkaline igneous rocks like syenite and carbonatite. There are also some rare Ta and Nb-rich phosphates, arsenates, carbides and borates, of no economic importance.

Sc

Scandium is widely distributed on earth (about 19 ppm in the crust), occurring in very minute quantities in over 800 mineral species, especially ferromagnesian minerals, some phosphates and rare earth-bearing minerals, usually substituting for aluminium. It is rarely an important constituent in any of these minerals, except for several very rare minerals including thortveitite, cascandite, kolbeckite, jervisite and bazzite. The blue colour of beryl (aquamarine variety) is thought to be caused by scandium.

These Sc-rich minerals are mostly found in veins and miarolitic cavities in granites, or in quartz veins, alpine veins and pegmatites. Scandium is also found in certain tungsten, fluorite and uranium ores. There has recently been a major find of scandium in laterite and clay developed on ultrabasic rocks near Port Macquarie in New South Wales.

REE, Ta and Nb minerals in Tasmania

Following is a list of known occurrences of REE, Y, Ta and Nb minerals in Tasmania. This information is taken from the new edition of *Catalogue of minerals of Tasmania* which is currently in preparation.

Allanite — $(Ce,Ca,Y)_2(Al,Fe^{3+})_3(SiO_4)(OH)$

This dark red-brown, glassy mineral may be considered to be a rare earth-rich epidote. It occurs as an accessory mineral in acid and alkaline igneous rock types, in pegmatites and some skarn rocks. The mineral is brown to black with a resinous luster.

It was originally recorded as scattered brownish crystals in hauyne-syenite porphyry in the Cygnet alkaline complex and this occurrence has been confirmed by more recent studies (Ford, 1983; Taheri and Bottrill, 1999).

Allanite is a common accessory in the tin-bearing granites of northeastern Tasmania (McClenaghan *et al.*, 1982) and has also been recorded in skarn from the King Island Scheelite mine. Minor amounts are recorded in the Housetop Granite near Hampshire (Whitehead, 1990).

Allanite is found in small (<0.1 mm) brown crystals in pyritic quartz veins in mica schist at the Mt Remus Mo-Co pyrite prospect near Cradle Mountain (Bottrill, 1994).

Beach sand occurrences include Cape Barren Island, Naracoopa and King Island (Bacon and Bottrill, in prep.).

Brannerite — $(U,Ca,Y,Ce)(Ti,Fe)_2O_6$

This rare black uranium titanium oxide occurs in gold-bearing quartz veins in Precambrian schist at the Specimen Reef mine near Savage River (N. J. Turner, pers. comm.).

Ferrotantalite — $FeTa_2O_6$

An uncommon heavy black mineral found in some pegmatites and tin-tungsten deposits. It is possibly present in heavy mineral concentrates from Station Creek, Dundas (Curtis, 1981), and as inclusions in cassiterite in heavy mineral concentrates from the Huskisson River (Townend, 1988). Both reports need confirmation.

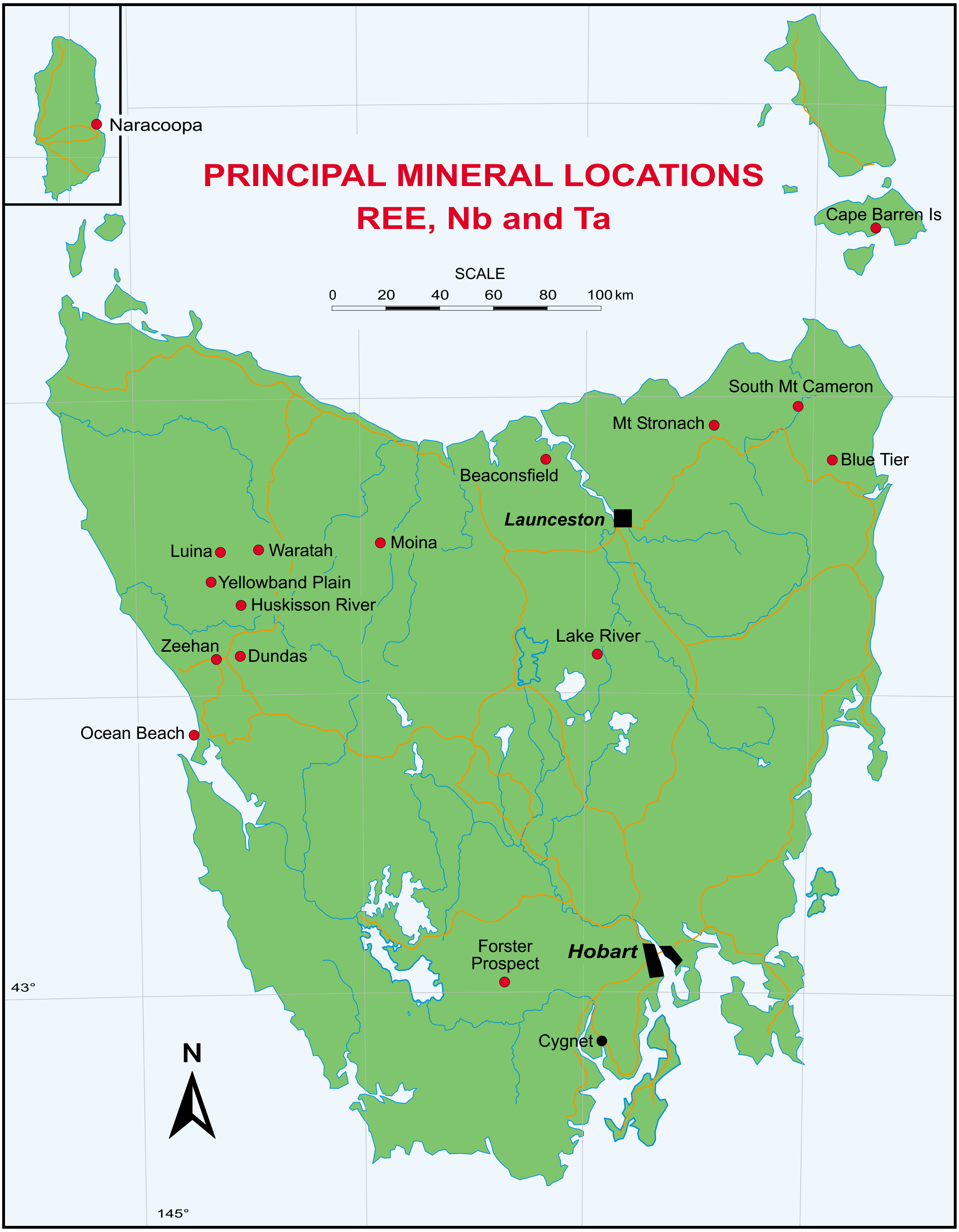
PRINCIPAL MINERAL LOCATIONS
REE, Nb and Ta
SCALE
0 20 40 60 80 100 km
Naracoopa
Cape Barren Is
South Mt Cameron
Mt Stronach
Blue Tier
Beaconsfield
Launceston
Luina
Waratah
Moina
Yellowband Plain
Huskisson River
Zeehan
Dundas
Lake River
Ocean Beach
Forster Prospect
Hobart
Cygnet
N
43°
145°

Figure 1

Florenceite-(Ce) — (Ce, La, Nd)$Al_3(PO_4)_2(OH)_6$

This uncommon rare earth mineral is mostly white and is usually found in a fine-grained or earthy state.

Florenceite is found as fine-grained aggregates in pyrite-chalcopyrite-siderite-quartz ores at the Prince Lyell mine at Queenstown (Bottrill, 1992) and also occurs as fine-grained aggregates in sub-basaltic kaolinitic clays near Legerwood. Small grains were reported in heavy mineral concentrates from the Savage River area (Shannon *et al.*, 1985).

Ilmenorutile — $(Ti,Nb,Fe)_2O_6$

This rare black mineral was reported from microscopic studies of the Cleveland tin skarn, near Luina (Kwak and Jackson, 1986).

Monazite-Ce — $(Ce,La,Nd)PO_4$

Analyses recorded by the Tasmania Department of Mines (1969) indicate that the 'monazite' tested is mostly the Ce-dominant species, although it is possible other members of the group also occur (i.e. Th, La or Nd-dominant). Monazite is a common mineral in many granitic and metamorphic rocks and most tin deposits, particularly alluvial deposits.

Monazite was first recorded from Tasmania by Professor Stelzner of the Freiberg Mining Academy, Saxony, in lode material form the West Bischoff tin mine at Waratah around 1893. It has since been noted in lode occurrences in other mines of the Mt Bischoff district and also from mines of the Moina district and the nearby Mt Claude and Lorinna areas.

Notable primary occurrences include the Shepherd and Murphy mine (Barrie, 1965) and the All Nations mine (relatively coarse crystals) at Moina. It is also common as a trace constituent in many granites.

Detrital monazite has been recorded from most of the streams draining outcrops of Devonian granite and tin-tungsten fields in Tasmania; the mineral commonly occurs with cassiterite in placers. Tourmaline, topaz, corundum and zircon accompany the monazite and cassiterite along the Ringarooma River and in the Scottsdale district. The Briseis, Pioneer, Endurance and Echo alluvial tin mines all contain monazite, as does Fraser River (Naracoopa) on King Island (Barrie, 1965). In 1945, 32.5 t of monazite concentrates were produced from the Endurance alluvial tin workings at South Mt Cameron (Barrie, 1965).

Detrital monazite (<10.22% ThO_2) occurs in the Stanley River tin field north of Zeehan, although the mineral has not been observed in the cassiterite veins. It is pale yellow, transparent-translucent, sub-crystalline and waterworn. Monazite is abundant in the North Heemskirk tin field as fine-grained, brown alluvial grains in alluvial tin drifts, but is rare in the South Heemskirk placers. At Yellowband Plain, about 16 km south of Mt Cleveland, monazite carrying 20–30% rare earths and 5–6% ThO_2 is widespread in stream placers. Other reported occurrences, probably alluvial or eluvial, include near St Valentines Peak; at the Cleveland Tin mine (in tin drift) at Luina; at Lottah (coarse specimens); and at the Salisbury mine near Beaconsfield (nearly white).

Attempts to mine the Mt Stronach placers (in the Scottsdale district) around 1900 failed because the concentrates yielded only 2% ThO_2, the only valuable extractable commodity at the time (used for making incandescent gas mantles). The composition of monazite from Mt Stronach is given in Table 1.

Monazite is stated to be rich in extensive ilmenite-rich deposits in beach sand near the Fraser River at Naracoopa, on King Island, where it occurs with cassiterite and other heavy minerals. Samples yielded the analysis in Table 1 (from Wylie, 1950). Black sand reported to contain monazite with titaniferous minerals, zircon, cassiterite and gold were mined at Low Head, northeast of Beaconsfield, in 1941. Other important monazite occurrences in beach sand include Badger Head (near Beaconsfield, reportedly abundant), Cape Barren Island, Rheban, Marrawah, Port Davey and Ocean Beach (Strahan).

Pyrochlore — $(Na,Ca)_2Nb_2O_6(OH,F)$

This mineral was tentatively reported by Twelvetrees (1903) in alkaline porphyry at Cygnet but remains unverified.

Perovskite — $(Ca,Na,Fe,Ce)(Ti,Nb)O_3$

This rare mineral occurs as an abundant accessory in the melilite-fasinite and melilite-basalt at Shannon Tier as microscopic yellowish-red grains and crystals (Edwards, 1950).

Some samples, supposedly found by a miner in the Hellyer or Que River mine between Waratah and Rosebery, were found to contain perovskite. This occurs as lustrous, mid-dark caramel-brown pseudo-cubes on a matrix of diopside and clinochlore. It seems an unlikely mineral in this geological environment, but closely resembles some perovskite from Italy.

Table 1

Partial analyses of monazite from Naracoopa, King Island, and Mt Stronach, near Scottsdale (from Wylie, 1950)

Wt. %	Naracoopa	Mt Stronach
Ce_2O_3	28.3	26.7
La_2O_3	16.8	14.4
Nd_2O_3	11.0	11.0
Pr_2O_3	3.12	3.23
Sm_2O_3	2.72	2.72
ThO_2	6.09	7.29

Rhabdophane — $CePO_4 \, nH_2O$

This uncommon secondary rare earth phosphate was found by XRD as a very fine-grained component in halloysite veins in Jurassic dolerite near Taroona.

Rutile — TiO_2

A very dark variety, sometimes called 'nigrine', with a reported specific gravity of 5.94, is associated with cassiterite on Cape Barren Island. The high specific gravity value was suggested to possibly indicate a considerable content of niobium and tantalum although in this case it is probable that the sample used for determination was contaminated with cassiterite (Department of Mines, 1970).

Wöhlerite — $NaCa_2(Zr,Nb)Si_2O_8(O,OH,F)$

This rare minerals was described "…in phonolites from Tasmania" by Vlasov (1966). This presumably refers to the well-known phonolite-like syenitic intrusive rocks at Cygnet, and may also relate to the unidentified Ca-Zr silicate found at The Neck, Bruny Island (unpublished data, M. Forster).

Xenotime — YPO_4

This mineral has been found as inclusions in biotite in granite at Mt Ramsay (Fander, 1982) and in greisens at Mt Bischoff (Wright and Kwak, 1988). It also occurs as small yellow grains in heavy mineral concentrates from stream sediments in the Yellowband Plain area near Mt Meredith, the Wilson River Ultramafic Complex (with magnetite and chromite; Just, 1986), Reward Creek, the Jane River gold field (with gold), and the Ringarooma River area of northeast Tasmania (with cassiterite; N. Allen, pers. comm.).

Resource potential in Tasmania

Ta/Nb

Tantalum and niobium minerals are rare in Tasmania, but a few occurrences have been reported. The unconfirmed reports of ferrotantalite from Dundas and the Huskisson River (see preceding mineralogy section) may be worth further investigation, as may the ilmenorutile occurrence recorded from Luina. The presence of niobian perovskite in some Tasmanian basalts is supported by the elevated Nb in some whole rock analyses of similar rocks (Table 2), but these rocks are unlikely to produce a large, high-grade deposit. The presence of pyrochlore and niobian wöhlerite at Cygnet are unconfirmed, but the rocks in that area are generally low in Nb. Rutile may host some of the anomalous Nb in the Tasmanian granites (Table 2), but this is also unconfirmed.

Very few Tasmanian rocks have actually been analysed for tantalum and these rocks have mostly been unmineralised and very low in tenor. Tantalum most commonly occurs in highly enriched, complex lithium and tin-bearing granite pegmatites (e.g. Greenbushes, WA, where the Ta ore mined averages only about 200 ppm Ta). Tasmanian granites are generally poor in such phases, although some of the pegmatitic and rare earth-rich areas may have potential, for example the Meredith, Dolcoath and Housetop granites in the northwest and the Mt Stronach, Gladstone and Killiecrankie areas in the northeast. A resource has recently been identified in a northeast Victoria tin field, suggesting that the potential does exist in Tasmania, which is closely related geologically. The highest tantalum value known in Tasmanian rocks is 44 ppm in a tin-bearing vein from the Blue Tier (Table 2). Weaker anomalous values have been recorded in some Devonian granites and Neoproterozoic felsites.

Niobium is more commonly determined on Tasmanian rocks, but is rarely anomalous (>100 ppm). Niobium is most abundant in rare earth-enriched carbonatites and highly alkaline and enriched igneous rocks. Alkaline igneous rocks do occur in Tasmania (for example at Cygnet and Eddystone), but mostly occur as relatively small bodies, with relatively low Nb and only low to moderate rare earth contents. The highest Nb value known in Tasmanian rocks is 214 ppm in a tin-bearing vein from the Ethel Prospect in the Blue Tier area (also with 44 ppm Ta; Table 2). This suggests the presence of columbite or related minerals in these tin deposits. Nb ranges between 100–150 ppm in some Tasmanian Neoproterozoic basalts in the Luina–Waratah area (Crimson Creek Formation) and some nepheline basalts of Tertiary age in the Lake River area. These rocks may thus have some economic potential.

Rare Earths

Various Tasmanian rocks are enriched in rare earths, particularly some Devonian granites and granite-related tin deposits, mostly as monazite, xenotime and allanite (Table 2). These rocks are probably indicative of potential primary REE sources rather than containing actual resources themselves. Many Cambrian rocks are also rather enriched in REE (some containing 500–2200 ppm total REE (Table 2). In particular, some altered talcose conglomerates and related dykes of uncertain affinity at the Forster Prospect, in the Weld River area of the upper Huon district, are very highly REE enriched. Some of the Tertiary alkaline basalts (e.g. Lake River) are also highly REE enriched, but these occurrences are mostly small in size.

Some of the Cretaceous alkaline igneous rocks in Tasmania (e.g. Cygnet and Eddystone) and alkaline basalts (e.g. Lake River) are enriched, but these occurrences are highly variable and mostly small. The economic potential of the rare-earth elements in some of the Cygnet porphyries was assessed by Cyprus Minerals using random sampling of some percussion and diamond-drill samples from the Mt Mary area. Some results were anomalous (one sample assayed in excess of 0.07 wt% total REE and Y) but were not considered sufficiently encouraging to warrant additional work (Jones, 1988). In comparison, the Brockman REE deposit, near Halls Creek in Western Australia, contains an estimated four million tonnes of reserves with 0.12 wt% Y_2O_3 and 0.07 wt% heavy rare earths (Highley *et al.*, 1988).

There is significant potential in the alluvial deposits derived from these primary sources, particularly in beach sands, for example at Trial Harbour, Strahan, Port Davey, Bruny Island, Marrawah, Naracoopa, Cape Barren Island, Rheban and the King River delta. Ocean Beach was examined during 1970–1971 by the Electrolytic Zinc Company of Australasia Ltd and a reserve of 1.47 million tonnes of sand containing 9.8% heavy minerals (including monazite) in five areas was defined. At Yellowband Plain, draining the Meredith Granite north of Zeehan, drilling indicated a thickness of five metres of alluvial materials containing 165 g/t monazite (Barrie, 1965). The only recorded production of REE in Tasmania was in 1945 when 32.5 t of monazite concentrates were produced from the Endurance alluvial tin workings at South Mt Cameron (Barrie, 1965).

No scandium deposits have been identified in Tasmania, but by analogy with the recent major find of ore-grade Sc (~100 ppm) in lateritised ultrabasic rocks near Port Macquarie in New South Wales, there is potential in similar laterite at Andersons Creek and perhaps the weathering zones of other serpentinite bodies and derived sediments such as at Adamsfield, Wilson River and Dundas, but no analyses are known. No highly anomalous (>90 ppm Sc) analyses are known anywhere in Tasmania, but the distribution has not been studied in detail.

References

BACON, C. A.; BOTTRILL, R. S. in prep. Heavy mineral sands in Tasmania. *Mineral Resources Tasmania.*

BARRIE, J. 1965. Rare earths, *in:* MCLEOD, I. R. (ed.). Australian Mineral Industry: The Mineral Deposits. *Bulletin Bureau of Mineral Resources, Geology and Geophysics Australia* 72:515–522.

BOTTRILL, R. S. 1992. The mineralogy of gold in the Mt Lyell orebodies (a preliminary report). *Report Department of Mines Tasmania* 1992/28.

BOTTRILL, R. S. 1994. The petrography of some rocks from the Anio Creek area. *Report Department of Mines Tasmania* 1994/23.

CURTIS, P. J. 1981. Heavy mineral concentrates mineralogy. Appendix 4 *in:* MACNAMARA, P. M. *Drainage sampling 1982–1983, Dundas, E.L. 15/76 West Tasmania*. CSR Limited [TCR 84-2157].

DEPARTMENT OF MINES TASMANIA, 1970. Catalogue of the minerals of Tasmania. *Record Geological Survey Tasmania* 9.

EDWARDS, A. B. 1950. The petrology of the Cainozoic basaltic rocks of Tasmania. *Proceedings Royal Society Victoria* 62:97–120.

FANDER, H. W. 1982. Rock samples Z1185–Z1198. Appendix 7 *in:* GREEN, N. P. *Interim report on Ramsay Grid CAF, Exploration Licence 5/63 Part 2*. Comstaff P/L [TCR 83-1907].

FORD, R. J. 1983. *The alkaline rocks of Port Cygnet, Tasmania*. Ph.D. thesis, University of Tasmania.

HIGHLEY, D. E.; SLATER, D.; CHAPMAN, G. R. 1988. Geological occurrence of elements consumed in the electronics industry. *Transactions Institution of Mining and Metallurgy* 97:C34–42.

JONES, P. A. 1988. *Progress report, October 1987 to October 1988, EL36/82, Cygnet, Tasmania*. Cyprus Gold Australia Company [TCR 88-2880].

JUST, J. 1986. *Report on mineralogical examination of rock samples, composite concentrate of heavy minerals, and pan concentrates from Tasmania*. Callina NL [TCR 87-2633].

KWAK, T. A. P.; JACKSON. 1986. The compositional variation and genesis of danalite in Sn-F-W skarns, NW Tasmania, Australia. *Neues Jahrbuch für Mineralogie Monatshafte* 1986(10):452-462.

MCCLENAGHAN, M. P.; TURNER, N. J.; BAILLIE, P. W.; BROWN, A. V.; WILLIAMS, P. W.; MOORE, W. R. 1982. Geology of the Ringarooma–Boobyalla area. *Bulletin Geological Survey Tasmania* 61.

SHANNON, C. H. C.; ANNETT, R. W.; ENZMANN, F.; VANZINO, L. 1985. *Report on field investigations within EL4/61, West Coast, Tasmania.* Industrial & Mining Investigations P/L [TCR 85-2502].

TAHERI, J.; BOTTRILL, R. S. 1999. Porphyry and sedimentary-hosted gold deposits near Cygnet: New styles of gold mineralisation in Tasmania. *Record Geological Survey Tasmania* 1999/01.

TOWNEND, R. 1988. *Preparation of 29 polished sections of magnetic chromite products and analysis of chromite occurrence*. Callina NL [TCR 89-2903].

TWELVETREES, W. H. 1903. A geological excursion to Port Cygnet in connection with the Australasian Association for the Advancement of Science, 1902. *Report Secretary Mines Tasmania* 1902–1903:25–32.

VLASOV, K. A. (ed.). 1966. *Geochemistry and mineralogy of rare elements and genetic types of their deposits. II. Mineralogy of rare elements.* Israel Program Scientific Translations : Jerusalem.

WHITEHEAD, C. H. 1990. Kara scheelite-magnetite deposit, *in:* TURNER, N. J.; TAHERI, J. Tin and tungsten deposits and related Devonian granitoids. *Excursion Guide E2, 10th Australian Geological Convention, Hobart* 24–30. Geological Society of Australia.

WRIGHT, J. H.; KWAK, T. A. P. 1988. Endogreisen, brecciation and fluid activity at the Mount Bischoff Sn-deposit, north-west Tasmania, Australia. *Journal Metamorphic Geology* 6:629–650.

WYLIE, A. E. 1950. Composition of some Australian monazites. *Australian Journal of Applied Science* 1:164–171.

[9 July 2001]

Table 2

Analyses of some Tasmanian rocks with anomalous REE, Ta, Nb and Sc

Reg No.	C107861	C107862	C108107	R004502	R004507	G401044						G401045	
Field No.				LSB24	LSB23		FG38	75848	HT7f	HT11	WT26		B2029
Location	Forster Pr Huon Dist.	Forster Pr Huon Dist.	Forster Pr Huon Dist.	Burburys Sugarloaf	Burburys Sugarloaf	Mt Black	Cape Barren Island	Pieman Dam	Hampshire	Hampshire	Hampshire	Mt Black	Mt Darwin
AMG-E	477940	477960	477930	532500	535600	386240	586900	380400	410200	401400	410000	386260	383115
AMG-N	5233480	5233490	5233470	5350500	5385800	5373580	5524000	5358200	5434500	5434800	5434700	5373630	5320620
Age	?	?	Cambrian	Tertiary	Tertiary	Cambrian	Devonian	Cambrian	Devonian	Devonian	Devonian	Cambrian	?
Lithology	dyke	dyke	conglomerate	basalt	basalt	breccia	granodiorite	rhyolite	granite	granite	granite	lava	vein
Formation						MRV			Housetop	Housetop	Housetop	MRV	
Ce	450	210	570	270	280	260	158	169	344	301	376	310	3
La	770	640	170	160	170	105	64	99	174	208	183	135	5
Nd	590	560	160	100	100	78		57				93	5
Pr													
Sm													
Eu													
Gd													
Dy													
Er													
Yb													
Y	330	490	64	47	61	48	287	223	69	110	63	64	648
Sc	42	69	28	17	14	30	38	11	3			24	
Tot REE	2182	1969	992	594	625	521	547	559	590	619	622	626	661
Zr	250	67	110	680	710	290	515	146	197	112	146	260	10
Nb	34	18	14	100	120	15	37	10	26	24	21	11	2.6
Ta													

MRV = Mount Read Volcanics

Table 2

Analyses of some Tasmanian rocks with anomalous REE, Ta, Nb and Sc (continued)

Reg No.	213550	CT87-14/4-6m	88 0003	880230	C1523	C1524	C1522	C1867	C1868	C1866	BT2	BT11
Location	Salisbury Hill Beaconsfield	Mt Mary Cygnet	Rocky River	Rocky River	Heazlewood area	Heazlewood area	Heazlewood area	Heazlewood area	Heazlewood area	Heazlewood area	Ethel Prospect Blue Tier	Australia mine Blue Tier
AMG-E	485560	505540	349162	3490800	360400	360400	360400	360400	360400	360400	584380	583610
AMG-N	5436500	5220480	5389890	5389900	5362600	5362600	5362600	5362600	5362600	5362600	5439000	5437360
Age	Cambrian	Cretaceous	Neoproterozoic	Neoproterozoic	Neoproterozoic	Neoproterozoic	Neoproterozoic	Neoproterozoic	Neoproterozoic	Neoproterozoic	Devonian	Devonian
Lithology	andesite	syenite	felsite	felsite	basalt	basalt	basalt	basalt	basalt	basalt	vein	granite
Formation		CAC	AMC	AMC	Crimson Ck	Crimson Ck	Crimson Ck	Crimson Ck	Crimson Ck	Crimson Ck	Blue Tier	Blue Tier
Ce	60	292	<15	44								
La	107	128	<5	9								
Nd	59	141	<20									
Pr	67	36										
Sm	46	29										
Eu	44	7										
Gd	42	6										
Dy	32	16										
Er	26	7										
Yb	19	8										
Y	85	80	2	15	23	26	42	31	39	30	192	295
Sc	26		16	38	25	28	31	24	22	25		
Tot REE	613	750	18	106	48	54	73	55	61	55	192	295
Zr	274		51	85	260	290	290	340	340	360		
Nb	41				110	115	130	145	145	150	214	67
Ta			13	16							44	23

CAC = Cygnet Alkaline Complex; AMC = Arthur Metamorphic Complex