Tasmanian Geological Survey
Record 2012/03

Mineral Deposit Models prepared for minerals prospectivity assessment:

Proposed reserve areas for Independent Verification Group

Mineral Resources Tasmania
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Mineral Resources Tasmania
Department of Infrastructure, Energy and Resources

Tasmania
Explore the possibilities

Mineral Resources Tasmania PO Box 56 Rosny Park Tasmania 7018

Phone: (03) 6165 4800 ● Fax: (03) 6233 8338

Email: info@mrt.tas.gov.au ● Internet: www.mrt.tas.gov.au

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Introduction

The minerals industries, comprising mineral exploration, mining and mineral processing, are of vital importance to the economy of Tasmania and employed over 4000 people in 2009/2010. The gross value of the output of the minerals industries in 2010/2011 was $2 587 603 616, of which $1 227 402 087 was from minerals and $1 360 201 529 was from value added metallurgical production from Tasmanian and other ores. Of mine production, 90% of value was realised from metallic minerals, 3.8% from non-metallic, industrial and fuel minerals and 6.2% from construction materials. The mineral industries are the major source of Tasmania's mercantile exports, valued at $1570.3 million and accounting for 49.3 per cent of the total in that year.

Tasmania is endowed with a variety of metallic mineral deposits, many of which are recognised as being of world class, using the definition of the United States Geological Survey (USGS; economic deposits containing the top ten per cent by mass of a given metal). The Rosebery and Hellyer mines are each world class deposits for three metals: zinc, lead and silver, and in addition both have significant copper and gold credits. Mount Lyell is a world class copper deposit, Renison and Mount Bischoff are world class tin deposits and there are world class tungsten deposits on King Island, the latter shortly to resume production. In addition there is a major iron resource at Savage River and nickel resource at the Avebury mine, currently on care and maintenance, near Zeehan. There are high grade gold deposits at the Henty and Tasmania mines, and rutile and zircon production has recently resumed at Naracoopa on King Island.

Tasmania also has significant deposits of coal, limestone, dolomite, magnesite, silica, clay, ochre and construction materials, some of which are currently in production.

Because mining involves depletion of non-renewable resources, mineral exploration is necessary to sustain the industry. In 2010/2011 Australian Bureau of Statistics (ABS) data show that $37.3 million was spent on mineral exploration in Tasmania. This represents 1.26% of the national total, a considerably higher proportion than the 0.86% Tasmanian share of Australia's land area. Of this total $17.0 million was spent on the search for new deposits, while $20.3 million was directed to the discovery of additional reserves adjacent to existing mines. This has been very successful in recent years, with significant new discoveries at the Renison Bell, Henty and Rosebery mines. Exploration is essential to the continued viability of the mining industry, because mineral resources are only renewed by geological processes at a very small fraction of the rate of extraction. For example, the Tasmania gold mine at Beaconsfield will close in mid 2012, due to the exhaustion of currently economic reserves.

Mineral exploration is a scientific activity which uses advanced technology to locate new deposits. An exploration program is based on available geological, geophysical and geochemical data and on judgements about where targeted types of mineral deposit are likely to occur. Exploration is an inherently high risk activity and it has been estimated that only one in 1000 programs results in the discovery of an economic deposit. It requires an average investment of over $50 million for such a discovery and only 59 major 'tier one' world class deposits (valued at $2.6 billion+) have been discovered in the 35 years to 2008 (Schodde, 2010).

Similarly, the determination of potential (undiscovered) mineral resources is inherently difficult and imprecise. Unlike estimates of timber resources, there is no direct method for estimating undiscovered deposits from satellite images or aerial photographs.

This report represents contributions of geoscientists from Geoscience Australia (GA), Mineral Resources Tasmania (MRT) and the University of Tasmania. It updates and builds on the work conducted in 1996 for the Tasmanian–Commonwealth Regional Forest Agreement (RFA), (*Social and Economic Report Vol. III Background Report Part D*).

As with the earlier report, for this report the qualitative methodology developed by the USGS in which geological units, or tracts, were identified in which the potential for specific types of mineralisation is ranked as high, medium, low or unknown was used. The Bureau of Resource Sciences (BRS, now part of GA) and MRT assessed the ranking for each type of mineralisation using a general descriptive model in which the geological features of the 45 model deposits were compared with those of the tract in question.

In addition to the ranking of the potential for the tract, the degree of certainty of the assessment was estimated according to the reliability of the geoscientific data base for the tract. MRT has developed a method of reliability assessment and has produced a map showing this reliability for deposits of metallic minerals. Both the geoscientific data bases and the models on which the assessments are based are subject to change with the acquisition of new knowledge, and sometimes revolutionary change. Hence there is a need for periodic reassessment.

Using the method outlined above, the mineral resource potential was assessed using 45 mineral deposit models, some of have been developed, or significantly modified for this assessment. King Island and the Furneaux Group are not included as they lie outside areas considered under the Tasmanian Forests Intergovernmental Agreement region.

Areas of significant potential for metallic minerals have been identified in western, northwestern, southwestern, northeastern and parts of central Tasmania.

There is high to moderate–high potential for a range of deposit classes including:

- base and precious metal deposits 'hosted' by volcanic rocks, similar to Rosebery, Hellyer, Mount Lyell and Henty;
- tin, tungsten, magnetite, base and precious metal mineralisation associated with granites, similar to the ore bodies of Renison, Mount Bischoff, King Island, Avebury, Kara, Magnet, Anchor and Aberfoyle;
- carbonate hosted base metal and silver deposits of Irish style, of which Oceana is a probable Tasmanian example;

- slate belt gold deposits such as the Tasmania mine at Beaconsfield and the New Golden Gate mine at Mathinna;
- iron deposits of the Savage River type;
- ironstone-hosted gold in northwest Tasmania;
- porphyry copper-gold deposits in the Mount Read Volcanics, particularly in southwest Tasmania;
- nickel, copper and platinoid mineralisation associated with ultramafic rocks and gabbros;
- carbonate-hosted gold deposits of the Carlin type;
- copper and other base metal deposits associated with basalts;
- sediment-hosted base metal deposits; and
- alluvial and beach deposits containing various combinations of gold, tin, chromite, platinum group metals (PGM), rutile and zircon
- geothermal energy.

There is high potential for various industrial and fuel mineral resources including:

- magnesite in northwest Tasmania;
- silica flour in northwest Tasmania and near Maydena;
- ochre in northwest Tasmania and near Beaconsfield;
- kaolin in northeast Tasmania;
- coal in central and eastern Tasmania;
- dolomite and limestone over large areas of the State; and
- construction materials, lump silica and dimension stone are widespread.

The tracts of mineral potential for various types of mineral deposits (maps 1 to 45 that accompany this report) represent GIS-based assessments of assessment criteria for each model combined with the 1:250 000 scale geology coverage, the 3-D geological model of Tasmania, which includes interpretations of subsurface granite distribution based on gravity and other geophysical information (Leaman and Richardson, 2003; Leaman, 2012), the MRT TIGER Deposits and Samples and Geochemistry databases and selected geological reports.

Because the main geological units favourable for metallic resources are obscured by younger strata several hundreds of metres thick in most of eastern and central Tasmania (Tasmania Basin Element), any assessment of the metallic mineral potential in this area is of low certainty, but available geophysical evidence, locally confirmed by drilling, indicates that mineralised rocks may exist at depth.

Models used in the 1996 mineral potential study carried out as a background study for the Tasmanian Regional Forest Agreement were extensively updated by Geoff Green, Michael Vicary, Clive Calver, Ralph Bottrill and Jafar Taheri of Mineral Resources Tasmania (MRT), including new models written by Geoff Green (Models M5, M8 and M45), by Michael Vicary and Geoff Green (Model M24), by Clive Calver (Models M43 and M44), and by Geoff Green, Ralph Bottrill and Jafar Taheri (Model M26). New models were also written by Subhash Jaireth (Models M22 and M25) and by Alison Kirkby, Tony Meixner and Ed Gerner (Model E14) of Geoscience Australia.

Interpretive and summary products as part of the Independent Verification Group process and the methodology for preparing them has been reported by Large and McNeill (2012). GIS analysis used in the preparation and presentation of summary information was carried out by David Green, Jo-Anne Bowerman, Rowan Blake, Daniel Bombardieri, Michael Davie, and Damien Shearer of MRT.

Model Listing

No.	*Model*	*Tract map name*	*model_code*
1	Ag-bearing polymetallic veins	agveins2	agvein_1
2	Au associated with alkaline intrusive rocks	alkpor2	alkpor
3	Placer Au	alluv_au	alluv_au
4	Au-BM-Sn veins	ausnven2	ausven2
5	Avebury-style Ni	avebNi	avebNi
6	Bauxite	bauxite	bauxite
7	Besshi-type massive sulphide	besshi4	besshi
8	Metalliferous black shales	blk_shales	blk_sha
9	Sediment-hosted Au (Carlin type)	carlin	carlin
10	Placer Cr	chrompla	chrompla
11	Basaltic Cu	cubaslt3	cubaslt
12	Epithermal Au-Ag	epiau3	epiau
13	Synorogenic nickel-copper deposits	gabbro2	gabbro2
14	Geothermal energy	geothermal	geoth
15	W-Sn-Cu-magnetite skarns	gr_all2	WSnskarn
16	Sn greisen	greisen	greisen
17	Au in ironstones	istone2	istone
18	Irish-style base metal	istyle	istyle
19	Lateritic Ni	laterNi	laterNi
20	Au associated with VHMS	mrv3	VHMS_Au
21	Polymetallic style VHMS	mrv4	Kuroko
22	Ni associated with Jurassic dolerite	norilsk	norilsk
23	Alluvial Sn	placersn	placersn
24	Mt Lyell type Cu-Au	porphcu	porphCu
25	REE heavy mineral sands	ree_hms	ree_hms
26	Proterozoic magnetite skarn	savage2	savage
27	Slate belt Au	sbelt3	sbelt
28	Replacement Sn	sn_repl	sn_repl
29	Sn-W-Mo veins	snven3_2	SnWMo_v
30	Early Cambrian ultramafic-related Ni	umafic3	umafic
31	Sandstone-hosted U	uranium2	uranium
32	Coal	coal2	coal
33	Dolomite	dolomite	dolomite
34	Limestone	lime	lime
35	Magnesite	mgsite	mgsite
36	Ochre	ochre	ochre
37	Oil Shale	oilsh	oilshale
38	Shoreline placer Ti	shore2_p	placerTi
39	Silica flour	silfr	silflr
40	Zeolites	zeolite	zeolite
41	Silica hard rock	silica	silica
42	Dimension stone	dimension	
43	Construction — hard rock	conmat_hr	
44	Construction — sand, gravel, clay	conmat_cgs	
45	Cobar style Cu Au, Zn, Pb	cobar	sed_Cu

MODEL M1: Silver-bearing polymetallic veins (based on Model 22c by Cox and Singer, 1986)

Approximate Synonyms

Felsic intrusion-associated Ag-Pb-Zn veins.

Description

Quartz-carbonate veins with base metal sulphides and Ag, Au   Sn related to hypabyssal granitic intrusions in sedimentary, igneous and metamorphic terranes.

General references

Sangster, 1984.

Geological environment

Rock types:

Veins related to calcalkaline to alkaline, diorite to granodiorite, monzonite to monzogranite in small intrusions and dyke swarms in sedimentary, igneous and metamorphic rocks. Sub-volcanic intrusions, necks, dykes, plugs of andesite to rhyolite composition.

Textures:

Granitic texture, fine to medium-grained equigranular and porphyro-aphanitic.

Age range:

Any age.

Depositional environment:

Near-surface fractures and breccias within thermal aureoles of intrusions. In some cases peripheral to porphyry systems.

Tectonic setting(s):

Continental margin and island arc volcanic-plutonic belts. Especially zones of local domal uplift.

Associated deposit types:

Tin/tungsten veins, mesothermal gold veins, Sn-Au-polymetallic veins, porphyry Cu-Mo, porphyry Mo low-F, disseminated tin, polymetallic replacement, skarns, epithermal deposits, greisens, etc.

Deposit description

Mineralogy:

Galena + sphalerite + pyrite   tetrahedrite-tennantite   chalcopyrite   arsenopyrite   Ag sulphosalts   argentite   Cu -Pb sulphosalts   in veins of quartz + siderite + calcite   ankerite/dolomite   chlorite   rhodochrosite.

Texture/structure:

Complex, multiphase veins with breccia, comb structure, crustification, and less commonly colloform textures. Textures may vary from vuggy to compact within mineralized systems.

Alteration:

Generally wide propylitic zones and narrow sericitic and argillic zones, but may be small or nonexistent. Some silicification of carbonate rocks to form jasperoid. Some quartz-carbonate-sericite alteration of ultrabasic rocks.

Ore controls:

Areas of high permeability, intrusive contacts, fault intersections, and breccia veins and pipes. Replacement ore bodies may form where structures intersect carbonate rocks.

Weathering gossans and Fe- Mn-oxide stains. Zn and Pb carbonates and Pb sulphates, arsenates and phosphates. Abundant quartz chips in soil. Supergene enrichment produces high-grade native and horn silver ores in veins where calcite is not abundant.

Geochemical signature:

Zn, Cu, Pb, As, Ag, Mn, Ba. Anomalies zoned from Cu-Au outward to Zn-Pb-Ag to Mn at periphery.

Examples

Misima I, PPNG *(Williamson and Rogerson, 1983)*
St Anthony (Mammoth), USAZ *(Creasey, 1950)*
Wallapai District, USAZ *(Thomas, 1949)*
Magnet (Cox, 1975)

Known deposits and mineral prospects in Tasmania

Most silver-bearing Ag-Pb-Zn sulphide vein deposits in Tasmania form the outer haloes of zoned mineral fields around Devonian granitoids. The best known of these is the Zeehan field. Similar zoned occurrences are reported at Mt Bischoff–Heazlewood, Moina–Round Hill, and at Scamander in eastern Tasmania (Collins *et al*., 1989).

In the Zeehan field the veins occupy a complex system of faults and fractures, apparently related to mid-Devonian deformation. The veins trend between NNW and NNE and intersect rocks of late Proterozoic to Early Devonian age, although most are in the Neoproterozoic Oonah and Crimson Creek formations.

In the Dundas field the veins occupy fractures in late Proterozoic and Cambrian rocks (including ultramafic rocks). However some of these are apparently replacement bodies.

Along the northern flank of the Meredith Granite, some copper, lead and zinc vein occurrences form a NNE trending zone. The Magnet Ag-Pb-Zn mine is the largest of these deposits, producing 0.6 Mt of ore (37 000 t of lead, eight million ounces of silver and an unknown quantity of zinc). It is located midway between the Cleveland and Mt Bischoff tin deposits, and the ore body occupies a steep west-northwest dipping fracture system within an up-thrust, early Cambrian mafic/ultramafic mass. The ore shoot is developed at the intersection of two major fractures (Cox, 1975).

In the Moina area most of the Ag-Pb-Bi-Au-Sn-W mineral occurrences are related to and centred on the Dolcoath Granite. The largest of the Pb-Ag-Zn veins is in the Round Hill mine where crudely-shaped saddle reefs are formed in the crests of asymmetrical, northwest-trending anticlines in the Moina Sandstone (Collins *et al*., 1989).

Geophysical studies show that most of Pb-Ag-Zn deposits are located within the 4 km depth contour of the Heemskirk Granite. A similar pattern is observed with respect to the Granite Tor Granite near Rosebery, where the occurrences are also located within the 4 km depth contour. However the role of NNE-trending Henty Fault in the localisation of these veins is also important. Geophysical studies have established that the Granite Tor Granite is a large body at shallow depth, and that only a small part of the granite is exposed at Granite Tor. Two shallow ridges of the granite extend to the WSW from Granite Tor, and northeast from Mt Pelion to the Dolcoath Granite (Taheri and Green, 1990). The WSW-trending granite ridge extends from the Granite Tor Granite to the Pine Hill Granite, and possibly as far west as the Heemskirk Granite.

The silver-bearing lead-zinc veins in western Tasmania can be interpreted to form two separate NNE-trending zones: the first one extends between the Meredith Granite and the Housetop Granite and the second trends along a ridge between the Heemskirk Granite in the west to the Dolcoath Granite in the east.

In the Northeast Element, there are a few known occurrences of lead-zinc veins, including the Paul Beahrs, Yarmouth, Scamander Bell and North Scamander prospects. All are associated with Devonian granites of the Scamander Tier, and form the outer zone of a zoned Sn-W-Cu-Pb-Zn-Ag field (Groves, 1972).

Assessment criteria

1. Distribution of Devonian granitoids.
2. Aeromagnetic and gravity data supporting the subsurface distribution of Devonian granites. In particular the granite depth contour of 6 km is important in assessing the prospectivity of the zones around granites.
3. Presence of major faults and fractures and rocks susceptible to brittle deformation. The presence of other suitable structures such as folds and breccia zones could be important within individual mineral fields.
4. Distribution of known mineral occurrences.

Assessment: Tract BM5a/H/B-D

The tract includes Devonian granites of northwestern Tasmania. The granites form two NNE-trending zones along the subsurface extension of granitoids. The area within the 6 km depth contour of the granite surface marks the width of the delineated zone around granites. Geophysical data indicate that the subsurface extension of the granites continues under Post Palaeozoic rocks in the Tasmanian Basin. The tract also includes the known lead-zinc mineral fields and has a high certainly level. This tract also includes the area around the Pieman Granite in the Rocky Cape Element, Granite Tor to Barn Bluff in the Tyennan Element, and the Penguin–Sheffield area. These regions have a moderate to high certainty level.

The tract also includes Devonian granite areas in the northeast Tasmania. Again the 6 km depth contour of the granite surface has been used to extend the tract around exposed bodies of granite. The area includes the known occurrences of lead-zinc veins in the zoned Sn-W-Cu-Pb-Zn-Ag mineral field in the Scamander area.

Based on the available information this part of the tract has a high potential for silver-bearing lead-zinc vein deposits with a high certainty level.

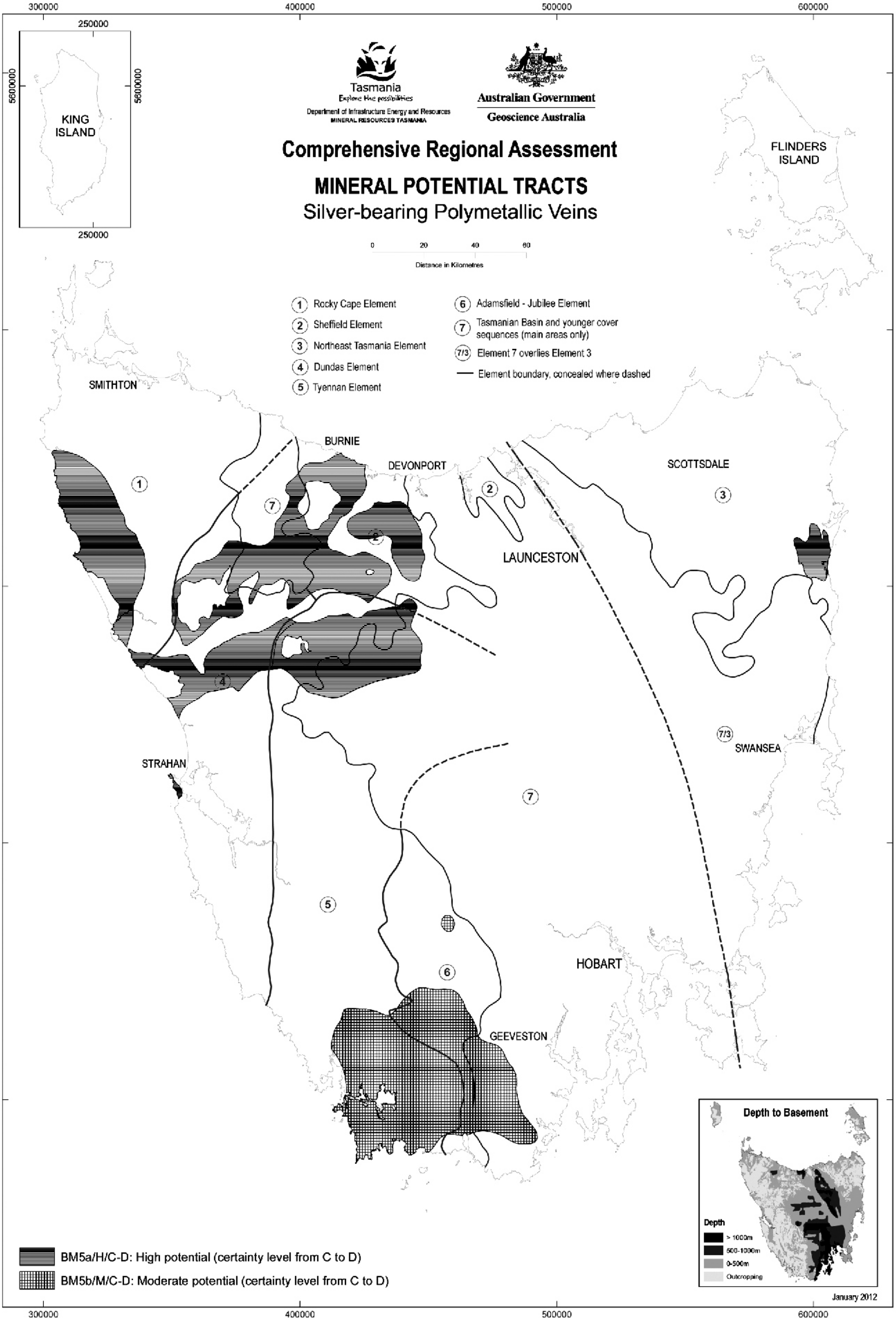
Assessment: Tract BM5b/M/B-C

This tract is in the Tyennan Element and includes poorly exposed Devonian granites in the area. The 6 km depth contour of the granite surface has been used to extend the tract around exposed bodies of granites. No deposits of this style are known in the area. The tract also includes the known occurrences of lead-zinc veins in the Mt Mueller area (although the relationships to granite are uncertain).

Based on the available information the tract has a moderate potential for silver-lead-zinc vein deposits with a moderate to high certainty level.

Economic significance

he silver-bearing lead-zinc veins have been mined for lead, zinc, copper and silver. Some deposits have also served as important source for gold. Global grade and tonnage data show that 90% of deposits contain more than 290 tonnes, 50% contain more than 7600 tonnes and 10% contain more than 200 000 tonnes of ore. In 90% of deposits the ores contain more than 140 g/t silver, and more than 2.4% lead. In 50% of deposits the ores contain more than 820 g/t silver, more than 0.13 g/t gold, more than 9% lead, and more than 2.1% zinc and more than 0.89% copper. The richest 10% of deposits contain more than 4700 g/t silver, more than 11 g/t gold, more than 33% lead, more than 7.6% zinc and more than 0.89% copper.



Map 1 — Model M1

MODEL M2: Gold associated with alkaline intrusive rocks

Model description

Description of the model after R. Bottrill and J. Taheri.

Description

Fine-grained gold and sulphides in brecciated stockworks in syenite and alkaline porphyries.

General references

Sillitoe, 1991; Bonham, 1989.

Geological environment

Rock types:

Host rocks are alkaline porphyries: syenite, monzonite and latite.

Textures:

Porphyritic: medium grained.

Age range:

Cretaceous in Tasmania, but may be of any age.

Depositional environment:

Alkaline porphyries intruding thick sedimentary sequences.

Tectonic setting(s):

Stable platform or foreland-interior basin, shelf margin.

Associated deposit types:

Carlin-style gold, kaolin, placer gold.

Deposit description

Mineralogy:

Gold/electrum, auriferous pyrite, chalcopyrite scheelite magnetite pyrrhotite Au/Ag tellurides molybdenite galena sphalerite arsenic minerals in a gangue of quartz/chalcedony calcite fluorite.

Texture/structure:

Stockworks, breccia pipes.

Alteration:

Silicification, argillisation, K-silicate.

Ore controls:

Fracturing.

Weathering:

Oxidation of pyrite to limonite and jarosite.

Geochemical and geophysical signature:

Au, Ag, variable As, Cu, Pb.

Examples

Zortman-Landusky, Montana (Bonham, 1989).
Golden Sunlight, Montana

(Bonham, 1989).
Ortiz, New Mexico (Bonham, 1989).
Young-Davidson, Canada (Sillitoe, 1991).

In Australia a similar style of mineralisation is reported at Mt Dromedary, NSW, where the mineralisation, in the form of narrow late-stage pyrite veins in quartz diorite, is thought to be associated with alkaline igneous rocks (Wall, 1981, cited in Taheri and Bottrill, 1999).

Sillitoe (1991) discussed two deposits of similar type: Young-Davidson deposit in Ontario, Canada and the Zortman-Landusky deposit in Montana, USA. Mineralisation in the Young-Davidson deposit is interpreted to be associated with an Archaean stock of syenite intruding into metavolcanic rocks and metasediments. The mineralisation is in the form of disseminations, stockworks and quartz veinlets in the syenite stock. The stock is altered into red syenite as a result of potassic alteration of a grey porphyritic syenite. The red syenite also contains hematite. The mineralisation is composed of pyrite, chalcopyrite, galena, molybdenite, scheelite, specularite, K-feldspar, tourmaline and calcite. The mineralisation is reportedly similar to that in copper-poor porphyry gold deposits such as Vundu, Fiji, where it is hosted by altered shoshonitic (alkalic) volcanic rocks.

In the Zortman-Landusky deposits disseminated gold mineralisation is associated with syenite and quartz latite porphyry stocks cut by trachyte porphyry dykes (Sillitoe, 1991). Gold mineralisation is of Au-Ag-Te-As-(Cu-Mo-Pb-Zn) association and is linked to sericitic, clay and potassic alterations. According to Sillitoe (1991) this is an intrusive-related non-porphyry type stockwork and disseminated gold mineralisation.

Known deposits and mineral prospects in Tasmania

The Cygnet district is known to have several gold occurrences and small deposits, but the origin and nature of the ore control is not very clear. The area had produced about 100 kg of gold by 1902. The gold was derived from mineralised breccias, veins and contact zones of Cretaceous alkaline intrusive rocks in Permian sedimentary rocks (Taheri and Bottrill, 1999).

The area is underlain by Permian sedimentary rocks, which are tillitic, calcareous, carbonaceous and pyritic in part, and these are intruded by Jurassic dolerite and a variable suite of Cretaceous alkaline rocks. The Cretaceous intrusive rocks are typically small, medium grained, felsic, quartz poor and porphyritic and consist of mostly monzonites and syenites, but include dacite, diorite and lamprophyre.

The mineralisation in the area is partly in the form of gold and sulphide-bearing quartz veins and hematitic or limonitic stockworks in the porphyry and at the contact. Recent exploration has revealed that mineralisation is associated with alteration which include silica, K-feldspar, carbonate, epidote, clay, pyrite and hematite (Jones, 1986, 1987, cited in Taheri and Bottrill, 1999).

Anomalous gold is reported from ferruginous mudstone, intrusive syeno-monzonites which are weakly stockworked, and brecciated and mylonitised mudstone. The intrusive rocks contain disseminations and stringers of pyrite, chalcopyrite, pyrrhotite, marcasite, magnetite and hematite. Quartz veins also contain minor sulphides and possibly cinnabar.

Gold mineralisation is thought to be partly of the Carlin-style and partly of an alkaline porphyry-hosted style (Jones, 1986, cited in Taheri and Bottrill, 1999).

Assessment criteria

1. Presence of Cretaceous alkaline intrusive rocks.
2. Presence of Permian carbonaceous and calcareous fluvioglacial deposits.
3. Distribution of hard rock and alluvial gold prospects and deposits.

Assessment: Tract Au9a/M-H/B

The tract is drawn based on the distribution of known Cretaceous intrusive rocks, Permian sedimentary rocks and placer and hard rock gold deposits. Most gold in the area has been recovered from Cenozoic sediments but the source deposits are very poorly understood. Some is sourced in the intrusive rocks themselves (alkaline-porphyry hosted).

On the available information the potential for alkaline porphyry-style gold in the Cygnet area is moderate to high with a certainty level of B.

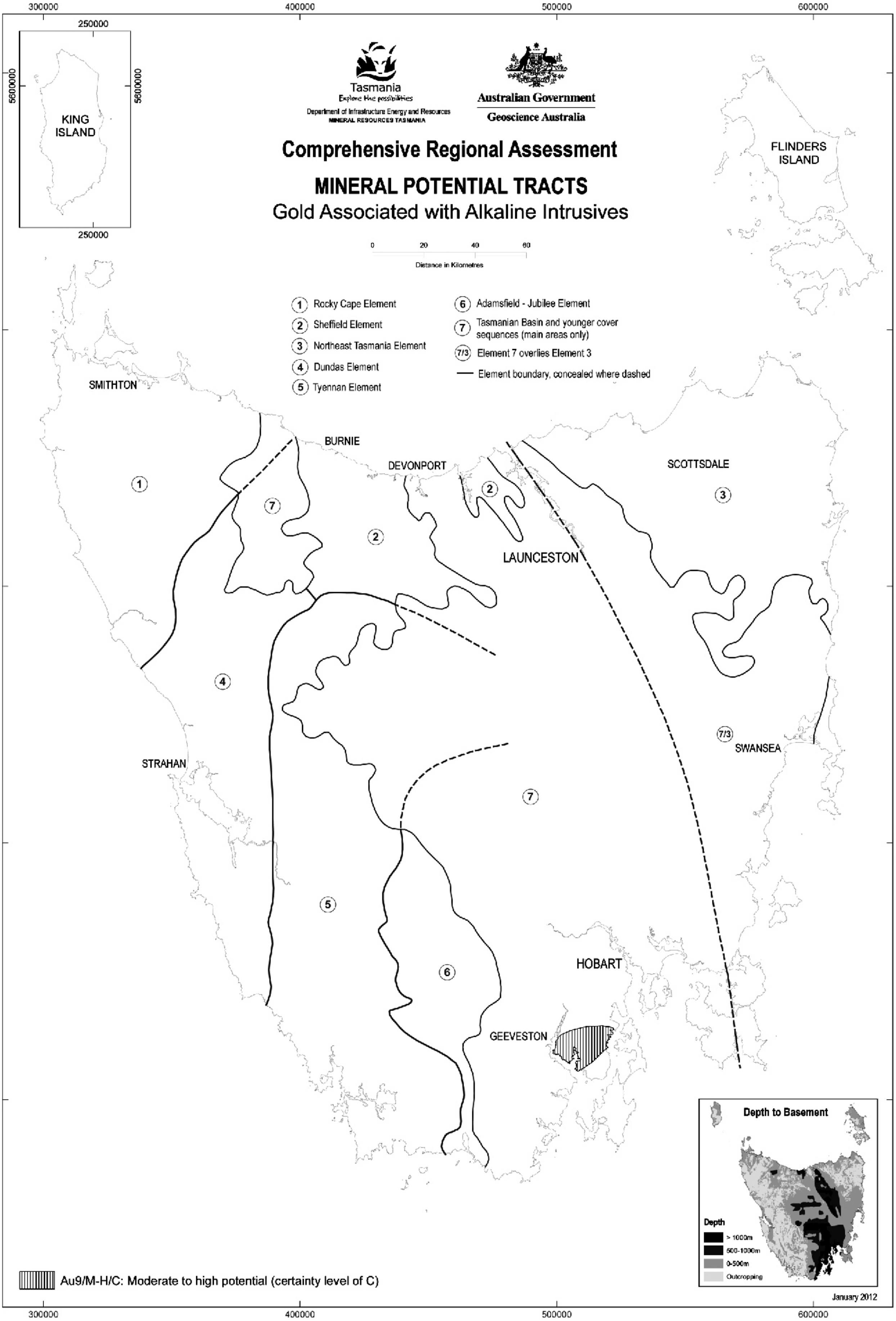
No gold is known to be related to the Cretaceous alkaline rocks in the Cape Portland area, but these may have potential.

The distribution of similar alkaline rocks elsewhere in the Tasmanian CRA is unknown. Hence the potential of gold mineralisation associated with alkaline rock in the CRA is unknown.

Economic significance

No resources are known in Tasmania.

In the Zortman-Landusky Deposits, Montana, reserves are 6.4 million ounces Au (1988); in the Golden Sunlight, Montana, 1.2 Mt.



Map 2 — Model M2

MODEL M3: Placer gold (Model 39A of Cox and Singer, 1986)

Model description

Modified after Warren E. Yeend.

Approximate synonym

None.

Description

Elemental gold as grains and (rarely) nuggets in gravel, sand, silt and clay, and their consolidated equivalents, in alluvial, beach, eolian, and (rarely) glacial deposits.

General references

Boyle, 1979; *Wells, 1973*; *Lindgren, 1911*.

Geological environment

Rock types:

Alluvial gravel and conglomerate, usually with white quartz clasts. Sand and sandstone of secondary importance.

Textures:

Coarse clastic.

Age range:

Cenozoic. Older deposits are known but their preservation is uncommon.

Depositional environment:

High-energy alluvial where gradients flatten and river velocities lessen, as at the inside of meanders, below rapids and falls, beneath boulders, and in vegetation mats. Winnowing action of surf caused Au concentrations in raised, present, and submerged beaches.

Tectonic setting(s):

Cenozoic conglomerates along major fault zones, shield areas where erosion has proceeded for a long time producing multi-cycle sediments; high-level terrace gravels.

Associated deposit types:

Black sands (magnetite, ilmenite, chromite), platinum group elements, yellow sands (zircon, monazite). Au placers commonly derive from various Au vein-type deposits but also other gold deposits, e.g. porphyry copper-gold, gold skarn, massive sulphide deposits and replacement deposits.

Deposit description

Mineralogy:

Au, commonly with attached quartz or limonite, rarely attached to sulphides and other gangue minerals. Associated with quartz and heavy minerals, which may include rutile, ilmenite, chromite, magnetite, limonite, pyrite, zircon, monazite, tourmaline, cassiterite, platinum-iron alloys and osmium-iridium alloys.

Texture/structure:

Usually flattened with rounded edges, also flaky or flour gold (extremely fine grained); rarely angular and irregular ('crystalline'), very rarely equi-dimensional nuggets.

Ore controls:

Highest Au values at base of gravel deposits in various gold 'traps' such as natural riffles in floor of river or stream, fractured bedrock, slate, schist, phyllite, dikes, bedding planes, all structures trending transverse to direction of water flow. Au concentrations also occur within gravel deposits above clay layers that constrain the downward migration of Au particles.

Geochemical signature:

Anomalous high amounts of Ag, As, Hg, Sb, Cu, Fe, S and heavy minerals magnetite, chromite, ilmenite, hematite, pyrite, zircon, garnet and rutile. Au nuggets have decreasing Ag content with distance from source.

Geophysical signature:

Seismic methods define buried channels or deep leads.

Examples

Sierra Nevada, USCA (*Lindgren, 1911*; *Yeend, 1974*)
Victoria, AUVT (*Knight et al., 1975*)

Known deposits and mineral prospects in Tasmania

Alluvial gold is widespread in western and northern Tasmania and is derived predominantly from primary deposits in the pre-Carboniferous rocks of the Dundas Trough and in the Northeast Tasmania Element (Bottrill, 1991). Bottrill defines thirteen principal areas of alluvial gold production in Tasmania. The most important area is in the Northeast Tasmania Element, where slate-belt gold veins in the Mathinna beds served as the primary source for numerous small deposits.

Most known alluvial gold prospects in Tasmania are thought to be Cenozoic in age and the known workings are located within alluvium and eluvium on slopes and terraces. Some workings are within Pleistocene fluvioglacial deposits. Some of the placer gold is reworked from paleoplacers, from Permian to Neogene in age. Much of the gold is flattened and rounded, with or without attached quartz, but some appears to be recrystallised in the sediments.

Based on the nature of the primary source known occurrences are divided into four groups (Bottrill, 1991): Paleogene to Recent deposits associated with late Devonian veins in lower Palaeozoic rocks (e.g. northeastern Tasmania, Beaconsfield and Moina); Paleogene to Recent deposits associated with mineralised lodes and beds in Precambrian rocks (e.g. northwestern Tasmania); Pleistocene to Recent deposits associated with Cambrian mineralisation, e.g. Mt Lyell and Ring River areas); and Pleistocene to Recent deposits associated with mineralised Cretaceous intrusive rocks (e.g. Cygnet).

Small placer gold deposits are commonly associated with the lode gold deposits in northeastern Tasmania. Most of the placer gold deposits were only worked to shallow depths. At Back Creek and Lefroy sub-basaltic deep leads are known but were not worked extensively. A 'deep lead' at Beaconsfield may be related to a decomposed limestone horizon. Many of the major placer tin deposits worked in the northeast were rich also in gold (e.g. the Boobyalla and Ringarooma rivers).

One of the largest alluvial fields was Lisle, which produced approximately nine tonnes of placer gold, and is located near Scottsdale. The gold is typically concentrated in sandy carbonaceous 'bottoms', presumably paleosols. Grains are rounded to angular and skeletal (crystalline) or colloform and porous, forms suggesting recrystallisation in situ, and these are sometimes chemically zoned (Bottrill, 1991). There is, unusually, little quartz associated with the alluvial gold, and the primary source is uncertain.

In the Jane River area of central Tasmania, gold is associated with rutile, zircon, chromite, pyrite and, more rarely with cinnabar, xenotime, monazite and gersdorffite in quartz gravels (Bottrill, 1989). The gold grains are similar to those at Lisle in form and nature, but contain minor mercury. The source is again uncertain, but there is a close relationship between the location of gold deposits and underlying Neoproterozoic carbonate units.

Placer gold (including some in shoreline deposits, e.g. Doctors Rocks) in the Wynyard and Arthur River areas may be recycled from Permo-Triassic sedimentary rocks of uncertain derivation (Bottrill, 1991).

Placer gold (including some in Paleogene to Neogene deposits, e.g. Bell Mount) in the Moina area may be derived from various sources including Cambrian mineralisation, and Devonian gold skarns and gold-quartz veins (Bottrill, 1991).

Many placer gold deposits in the Dundas Trough Element (e.g. Ring River–Pieman River) were probably derived from Cambrian gold-rich sulphide deposits, although gold-quartz lodes are also locally important. Such gold-quartz lodes are sporadic throughout western and northern Tasmania.

Mixed gold-osmiridium placers occur in several areas, particularly the Wilson River area in the Dundas Element, the Corinna–Savage River–Heazlewood area (Rocky Cape and Dundas elements) and in the Adamsfield area in the Adamsfield–Jubilee Element. These placers are in close proximity to Cambrian ultramafic rocks (see tracts for platinum group element deposits). Tin was also an important by-product of some of these deposits.

In the Corinna–Savage River area about one tonne of gold was produced, including Tasmania's largest nuggets (<7.6 kg). The sources are probably varied, including carbonate-replacement, ironstone and vein-style deposits (Bottrill, 1991).

Assessment criteria

1. Presence of gold-bearing source rocks.
2. Distribution of alluvial, eluvial, fluvioglacial and lacustrine deposits.
3. Distribution of Cenozoic deposits.
4. Distribution of alluvial gold prospects and deposits.

Assessment: Tract Au7/M-H/B

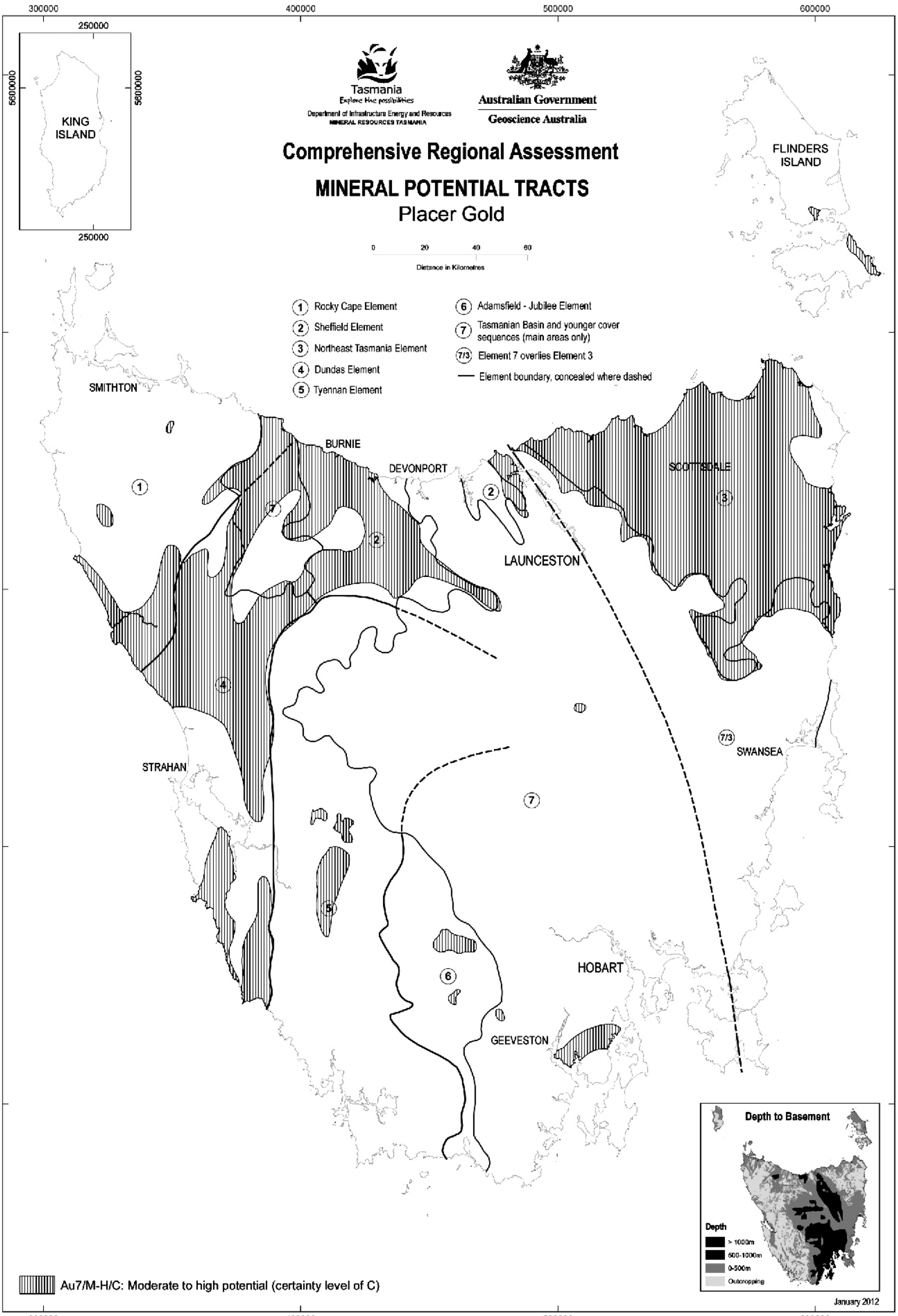
The tract is drawn based on the distribution of known placer deposits, primary gold deposits and associated Cenozoic sediments. Alluvial gold has been recovered from the Cenozoic sediments and more deposits are present in areas where these sediments are not mapped in great detail.

The potential for placer gold is moderate to high with a certainty level of B.

Related deposits

Diamond deposits:

A few diamonds of small size (average about one-eighth carat and up to one-third carat) have been found in gold-bearing alluvial deposits in Sunday Creek, a small tributary of the Pieman River and in Badger Creek, Middleton Creek and Harveys Creek tributaries of the Savage River. The source rock is thought to be ultramafic-mafic sequences in the Heazlewood area. The model is the same as for Eastern Australia (the subduction zone model of Barron *et al.*, 1996). Similar complexes are exposed in several other areas in Tasmania, but no diamonds have been reported. There is no definite information on the presence of indicator minerals for primary diamond deposits and hence their potential is unknown.



Map 3 — Model M3

MODEL M4: Gold-base metal-tin vein deposits

Model description

Description of the model by S. Jaireth.

Approximate synonym

Felsic intrusion-associated polymetallic veins.

Description

Sn-Au-polymetallic sulphide-quartz vein deposits in marine volcanic rocks of intermediate to felsic composition.

General references

Taheri and Green, 1990.

Geological environment

Rock types:

Marine rhyolite, dacite, andesite and subordinate basalt and associated sediments, principally organic-rich mudstone or shale. Pyritic, siliceous shale.

Age range:

Devonian in Tasmania, but may be of any age.

Depositional environment:

Fractures and breccias within thermal aureole of granitic intrusions remobilising gold and base metals from volcanic host rocks.

Tectonic setting(s):

Island arc, local extensional tectonic activity, volcanic-plutonic belts especially zones of local domal uplift, faults, or fractures.

Associated deposit types:

Ag-bearing polymetallic veins, mesothermal gold veins, tin veins, polymetallic replacement, tin replacement, placer Au.

Deposit description

Mineralogy:

Pyrite, arsenopyrite, stannite, chalcopyrite, pyrrhotite, cassiterite, gold, tellurides, bismuth, sphalerite, galena, tourmaline, carbonates, fluorite, tetrahedrite.

Texture/structure:

Cross-cutting veins, stringer zones, and fissure fillings. Breccia and replacement textures.

Alteration:

Host rocks show silicification, chloritisation, albitisation and sericitisation.

Ore controls:

Areas of high permeability, fault zones, zones of brecciation.

Weathering:

Erosion of mineralised zones may lead to deposition of Au and Sn placers.

Geochemical signature:

Anomalous soil geochemistry (Sn, Au, As, Cu, Zn, Pb).

Geophysical signature:

IP and EM anomalies.

Examples

Lakeside Prospect, AUTS (Taheri and Green, 1990).

Known deposits and mineral prospects in Tasmania

Within Tasmania known mineral occurrences of this type are located within the Dundas Element. Spatially they are closely associated with the Henty Fault. In the Sterling Valley –Farrell field, a series of vein and fissure-style lodes occur within the Farrell Slates and the adjacent Cambrian volcanic rocks. Other Devonian vein deposits hosted by, or in rocks overlying, the Mount Read Volcanics (e.g. Round Hill deposit) are also characterised by high gold contents.

Recent gravity data has revealed the extensive distribution of Devonian granites in the area. These studies have shown that the Granite Tor Granite is a large body at shallow depth, and that only a small part of the granite is exposed at Granite Tor. Two shallow ridges of the granite extend to the WSW from Granite Tor, and northeast from Mt Pelion to the Dolcoath Granite (Taheri and Green, 1990). The WSW-trending granite ridge extends from the Granite Tor Granite to the Pine Hill Granite, and possibly as far west as the Heemskirk Granite. Taheri and Green (1990) have concluded that mineralisation in the Lakeside prospect and the Sterling Valley–Mt Farrell field is essentially Devonian and formed above a high point (less than one kilometre depth) above the buried ridge of granite. However the gold may have been derived from the Mount Read Volcanics host rocks.

Assessment criteria

1. Distribution of Devonian granites.
2. Distribution of the Mount Read Volcanics.
3. Presence of proximity to large faults and fault zones such as the Henty Fault.
4. Distribution of known mineral occurrences.

Assessment: Tract Au3a/H/C-D

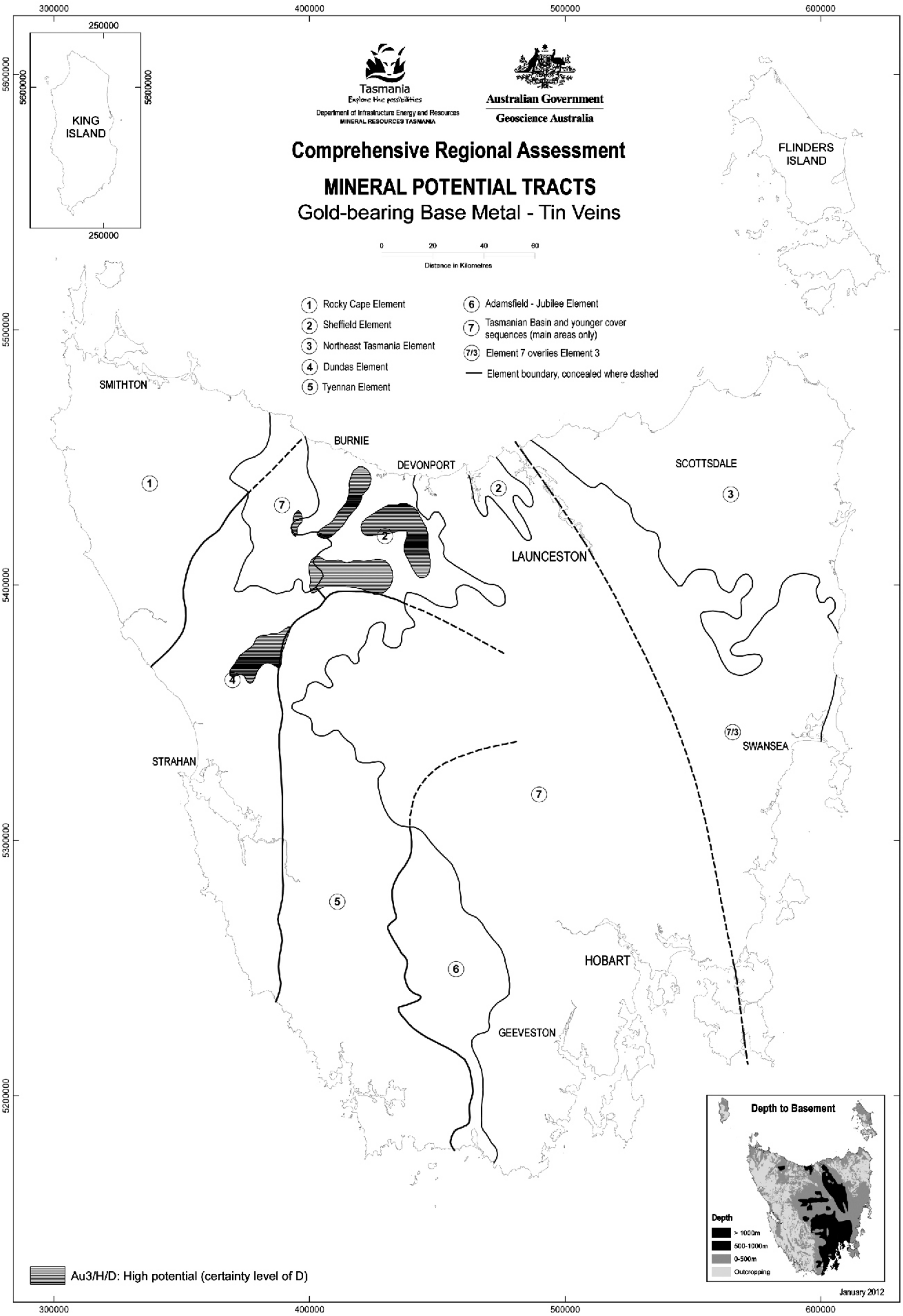
The tract is delineated based on the distribution of Mount Read Volcanics, Devonian granite isopleths and known mineral occurrences in the area. As mentioned previously most known occurrences of this type are located between the one and three kilometre depth contours of Devonian granite in the area. Hence the tract takes into account the relevant granite depth contours.

Based on the available information there is a high potential for this type of gold deposit in the area with a high certainty level of C-D, depending upon quality of mapping.

Economic significance

The deposits with known resources/production, including Lakeside and Round Hill, are considered to be sub-economic.

The total resource for the Lakeside deposit is 750 000 tonnes at 2.1 g/t gold. Round Hill has produced 0.06 million tonnes of ore at 0.5 g/t gold, 8.1% Pb and 186 g/t Ag.



Map 4 — Model M4

MODEL M5: Avebury-type hydrothermal nickel

Model description

Description of the model by Geoffrey R. Green, Yanis Miezitis and Dean Hoatson.

Approximate synonyms

N/A

Description

Disseminated nickel in ultramafic rocks near their contact with sedimentary sequences intruded by fractionated, reduced granite.

General references

Callaghan and Green (*in* Green *et al*., in press), Lygin *et al*., 2010*a*, *b*; Keays *et al*., 2009).

Geological environment

Rock types:

Host rocks include serpentinite and peridotite or dunite altered to skarn-like assemblages.

Textures:

Sulphide ore is dominated by pentlandite as disseminations and stringer veinlets associated with hydrothermal magnetite.

Age range:

Host rocks Terreneuvian (early Cambrian), mineralisation probably Upper Devonian.

Depositional environment:

Margins of ultramafic bodies intruded by granite within 1–2 km below ore.

Tectonic setting(s):

Post-collisional intrusive granites emplaced in polydeformed terrane including fault bound, dismembered ultramafic-mafic complexes.

Associated deposit types:

Magnetite-base metal skarn deposits, tin greisen deposits.

Deposit description

Mineralogy:

Low sulphidation pentlandite + magnetite pyrrhotite Cr-magnetite rare chalcopyrite, millerite, niccolite, gersdorrfite, maucherite, mackinawite, bismuth, galena and valleriite. Heazlewoodite occurs at Nickel Reward and Lord Brassey. Sphalerite and shandite occur at Nickel Reward.

Texture/structure:

Predominantly disseminated and veinlet sulphides closely associated with magnetite. Pentlandite occurs as grains 5–500 m and patches to >10 mm.

Alteration:

Two assemblages; massive antigorite-chromite-magnetite sulphides (60% of ore) and tremolite-actinolite-diopside-magnetite-chromite sulphides. Primary Cr-spinel altered to Cr-magnetite (40% of ore). Adjacent country rock may contain skarn-like assemblages with axinite and tourmaline.

Ore control:

Sulphides typically occur within ultramafic rocks near steep, probably faulted, contacts with country rock, but zones of mineralisation may also occur within ultramafic bodies. Low sulphur content in the hydrothermal fluid and a source of reduced sulphur at the depositional site appear to be critical factors in the mobilisation and deposition of Ni.

Weathering:

Nearby Burbank deposit deeply weathered to smectite-goethite-carbonates-chalcedony within zones of anomalous Ni and Zn.

Geochemical signature:

Low Cu, PGEs; ultramafic rocks enriched in As, Cs, W, U, Pb, Bi, Sn, Sb.

Geophysical signature:

Strong magnetic signature.

Examples

Avebury, Tasmania (Keays *et al*., 2009; Lygin *et al*., 2010*a*,*b*; Callaghan and Green, in Green *et al*., in press).

Nickel Reward, Tasmania (Callaghan and Green, *in* Green *et al*., in press; Williams, 1958).

Pembroke, Queensland (Barton, 2010).

Known deposits and mineral prospects in Tasmania

Avebury, Nickel Reward, Lord Brassey, Burbank.

Assessment criteria

1. Presence of granite at inferred depths of less than 4 km, particularly granite associated with hydrothermal Sn deposits and/or magnetite-bearing skarn.
2. Presence of ultramafic complexes, or their subsurface extent as inferred from aeromagnetic data.

Assessment: Tract AvNi1a/H/D

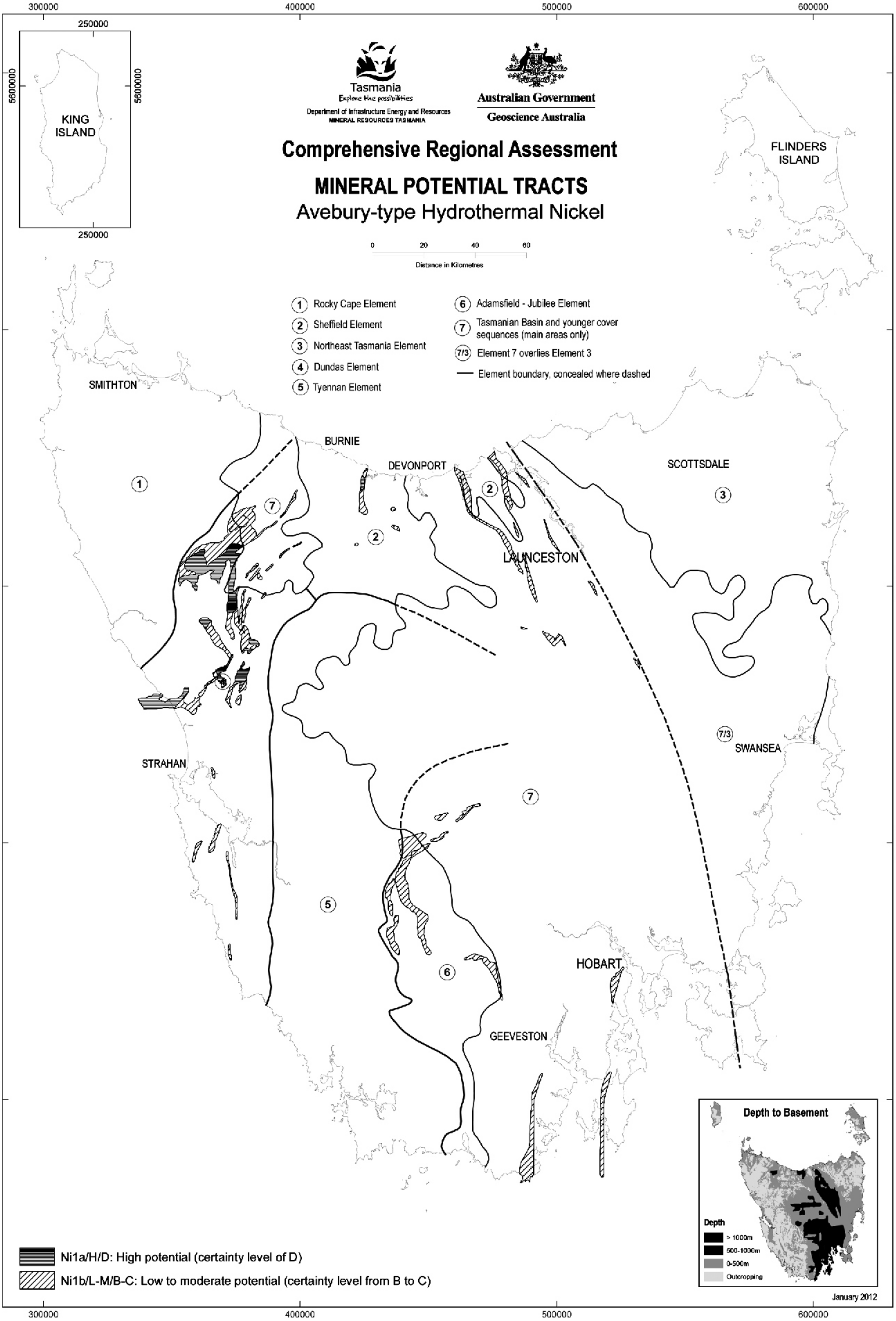
The Avebury–Trial Harbour area contains the type deposit of this style and hence is assessed as having high potential and it has a certainty level of D.

Assessment: Tract AvNi1b/H/C

The Serpentine Hill and Heazlewood River ultramafic complexes and bodies in the Dundas, Wilson River, Huskisson River and Mount Stewart areas and subsurface extensions all satisfy the assessment criteria and are therefore considered to be of high potential with a certainty level of C. One deposit in the Heazlewood River complex, Lord Brassey, has sufficient similarity to Avebury to be assigned to the style with moderate confidence (Callaghan and Green, *in* Green *et al*., in press).

Economic significance

The only known multi-million tonne deposit of this style, Avebury, is currently under care and maintenance. Detailed work is proceeding to provide methods to successfully produce saleable nickel concentrate and it is likely that the deposit will become an important mine in the near future. The geology of western Tasmania is consistent with a high potential for further major deposits of the Avebury style.



Map 5 — Model M5

MODEL M6: Bauxite deposits

Model description

Description of the model after S. Jaireth.

Description

Aluminium-rich saprolite or laterite.

General references

Williams, 1943; Jennings *et al.*, 1967; Matthews, 1975; Bacon *et al.*, 2008.

Geological environment

Rock types:

Sedimentary rocks, dolerite and basalt.

Textures:

Variable.

Age range:

Pre Quaternary.

Depositional environment:

Near-surface soil profile.

Tectonic setting(s):

Paleogene–Neogene graben; stable areas with deep weathering but low erosion.

Associated deposit types:

Ochre, kaolinite, gravel.

Deposit description

Mineralogy:

Gibbsite, goethite, kaolinite, quartz.

Texture/structure:

Fine grained, pisolitic-nodular.

Alteration:

Kaolinitisation.

Ore controls:

Areas of high-Al rocks and deep lateritic weathering.

Weathering:

Lateritic.

Geochemical signature:

High Al, Fe; low Si, K, Mg, Na, Ca.

Examples

Ouse (Jennings *et al.*, 1967).

Known deposits and mineral prospects in Tasmania

Bauxite deposits are known in some 25 localities in Tasmania, where they occur in the remnants of ferruginous pisolitic laterite, developed either on dolerite, basalt and earlier rock types, preserved in down-faulted blocks within Paleogene–Neogene grabens, or as laterite developed on Paleogene–Neogene basalt. The deposits appear to range in age from pre-Early Eocene to ?Pliocene.

The largest deposits are in the Ouse district, some 70 km northwest of Hobart, where they are formed over a Jurassic dolerite sill and underlie Oligocene to Miocene basalt and freshwater sediments. Other important occurrences are in the St Leonards, Riccarton, Rosedale, Meadowbank, Fordon, Myalla, Swansea, Trevallyn, Cressy, Campbell Town and Conara districts.

The overall grade of these bauxites is generally lower than that of imported ore, but Comalco considered some (e.g. St Leonards) to be metallurgically acceptable (D. Zani, pers. comm.). Recent exploration by Australian Bauxite Limited in the Deloraine area has identified a prospect which is considered to be of direct shipping quality.

Assessment criteria

1. Distribution of basalt and dolerite.
2. Distribution of Paleogene–Neogene weathering profiles.
3. Distribution of Paleogene–Neogene grabens.

Assessment

Periods of deep weathering during the late Mesozoic? and Cenozoic produced lateritic profiles on a variety of older and contemporaneous rock types, including dolerite and Parmeener Supergroup strata. Some profiles survived erosion and were then protected by burial beneath Paleogene–Neogene deposits. Some Paleogene–Neogene rocks, both sediments and basalts, were subsequently also lateritised. These form a slightly resistant duricrust on the present land surface, particularly in areas that were removed from active erosion.

Some of the lateritic profiles developed on quartz-poor, aluminium-rich rocks (e.g. basalt and dolerite) are highly aluminous (bauxitic).

The general criterion for prospectivity is the preservation of part of the lateritic surface. For the older laterite this preservation is possible where Palaeocene or Early Eocene strata or basalt flows are present (potential mostly H-M/C-B; L/B for Macquarie Graben), and for the younger laterite preservation is possible where Early Miocene or older basalt flows and/or sediments are present (L-M/C-B). In particular the potential is high where laterite or pedological ferricrete or silica stone has been mapped (H/C). Lateritic profiles are known in some poorly mapped areas, such as between Swansea and Rheban, and the potential for bauxite is regarded as low to moderate (L-M/B). For more detailed assessment, consideration of Cenozoic erosion history could be undertaken.

Assessment: Tract Bxa/M/M

This tract is based on the distribution of known occurrences of bauxite which are associated with Paleogene–Neogene deposits in the Deloraine–Campbell Town–St Leonards and Myalla areas. It has a moderate potential and certainty rating.

Assessment: Tract Bxb/L-M/M

This tract is based on the distribution of known bauxite deposits which are developed on Jurassic and/or Paleogene–Neogene deposits in the Ouse and Swansea areas. It has a low potential and a moderate certainty rating.

Economic significance

Although Jurassic dolerite and basalt have the potential to produce bauxite deposits the available information is not enough to assess their potential in forming economic deposits, although Comalco considered them to be metallurgically acceptable (D. Zani, pers. comm.).

Associated deposit types

Kaolin deposits

Model Description

Description of the model after R. S. Bottrill.

Description

Kaolinite-rich saprolite and/or altered felsic intrusive rocks.

General references

Bottrill, 1992.

Geological environment

Rock types:

Sedimentary rocks, granite, dolerite and basalts.

Textures:

Variable.

Age range:

Any; Devonian granites, Paleogene–Neogene sediments.

Depositional environment:

Near-surface, soil profile.

Tectonic setting(s):

Paleogene–Neogene graben; stable areas with deep weathering but low erosion.

Associated deposit types:

Ochre, bauxite, gravel.

Deposit description

Mineralogy:

Kaolinite halloysite gibbsite goethite quartz.

Texture/structure:

Very fine grained, argillaceous.

Alteration:

Kaolinitisation

Ore controls:

Periods of deep weathering during the late Mesozoic? and Cenozoic produced lateritic profiles on a variety of older and contemporaneous rock types, including dolerite and Parmeener Supergroup strata. Some profiles survived erosion and were then protected by burial beneath Paleogene–Neogene deposits. Some Paleogene–Neogene rocks, both sediments and basalt, were subsequently lateritised. Some of the lateritic profiles developed on aluminium-rich rocks (e.g. granites) are highly aluminous (kaolinitic to bauxitic).

Weathering:

Lateritic.

Geochemical signature:

High Al; low Fe, K, Mg, Na, Ca.

Examples

Tonganah (Bottrill, 1992).

Known deposits and mineral prospects in Tasmania

Kaolinite deposits are known at many localities throughout Tasmania, where they mostly occur in saprolite, developed on granite and many other rock types, often preserved in down-faulted blocks within Paleogene–Neogene grabens. The deposits may be largely Paleogene–Neogene, although the Tonganah deposits have been considered to possibly result from Devonian metasomatism. The age of the Surges Bay kaolin deposit is uncertain.The largest high quality proven resources were in the Tonganah mine (Scottsdale district), where they formed from Devonian granite (by Paleogene–Neogene weathering or Devonian metasomatism?). Another important abandoned mine is in the South Mt Cameron area, in a similar geological setting. Other abandoned kaolin mines are at Surges Bay (in kaolinised Cretaceous syenite), St Helens (in Paleogene–Neogene sediments) and Mawbanna (near Wynyard, in Precambrian siltstone). Significant resources exist near Western Junction (near Launceston, in Paleogene–Neogene sediments), Dulverton (near Railton, in Permo-Triassic coal measures) and Browns Plains (Savage River, in Paleogene–Neogene sediments).The overall quality of these kaolins is generally lower than that of many imported products, but the Tonganah clay was acceptable as a paper filler.

Assessment criteria

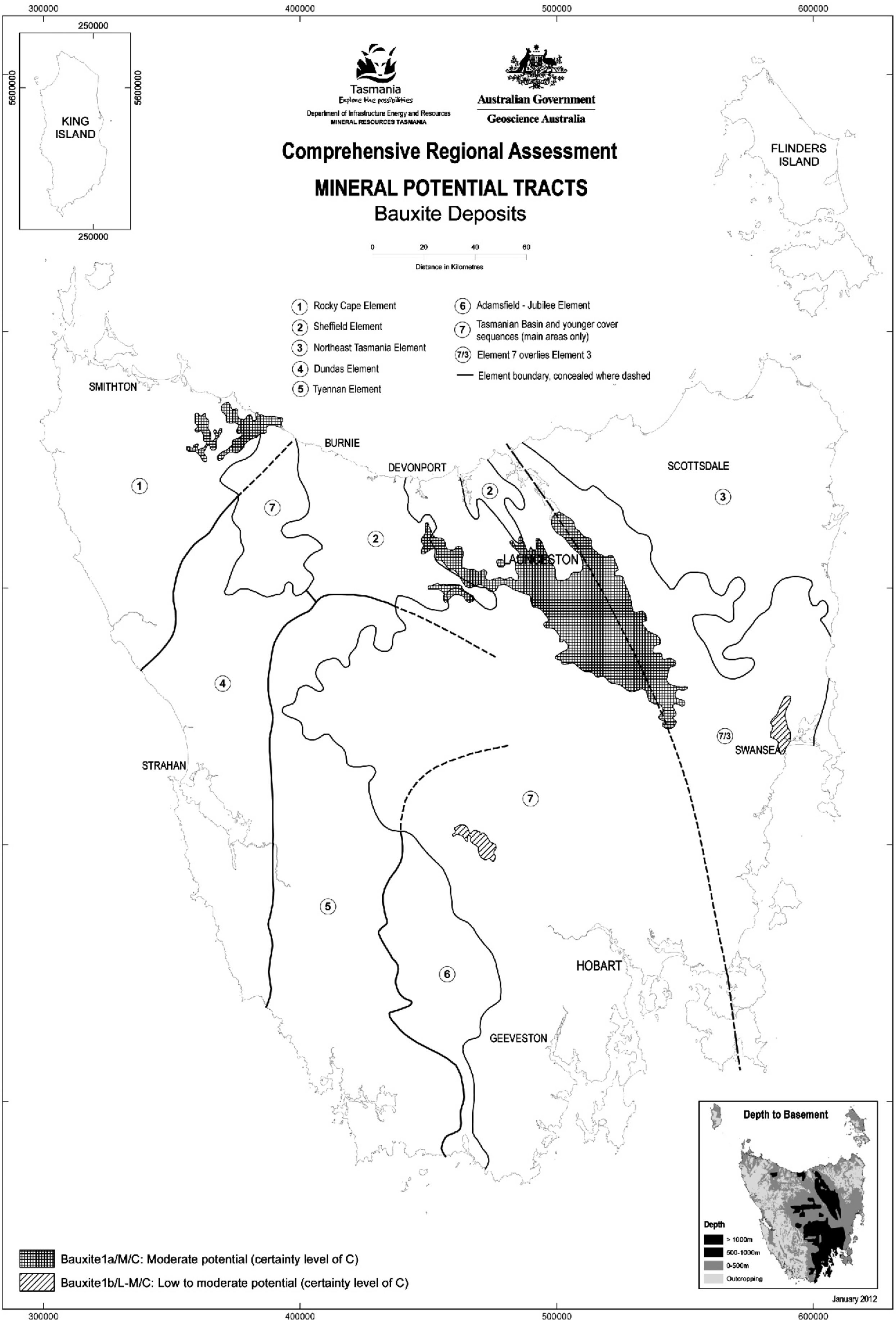
1. Distribution of granites.
2. Distribution of Paleogene–Neogene weathering profiles.
3. Distribution of Paleogene–Neogene grabens.

Assessment

The general criterion for prospectivity is the preservation of part of the Tertiary weathering surface over aluminous rock types. The potential for kaolin in the northern, deeply weathered parts of the Scottsdale and Blue Tier batholiths, where deposits are known, is regarded as moderate to high (M-H/B). In the areas of Paleogene–Neogene sediments (e.g. Longford Basin, St Helens, Tamar basin), and in the Cretaceous Cygnet alkaline complex, the potential is moderate.

Economic significance

Tonganah has produced large quantities of kaolinite (~0.6 Mt) for use as a paper filler over many years, as have several smaller deposits.



Map 6 — Model M6

MODEL M7: Besshi-type massive sulphide (MODEL 24B by Cox and Singer, 1986)

Model description

Description of the model after Dennis P. Cox.

Approximate synonyms

Besshi type, Kieslager.

Description

Thin, sheet-like bodies of massive to well-laminated pyrite, pyrrhotite, and chalcopyrite within thinly laminated clastic sediments and mafic tuffs.

General references

Klau and Large, 1980; Fox, 1984.

Geological environment

Rock types:

Clastic terrigenous sedimentary rocks and tholeiitic to andesitic tuff and breccia. Locally, black shale, oxide-facies iron formation, and red chert.

Textures:

Thinly laminated clastic rocks. All known examples are in strongly deformed metamorphic terrane. Rocks are quartzose and mafic schist.

Age range:

Any age but mainly Palaeozoic and Mesozoic.

Depositional environment:

Uncertain. Possibly deposition by submarine hot springs related to basaltic volcanism. Ores may be localised within permeable sediments and fractured volcanic rocks in anoxic marine basins.

Tectonic setting(s):

Uncertain. Possibly rifted basin in island arc or back arc. Possibly spreading ridge underlying terrigenous sediment at continental slope.

Associated deposit types:

None known.

Deposit description

Mineralogy:

Pyrite + pyrrhotite + chalcopyrite + sphalerite ± magnetite valleriite galena bornite tetrahedrite cobaltite cubanite stannite molybdenite. Quartz, carbonate, albite, white mica, chlorite, amphibole, and tourmaline.

Texture/structure:

Fine-grained, massive to thinly laminated ore with colloform and framboidal pyrite. Breccia or stringer ore. Cross-cutting veins contain chalcopyrite, pyrite, calcite or galena, sphalerite, calcite.

Alteration:

Difficult to recognise because of metamorphism. Chloritisation of adjacent rocks is noted in some deposits.

Ore controls:

Uncertain. Deposits are thin, but laterally extensive and tend to cluster in *en echelon* pattern.

Weathering:

Gossan.

Geochemical signature:

Cu, Zn, Co, Ag, Ni, Cr, Co/Ni >1.0, Au up to 4 ppm, Ag up to 60 ppm.

Geophysical signature:

Magnetic surveys may detect associated magnetite and/or pyrrhotite within ore body or magnetite within wall rocks. IP techniques may detect pyritic schists. EM techniques may detect massive sulphide mineralisation. Radiometrics may show K-depletion in alteration envelope.

Examples

Besshi, JAPN	(*Kanehira and Tatsumi, 1970*)
Motoyasu, JAPN	(*Yui, 1983*)
Kieslager, ASTR	(*Derkman and Klemm, 1977*)
Raul, PERU	(*Ripley and Ohmoto, 1977*).

Known deposits and mineral prospects in Tasmania

In Tasmania, most of the known occurrences of this type are within the Arthur Metamorphic Complex (AMC). As noted by Turner *et al.* (1992), the AMC displays important similarities with the Japanese Sambagawa Metamorphic Belt which hosts the Besshi 'type-deposit'. Most of the known mineralisation in the AMC lies within the Bowry Formation, near the eastern edge of a sequence dominated by amphibolite and mafic to pelitic schist.

Mineralisation at the Alpine prospect in the southern part of the AMC comprises pyrite-chalcopyrite with minor sphalerite, magnetite and hematite, and could be considered as typical Besshi type (Turner *et al.*, 1992). In the northern part of the AMC, minor chalcopyrite occurs in pyrite-magnetite lodes at the small Victory prospect on the Arthur River and in association with the Keith River and Lyons River gossan zones, which extend along strike for eight kilometres (Porter, 1971; Turner *in* Burrett and Martin, 1989, p.23).

Assessment criteria

1. Presence of metamorphosed and/or unmetamorphosed sequence of clastic terrigenous sedimentary rocks and submarine volcanic rocks of predominantly mafic composition.
2. Distribution of known mineral occurrences.

Assessment: Tract BM2a/H/B-C

The tract has been delineated on the basis of the distribution of major units containing submarine mafic rocks, particularly those thought to have oceanic, back arc or advanced continental rift affinities.

The Arthur Metamorphic Complex comprise strongly deformed and metamorphosed (locally blueschist facies) chloritic schists with minor phyllite, dolomite and magnesite (Lac), and tholeiitic amphibolite (Lma). Features such as tectonic setting (near a possible terrane boundary with likely major thrusting), compressional tectonics, strong deformation, high pressure metamorphism, and the association of continentally derived clastic sediments and probable rift tholeiites, all appear typical for terranes hosting Besshi-style deposits. Mineral exploration companies have regarded the southern part of the AMC as a target area. As some comparable mineralisation is known, the AMC is rated as having high potential for this style.

Assessment: Tract BM2b/M/B-C

In the Dundas–Sheffield Element there are a number of Cambrian melanges containing pyritic, carbonaceous and cherty siltstone, chert, greywacke, siltstone, dolomite and tholeiitic basalt and gabbro. These include the Cleveland–Waratah Association and correlates near Sheffield (the Barrington Chert and Motton Spilite), the melange on the eastern shore of Port Sorell, the melange west of the ultramafic complex at Beaconsfield, the Birchs Inlet Volcanics and the poorly known sequence of the Mainwaring River area. The tectonic, sedimentological and geochemical affinities of these rocks are not well understood, but there are a number of features which may indicate potential for Besshi-style mineralisation, particularly the presence of submarine tholeiitic volcanic rocks. However no comparable mineralisation has been documented. These tracts are considered to have moderate potential for this style.

A few amphibolites occur in the Tyennan Element, notably in the Atkins Range area. These are probably tectonically emplaced, have tholeiitic affinities and at least some have undergone high pressure (blueschist facies) metamorphism. They are similarly rated as having moderate potential for Besshi-style deposits.

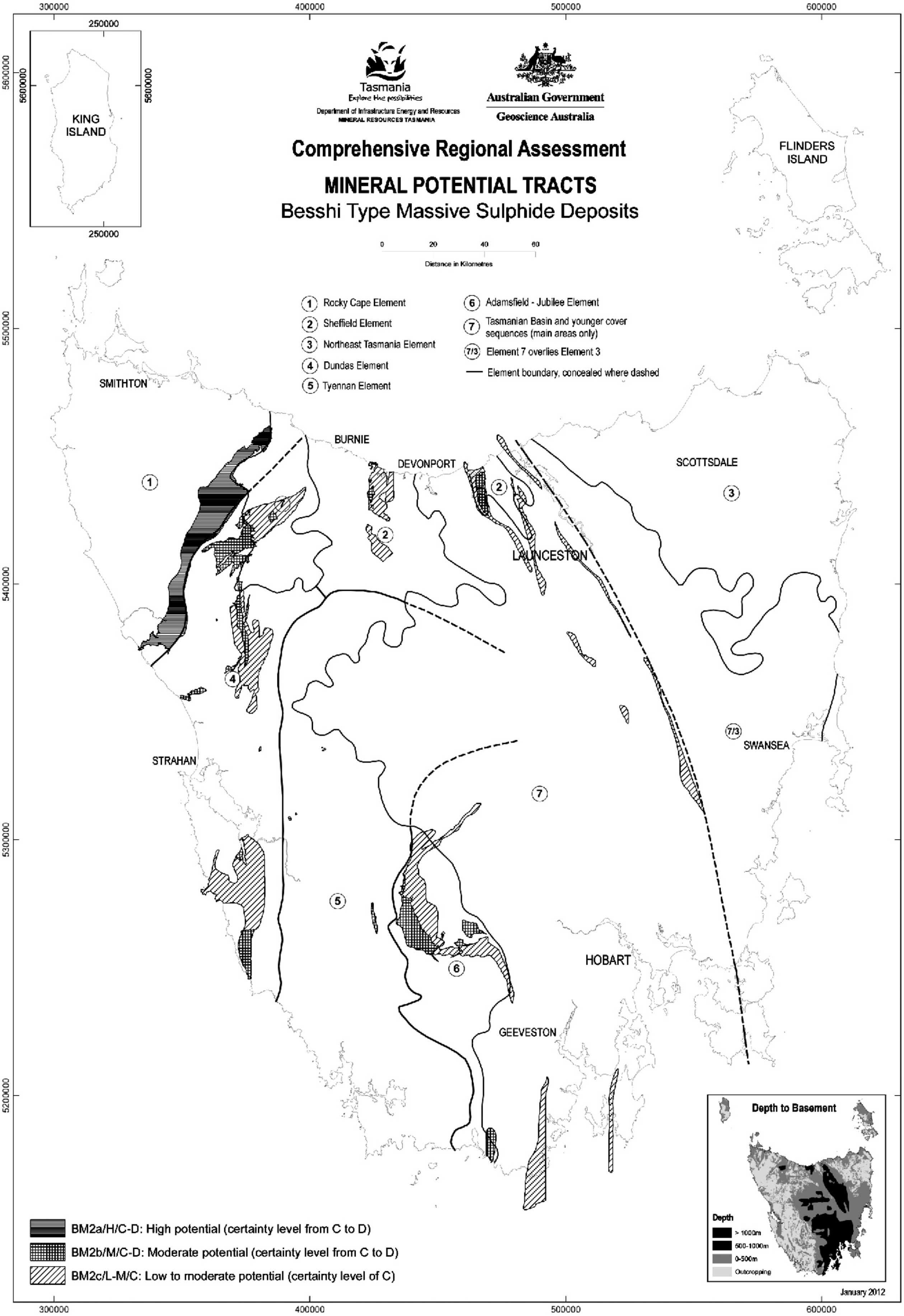
These areas have certainty levels of B and C depending on the detail of geological mapping in the area.

Assessment: Tract Eastern Tasmania: BM2c/L-M/B

An interpretation based largely on the 3D geological model of Tasmania postulates that a number of rock units outcropping in western Tasmania which have potential for this style of mineralisation also occur as basement rocks beneath a cover of Parmeener Supergroup and younger rocks. A number of concealed bodies of mafic rocks are postulated to occur widely in eastern Tasmania and these are considered to have low to medium potential for this deposit style with a certainty level of B.

Economic significance

Volcanic-hosted massive sulphide deposits are a significant source for copper, lead and zinc. Some of these deposits can have a few tens of ppm of silver and at least a ppm of gold. Global grade/tonnage models for this type of deposit indicate that 90% of these deposits have more than 0.012 million tonnes of ore, 50% have more that 0.22 million tonnes and 10% have more than 3.8 million tonnes. Similarly in 90% of these deposits the ores have more than 0.56% copper, 50% have more than 1.5% copper and 2.0% zinc, and 10% have more than 3.3% copper.



Map 7 — Model M7

MODEL M8: Metalliferous sulphidic euxinic shales

Model description

Description of the model by Geoffrey R. Green.

Approximate synonyms

N/A

Description

Sulphide-rich layers in marine euxinic shales with concentration factors of a range of elements including Ni, Au, Ag, Se, Mo, As, Pt, Pd, Os, Ir, Cu, Pb and Zn 10^7 compared with seawater. Enrichments in non-chalcophile redox-sensitive elements (V, U, Cr, Ba) show lower concentrations (c. 10^4 to 10^6). Associated pyritic black shales show element concentrations of 10^4 to 10^6 compared with seawater.

General references

Lehmann *et al.*, 2007; Large *et al.*, 2011; R. Large, pers. comm.

Geological environment

Rock types:

Host rocks are sulphidic black shales. Contemporaneous phosphorites, barite deposits and alginites may be present in lateral facies.

Textures:

Clastic millimetre-sized sulphides in a siliceous-carbonaceous matrix and mico-laminated sulphide sediment.

Age range:

Archaean to Jurassic.

Depositional environment:

Sediment-starved marine basins in passive margin settings.

Tectonic setting(s):

Post-collisional intrusive granites emplaced in polydeformed terrane including fault bound, dismembered ultramafic-mafic complexes.

Associated deposit types:

Magnetite-base metal skarn deposits, tin greisen deposits.

Deposit description

Mineralogy:

In Lower Cambrian Niutitang Formation of southern China (Mo, Fe, Ni)$(S,As)_2$ S7 phase associated with Ni and As-rich pyrite with diagenetic pyrite, millerite and gersdorffite. Phosphates and bitumen are present.

Texture/structure:

Conformable sulphide-rich layers within black shales. Sulphide nodules and clasts and laminated sulphide sediments contain micrometre-sized pseudomorphed globular aggregates.

Alteration:

N/A. The metalliferous black shales are considered to be key source beds for subsequent orogenic gold deposits (Large *et al.*, 2011).

Ore control:

Metals are concluded to be sequestered from upwelling seawater by organic complexes and sulphides.

Weathering:

N/A

Geochemical signature:

Enrichment in suite of elements including Ni, Au, Ag, Se, Mo, As, Pt, Pd, Os, Ir, Cu, Pb and Zn.

Geophysical signature:

Probable strong IP signature.

Examples

Niutitang Formation and correlates, Yangtze Platform China (Ni-Mo)
Alum Shale, Sweden (U)
Talvivaara, Finland (Ni, Cu, Zn)
Nick deposit, Canada (Ni, Zn, V).

Known deposits and mineral prospects in Tasmania

None.

Assessment criteria

1. Presence of organic-rich pyritic black shales.
2. Presence of penecontemporaneous alginate, phosphorite, baritic units.

Assessment: Tract MSES/M/B

This tract is based on the distribution of four major sequences within Tasmania which contain a high proportion of carbonaceous black shale and siltstone. These are:

(a) Pyritic carbonaceous units in the Rocky Cape Group including parts of the Balfour Sub-Group, Irby Siltstone and Cowrie Siltstone.

(b) Carbonaceous schist of the Tyennan region, considered to be deformed and metamorphosed equivalent of similar units in the Rocky Cape Group.

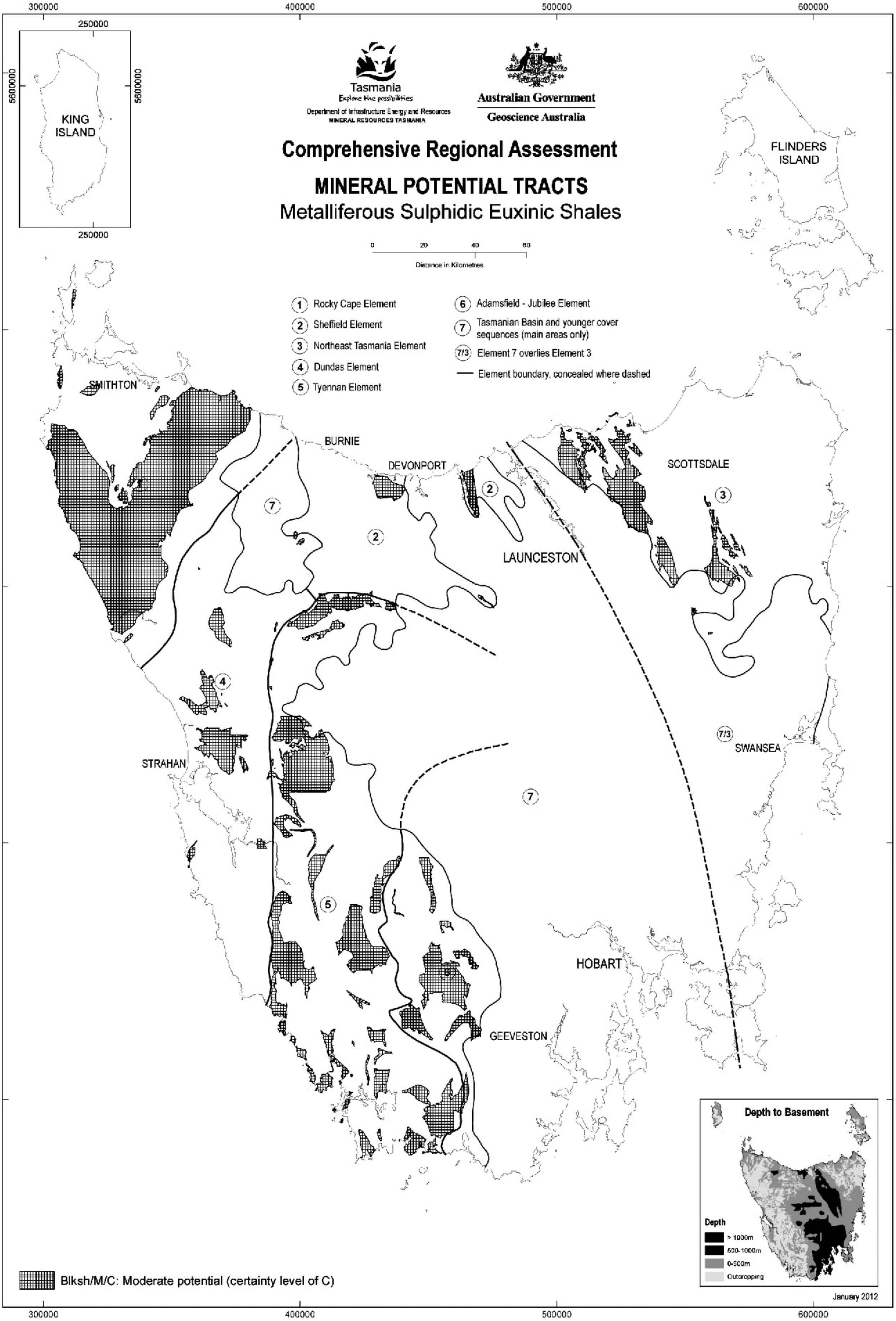
(c) Carbonaceous siltstone of the Bell Shale and correlates in the Eldon Group.

(d) Carbonaceous pelites in the Mathinna Supergroup, notably the Turquoise Bluff Slate, Yarrow Creek Mudstone and Lone Star Siltstone. The latter contains a marker horizon of Late Silurian pyritic graptolitic carbonaceous shale suggestive of deposition in sediment-starved conditions.

The tract has a moderate potential and a moderate certainty level.

Economic significance

Deposits of this type are potentially of economic significance, but because of insufficient detailed evidence of the depositional paleoenvironments, tectonic settings and geochemical nature of the shale units, there is a high degree of uncertainty in applying the model.



Map 8 — Model M8

MODEL M9: Descriptive model of carbonate-hosted Au-Ag

Model description

Based on the model by William C. Bagby, W. David Menzie, Dan L. Mosier and Donald A. Singer.

Approximate synonym

Carlin-type.

Description

Very fine-grained gold and sulphides disseminated in carbonaceous calcareous rocks and associated jasperoids.

General reference

Tooker, 1985.

Geological environment

Rock types:

Host rocks: thin-bedded silty or argillaceous carbonaceous limestone or dolomite, commonly with carbonaceous shale. *Intrusive rocks:* felsic dykes.

Textures:

Dykes are generally porphyritic.

Age range:

Mainly Paleogene, but can be any age.

Depositional environment:

Best host rocks formed as carbonate turbidites in somewhat anoxic environments. Deposits formed where these are intruded by igneous rocks under non-marine conditions.

Tectonic setting(s):

High-angle normal fault zones related to continental margin rifting.

Associated deposit types:

W-Mo skarn, porphyry Mo, placer Au, stibnite-barite veins, gold in alkaline porphyries.

Deposit description

Mineralogy:

Native gold (very fine grained) + pyrite + realgar + orpiment arsenopyrite cinnabar fluorite barite stibnite. Gangue quartz, calcite, carbonaceous matter.

Texture/structure:

Silica replacement of carbonate. Generally less than 1% fine grained sulphides.

Alteration:

Unoxidised ore: jasperoid + quartz + illite + kaolinite + calcite. Abundant amorphous carbon locally appears to be introduced. *Hypogene oxidised ore:* kaolinite + montmorillonite + illite + jarosite + alunite. Ammonium clays may be present.

Ore controls:

Selective replacement of carbonaceous carbonate rocks adjacent to and along high-angle faults, or regional thrust faults or bedding.

Weathering:

Light-red, grey, and/or tan oxides, light-brown to reddish-brown iron oxide-stained jasperoid.

Geochemical signature:

Au + As Hg W Mo; As Hg Sb Tl F (this stage superimposed on preceding); NH_3 important in some deposits.

Examples

Carlin, USNV	(Radtke *et al.*, 1980)
Getchell, USNV	(*Joralemon, 1951*)
Mercur, USUT	(*Gilluly, 1932*).

Known deposits and mineral prospects in Tasmania

There are no definite deposits of this type known in Tasmania, but there are several areas with moderate to high potential.

In the Glovers Bluff/Weld River area, in the Jubilee Element, gold is associated with chert and altered, silicified Proterozoic dolomite (Bottrill and Woolley, 1996). The gold is associated with minor sulphides (pyrite, galena, sphalerite, loellingite, chalcopyrite), protographite and magnetite, and gangue minerals include calcite, serpentine, brucite, diopside and andradite. The mineralisation shows some affinities with the Carlin-style mineralisation, but may be a skarn-type deposit (e.g. Red Dome). The only intrusive rocks present are Jurassic dolerite, lamprophyre (Devonian?) and basalt (Cambrian?). A preliminary fluid inclusion study on some silicified rocks (Taheri, 1990) indicated that the rocks within the area have at least been affected by a low salinity, moderate temperature fluid (250–280°C) of possibly meteoric-hydrothermal or metamorphic origin. High temperature fluid (>350°C) of unknown origin has also been reported from the area. However the genesis of the mineralisation is poorly understood. The mineralisation is also poorly defined, but a low grade resource has been estimated (1.1 Mt @ 0.45 g/t).

Carlin-style gold mineralisation in silicified Proterozoic dolomite has also been suggested as the source of some placer gold in the Corinna district (Bottrill *et al.*, 1992), but this is unproven. The Jane River goldfield is also associated with Proterozoic dolomite, but the mineralogy, including cinnabar-chromite, may indicate a McLaughlin-style of mineralisation (hot spring Au-Hg with ultrabasic rocks), although there are no known ultrabasic rocks exposed in the area (Bottrill, 1989; Turner, 1990).

Carlin-style gold has also been explored for in Gordon Limestone near Lynchford, in the Dundas Element (Newnham, 1995). Gold occurs with anomalous As and Sb in pyritic, silicified limestone near fault zones, but the mineralisation style is not well defined and has been included in the Slate Belt Gold mineralisation tract.

The presence of large amounts of residual gold (originally considered a deep lead) above deeply leached Ordovician limestone at Beaconsfield (Bottrill *et al.*, 1992) may also suggest this style, but this is also unproven.

The Cygnet district is known to have several gold occurrences and small deposits, but the origin and nature of the ore controls are not very clear. The area had produced about 100 kg of gold by 1902, mostly placer. The gold was derived from mineralised breccias, veins and contact zones of Cretaceous alkaline intrusive rocks in Permian sedimentary rocks, such as in the Mt Mary and Livingstone mines (Bottrill, 1995*a*).

The area is underlain by Permian sedimentary rocks, which are variably tillitic, calcareous, carbonaceous and pyritic. These are intruded by Jurassic dolerite and a variable suite of Cretaceous alkaline rocks. The Cretaceous intrusive rocks are typically small, medium grained, felsic, quartz poor and porphyritic, and consist of mostly monzonite and syenite, but include dacite, diorite and lamprophyre.

The mineralisation in the area is partly in the form of gold and sulphide-bearing quartz veins and hematitic or limonitic stockworks in the porphyries and at their contacts. Recent exploration has revealed that mineralisation is associated with alteration which includes silica, K-feldspar, carbonate, epidote, clay, pyrite and hematite (Jones, 1986, 1987, cited in Bottrill, 1995*a*).

Anomalous gold is reported from ferruginous mudstone, intrusive syeno-monzonites which are weakly stockworked, and brecciated and mylonitised mudstone. The intrusive rocks contain disseminations and stringers of pyrite, chalcopyrite, pyrrhotite, marcasite, magnetite and hematite. Quartz veins also contain minor sulphides and possibly cinnabar. Gold mineralisation is thought to be partly of the Carlin-style and partly of an alkaline porphyry-hosted style (Jones, 1986, cited in Bottrill, 1995*a*). The gold occurrences in the Cygnet area represent a distinct style of mineralisation and are discussed in the gold associated with alkaline intrusive rocks section.

Assessment criteria

1. Presence of intrusive rocks.
2. Distribution of gold prospects.
3. Occurrence of carbonates.

Assessment: Tract Au8a/M-H/B-C

This tract is based on the distribution of Neoproterozoic carbonate units at the southern end of the Arthur Lineament. Alluvial gold of unknown origin also occurs in the area (Zaw *et al.*, 1992). The tract has a certainty level of moderate to high.

Assessment: Tract Au8b/L-M/B

This tract is based on the presence of outcropping Neoproterozoic carbonate units. The potential is rated as low to moderate with a moderate level of certainty.

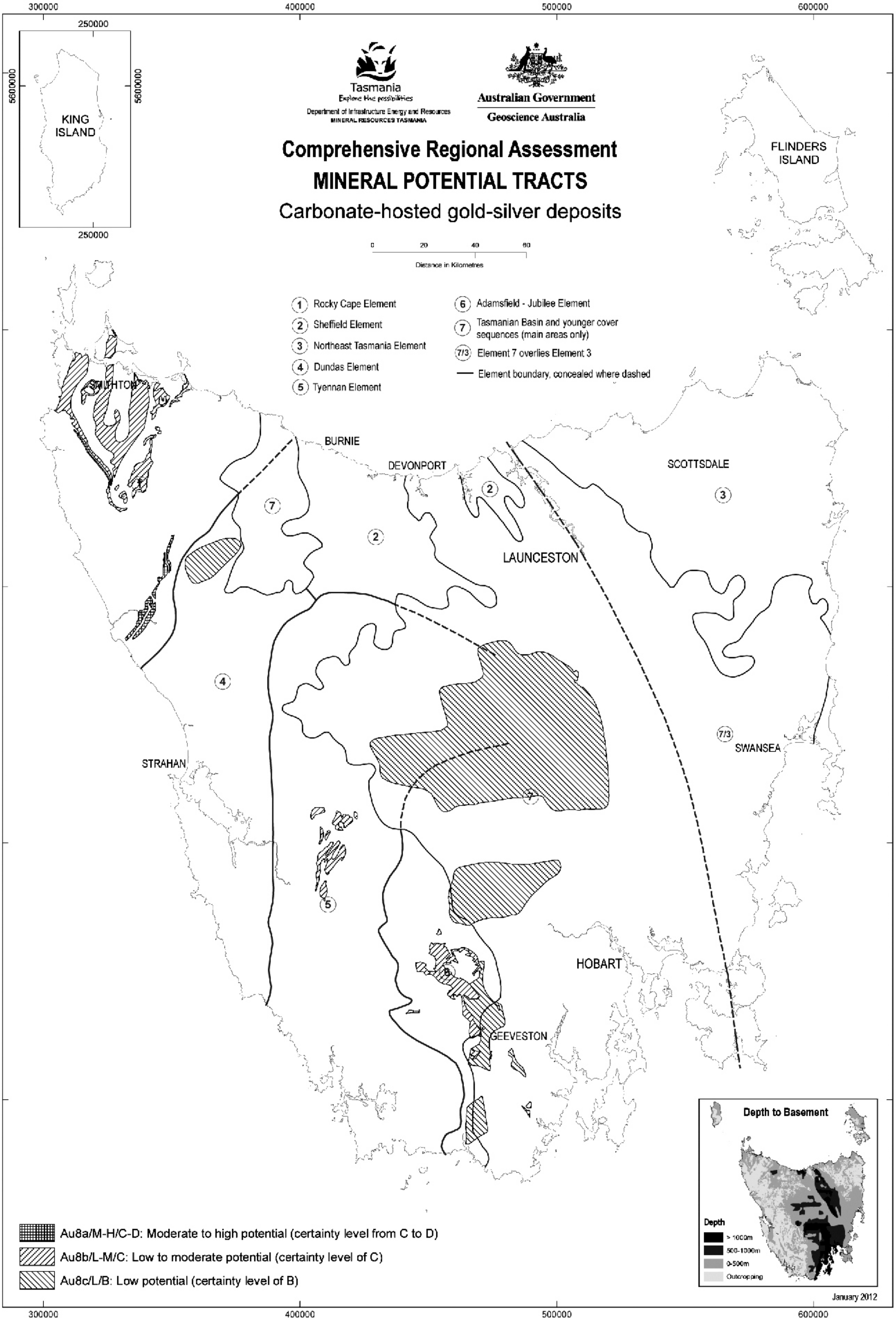
Assessment: Tract Au8c/L /L

This tract is based on the distribution of buried Neoproterozoic carbonates as predicted by the 3D geological model of Tasmania. It has a low potential and a low level of certainty.

Economic significance

No resources have been proven in Tasmania to date.

The grade and tonnage model of carbonate-hosted Au-Ag indicates >50% of deposits are >5 Mt and >2.5 g/t Au.



Map 9 — Model M9

MODEL M10: Chromite/PGEs/Au in alluvial placers (Model 39B of Cox and Singer, 1986)

Model description

Description of the Cox and Singer 39B model after Warren E. Yeend and Norman J. Page, modified by D. Perkin.

Approximate synonym

Placer chromite/placer platinum/residual deposit.

Description

Chromite, platinum-group alloys and gold in grains and (rarely) nuggets in gravel, sand, silt, and clay, and their consolidated equivalents, in alluvial, beach, eolian and (rarely) glacial deposits derived from ultramafic sources.

General references

Boyle, 1979; *Wells, 1973*; *Lindgren, 1911*; *Mertie, 1969*.

Geological environment

Rock types:

Alluvial gravel and conglomerate and heavy minerals indicative of ultramafic sources and low-grade metamorphic terrane. Sand and sandstone of secondary importance.

Textures:

Coarse to fine clastic.

Age range:

Paleogene to Recent.

Tectonic setting(s):

Moderately maturely weathered fold belt terranes containing synorogenic ophiolite or alpine-type mafic and ultramafic rocks or Alaskan-type intrusive complexes. Near plate margin where relatively recent uplift has resulted in youthful to moderately mature topography/geomorphology.

Depositional environment:

Sedimentary fluvial, sinuous channel fill, trap sites, gutters, potholes etc.; deep leads.

Host rocks:

Unconsolidated clastic sediments; generally basal coarse sand and gravel which may be covered by later alluvium several tens of metres thick.

Characteristic associated rocks:

Basement bedrock over which the coarse alluvial gravel lies is lithologically very variable. PGMs and chromite are derived from weathering of layered and/or zoned mafic-ultramafic rocks located within the catchment area.

Examples

Australian PGEs

Fifield, NSW
Adamsfield, Bald Hill–Savage River, Wilson River area, Tasmania.

World

Urals, USSR
Goodnews Bay, USA
San Juan and Atrato Rivers, Columbia
Yubdo, Ethiopia
Yodda and Gira rivers, PNG.

Commodities

- Detrital chromite
- Platinum group minerals (PGMs) and native metal alloys of PGEs, and iron e.g. platinum (and isoferroplatinum), 'osmiridium' and 'iridosmine' (mixtures of iridium-osmium-ruthenium alloys), palladium, rhodium, gold.

Typical grade and tonnage

Chromite — no economic deposits currently recognised.

Alluvial platinum deposits and deep leads at Fifield, NSW initially contained from a thousand to several hundred thousand cubic metres of alluvial wash grading from 7 to 25 grams per cubic metre. Pt (associated with minor Au) occurred at depths of <25 metres.

Osmiridium deposits at Adamsfield are smaller redistributed eluvial and alluvial deposits with slightly lower grades containing osmiridium (an mixture of various alloys averaging 45% osmium, 41% iridium and 6% ruthenium).

Deposit description

Form of deposit:

Tabular to sheet like; flat lying. In alluvial channels or paleodrainage channels. Irregular but may be elongate in direction of paleodrainage. Occasionally in lateritised eluvial concentrations.

Ore mineralogy:

Detrital PGE alloys, Pt-Fe alloys, occasionally minor gold.

Ore texture/form:

Sparse, generally fine to medium-grained detrital grains, often rounded, sometimes flattened.

Weathering:

Some iron staining or coating.

Source of ore fluids/sulphur/metals

Layered mafic intrusions, alpine serpentinite and/or ophiolite complexes or Alaskan (Ural) type concentrically zoned alkaline mafic-ultramafic intrusions are generally the source rocks for alluvial PGEs and may be found upstream from such alluvial deposits.

Timing of ore emplacement relative to host rocks

Detrital heavy minerals and accompanying PGMs deposited together with enclosing clastic sediments.

Ore controls

Where a platinum source exists in the catchment area of a stream, particulate PGMs will tend to occur at or near the bottom of an alluvial channel or deep lead. Small dense detrital PGMs are associated with hydraulically equivalent larger but lighter siliceous gravels and pebbles. Lodgement of dense particulate PGMs may occur in a trap site (bar, pothole, lag pebble layer) in relatively high energy environments.

Genetic model

Platinum and PGMs have relative densities ranging from 12 to 22.7 as contrasted with quartz and other silicic rocks whose densities range from 2.7 to 3.3. In a moving stream or fluvial environment, dense granular particles of platinum or PGMs sink quickly towards bedrock and form concentrations relatively close to their source in natural sedimentary traps in the coarser lag gravels. Chromite SG is around 4.5 to 6.5.

Exploration guides

Richer alluvial deposits tend to occur within 15 or 20 km of layered and/or zoned mafic-ultramafic source rocks which may possibly be delineated using geophysics. In addition, seismic, magnetic and radioactive surveying methods may be used to outline the channel facies of the placer.

Known deposits and mineral occurrences in Tasmania

Major deposits are known in the Adamsfield, Heazlewood (Bald Hill)–Savage River and Wilson River areas of Tasmania. In the early part of this century, a large part of the world's 'osmiridium' was sourced from these areas. Other occurrences are known from South Cape in the south to Beaconsfield on the central north coast.

Assessment criteria

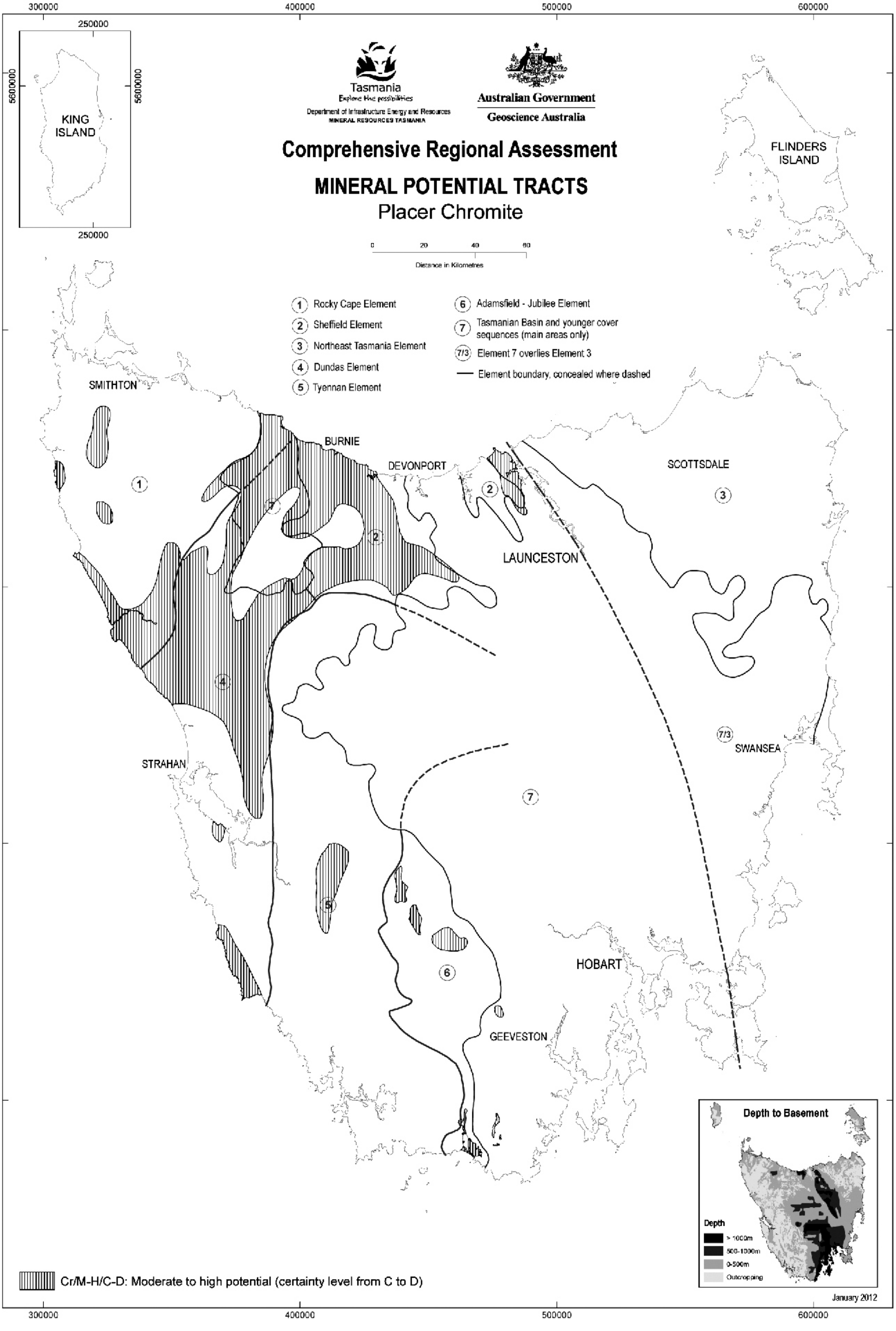
- Presence of ultramafic rocks in the area.
- Presence of detrital chromite and PGEs in the area.

Assessment: Tract Cr/ M-H/B-C

Based on the distribution of known deposits, source rocks and potential host rocks in the area, the tract has a moderate to high potential for alluvial chromite and detrital platinum group deposits with a certainty level of B to C.

Economic/national significance

The alluvial PGE deposits of Fifield, NSW and those in Tasmania have until recently been the sole major sources of platinum group elements produced in Australia. Past production from these sources has been relatively small, aggregating less than 2000 kg PGEs, which is worth about $20 million in 1991 money terms. Currently there is no alluvial PGE production. Although Australia is dependent on imports for the bulk of its supply of strategically important platinum group elements, a small quantity (about 6000 kg) of PGEs (Pd, Pt) has been produced in Australia since 1969 as a by-product of nickel mining in WA where production is continuing.



Map 10 — Model M10

MODEL M11: Basaltic copper deposits (Model 23 in Cox and Singer, 1986)

Model description

Description of the model by Dennis P. Cox.

Approximate synonym

Volcanic redbed Cu (*Kirkham, 1984*).

Description

A diverse group including disseminated native copper and copper sulphides in the upper parts of thick sequences of subaerial basalt, and copper sulphides in overlying sedimentary beds.

General reference

Kirkham, 1984.

Geological Environment

Rock types:

Subaerial to shallow marine basalt flows, breccias and tuffs, red-bed sandstone, tuffaceous sandstone, conglomerate, younger tidal facies limestone and black shale.

Textures:

Amygdules, flow-top breccias in lava. Laminated algal carbonate rocks. Sediments with high original porosity.

Age range:

Proterozoic, Triassic and Jurassic, and Paleogene–Neogene deposits known.

Depositional environment:

Copper-rich (100–200 ppm) basalt interlayered with red clastic beds and overlain by mixed shallow marine and continental deposits formed near paleo-equator.

Tectonic setting(s):

Intracontinental rift, continental margin rift. Regional low-grade metamorphism may mobilise copper in some districts. Deposits are characteristic of the Triassic part of the Wrangellia terrane in Alaska.

Associated deposit types:

Sediment-hosted copper. Volcanogenic Mn at Boleo, Mexico.

Deposit description

Mineralogy:

Native copper, native silver in flows and coarse clastic beds. Chalcocite and other Cu_2S minerals and locally bornite and chalcopyrite are concentrated in overlying shale and carbonate rocks. Fine-grained pyrite is common but not abundant with copper sulphide minerals.

Texture/structure:

Flow-top breccia and amygdule fillings in basalt. Fine grains in matrix and along shaly parting in clastic rocks. Massive replacement of carbonates at Kennicott. Finely varved chalcopyrite sediment at Denali.

Alteration:

Calcite-zeolite + epidote + K-feldspar. Red colouration due to fine hematite.

Ore controls:

Flow-top breccias, amygdules, fractures in basalt; organic shale, limestone in overlying sequence. Limestone is tidal, algal, with stromatolite fossils. Synsedimentary faulting may be important.

Weathering:

Widely dispersed copper nuggets in streams draining basalt.

Geochemical signature:

Cu-Ag-Zn-Cd. Co at Boleo, Mexico. Cu:Zn ratio is very high. Au anomalously low.

Geophysical signatures:

Unknown.

Examples

Keweenaw, USMI	(*White, 1968*)
Calumet, USMI	(*Ensign et al. 1968*)
Kennicott, USAK	(*Bateman and McLaughlin, 1920*)
Denali, USAK	(*Seraphim, 1975*)
Boleo, MXCO	(*Wilson, 1955*)
Buena Esperanza, CILE	(*Ruiz, 1965*)
Redstone, CNNT	(*Ruelle, 1982*)
Sustut, CNBC	(*Harper, 1977*)

Known deposits and mineral prospects in Tasmania

Although favourable geological environments for this type of deposit exist in a number of areas within Tasmania, known occurrences of this type have been reported in association with Cambrian mafic volcanic rocks and volcaniclastic rocks of the Mainwaring Group in the Cypress Creek area. The Mainwaring Group rock consists of andesite, basalt, agglomerate, tuff, slate and siltstone. All volcanic rocks are chloritised and epidotised (McGregor, 1969). Regional and limited detailed stream sediment samples revealed anomalous values of copper, nickel and zinc.

Native copper flakes were reported in dense hard volcanic breccia, hard massive volcanic rocks and sheared and altered gabbro. The rocks also contain minor disseminated chalcopyrite and pyrite and it is thought that native copper resulted from oxidation and supergene enrichment processes (McGregor, 1969).

In the Copper Creek area the Mainwaring Group of rocks is also reported to contain chalcopyrite and bornite veins and stringers with quartz (McGregor, 1969).

The other prospective area is in the Smithton basin where Proterozoic basalt contains native copper with epidote in vesicles (G. Green, pers. comm.)

Native copper has also been reported from zeolite veins in brecciated dolerite on Bruny Island (Bottrill, 1995*b*). The potential for copper mineralisation in this rock type is unknown.

Assessment criteria

1. Distribution of subaerial to shallow marine basalt flows, breccias and tuffs, red-bed sandstone, tuffaceous sandstone, conglomerate and younger tidal facies limestone and black shale.
2. Distribution of mineral occurrences.

Assessment: Tract Elliott Bay and Smithton Trough: BM4a/H / B-C

The tract is delineated based on the presence of rock units containing mafic volcanic and volcaniclastic rocks. In the Elliott Bay area in the Dundas Element the favourable rock units are melange including pyritic, carbonaceous and cherty siltstone, chert, greywacke, siltstone and dolomite and basalts of the Mainwaring Group (correlated with part of the Luina Group). This area also contains known mineral occurrences of this type although the processes responsible for the formation of mineralisation are not very clear. The certainty level is moderate to high.

The part of the tract within the Rocky Cape Element includes an area in the Smithton basin occupied by turbiditic volcaniclastic rocks, mafic volcanic rocks, minor diamictite and some tholeiitic basalts. Mineralisation of this style is known in the basalts and copper contents of up to 540 ppm are known in slightly altered basalt (M. P. McClenaghan, pers. comm.). Based on the available information the delineated tract has a moderate potential with a certainty level of moderate to high.

Assessment: Tract Cape Sorell–Waratah-Beaconsfield–O'Connors Peak and Arthur Metamorphic Belt: BM4b/M/B-C

The tract is delineated based on the presence of rock units containing mafic volcanic and volcaniclastic rocks. The Dundas Element rocks of the Proterozoic Crimson Creek Formation and correlates and early Cambrian Luina Group include turbiditic volcaniclastic rocks and minor mafic volcanic rocks and tholeiitic basalts which are favourable for this type of mineralisation.

The part of the tract within the Sheffield Element is based on the distribution of early Cambrian Motton Spilite and Proterozoic Port Sorell Formation.

In the Arthur Metamorphic Belt the tract is delineated based on the presence of rock units containing mafic volcanic and volcaniclastic rocks, mostly metamorphosed to amphibolite grade. No mineralisation of this style is known.

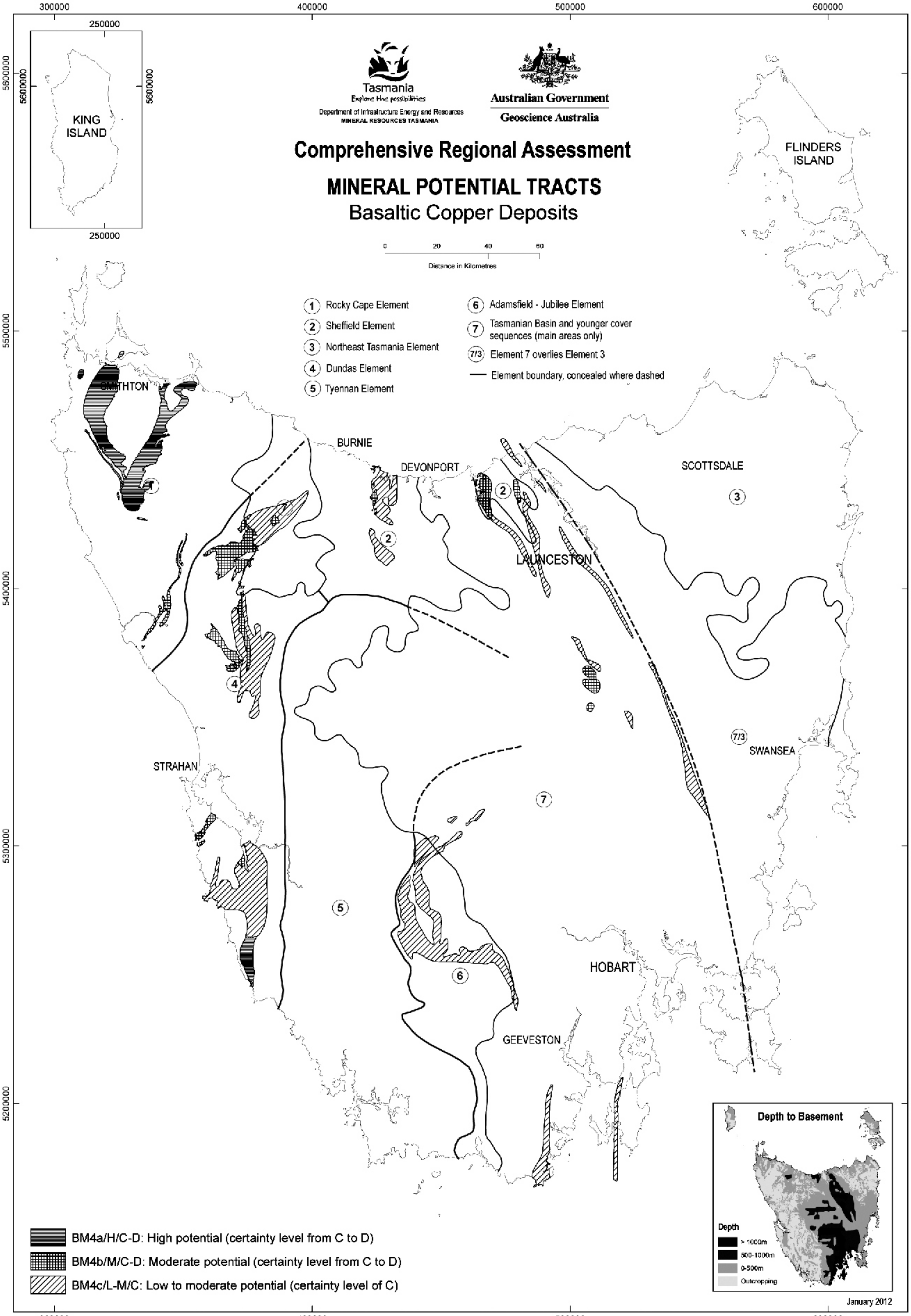
Certainty levels in this tract include areas of moderate to high.

Assessment: Tract Eastern Tasmania: BM4c/L-M/B

This tract is based on the subsurface distribution (<1 km) of the Luina Group and correlates as predicted by the 3D geological model of Tasmania. It has a low to moderate potential with a moderate certainty level.

Economic significance

Basaltic copper style of mineralisation occurs in Neoproterozoic mafic volcanic and volcaniclastic rocks of the Mainwaring Group in the Elliott Bay area. The copper mineralisation associated with the Cleveland Devonian tin-replacement deposit (pre-mining resource of 10.3 million tonnes at 0.33% copper) and also at the New Jasper copper deposit may have resulted from the leaching of the basaltic host rocks. This suggests that these rocks may have a high copper content and have potential to act as source rocks for copper in basalt mineralisation.



Map 11 — Model M11

MODEL M12: Epithermal gold-silver deposits (Model 25B of Cox and Singer, 1986)

Model description

Description of the model after Dan L. Mosier, Takeo Sato, Norman J. Page, Donald A. Singer and Byron R. Berger.

Approximate synonym

Epithermal gold (quartz-adularia) alkali-chloride type, polymetallic veins.

Description

Galena, sphalerite, chalcopyrite, sulphosalts + tellurides + gold in quartz-carbonate veins hosted by felsic to intermediate volcanic rocks. Older miogeosynclinal evaporites or rocks with trapped seawater are associated with these deposits.

General references

Buchanan, 1980; White and Hedenquist, 1990; Henley *et al.*, 1984; Berger and Bethke, 1985.

Geological environment

Rock types:

Host rocks are andesite, dacite, quartz latite, rhyodacite, rhyolite and associated sedimentary rocks. Mineralisation related to calc-alkaline or bimodal volcanism.

Textures:

Porphyritic.

Age range:

Mainly Neogene (most are 29-4 Ma).

Depositional environment:

Bimodal and calc-alkaline volcanism. Deposits related to sources of saline fluids in pre-volcanic basement such as evaporites or rocks with entrapped seawater.

Tectonic setting(s):

Through-going fractures systems, major normal faults, fractures related to doming, ring fracture zones, joints associated with calderas. Underlying or nearby older rocks of continental shelf with evaporite basins, or island arcs that are rapidly uplifted.

Associated deposit types:

Placer gold, epithermal quartz, alunite Au, polymetallic replacement. Porphyry Cu-Au.

Deposit description

Mineralogy:

Galena + sphalerite + chalcopyrite + copper sulphosalts + silver sulphosalts   gold   tellurides   bornite   arsenopyrite. Gangue minerals are quartz + chlorite   calcite + pyrite + rhodochrosite + barite   fluorite   siderite   ankerite   sericite   adularia   kaolinite. Specular hematite and alunite may be present.

Texture/structure:

Banded veins, open space filling, lamellar quartz, stockworks, colloform textures.

Alteration:

Top to bottom: quartz   kaolinite + montmorillonite   zeolites   barite   calcite; quartz + illite; quartz + adularia   illite; quartz + chlorite; presence of adularia is variable.

Ore controls:

Through-going or anastomosing fracture systems. High-grade shoots where vein changes strike or dip and at intersections of veins. Hanging-wall fractures are particularly favourable.

Weathering:

Bleached country rock, goethite, jarosite, alunite. Supergene processes are often an important factor in increasing grade of deposit.

Geochemical signature:

Higher in system Au + As + Sb + Hg; Au + Ag + Pb + Zn + Cu; Ag + Pb + Zn, Cu + Pb + Zn. Base metals generally higher grade in deposits with silver. W + Bi may be present.

Examples

Pajingo, AUQL	(Bobis *et al.*, 1996)
Creede, USCO	(*Steven and Eaton, 1975*; *Barton et al., 1977*)
Pachuca, MXCO	(*Geyne et al., 1963*)
Toyoha, JAPN	(*Yajima and Ohta, 1979*).

Known deposits and mineral prospects in Tasmania

There are at least two known mineral occurrences of this type: Fire Tower in the Sheffield Element and the Ten Mile Creek in the Dundas Element. In the two prospects mineralisation is hosted by altered rhyolitic intrusive and epiclastic rocks. In the Ten Mile Creek area mineralisation is underlain by a potassic quartz-feldspar-biotite porphyritic rhyolite intrusive correlatable with the Cambrian Bonds Range Porphyry. Brecciation, hematite veining and stockworks are noted in the porphyritic intrusive, which is locally sericitised (minor pyrite) and chloritised. Anomalous stream sediments (Sn, W, As and Au) were also reported from the area.

The porphyritic rhyolite in the Ten Mile Creek area is intruded by smaller fine-grained rhyolite sills which are also chloritised and hematised.

In the Fire Tower prospect a major silica-sericite-pyrite-carbonate-gold arsenopyrite zone in quartz, carbonate, hematite stockwork has been delineated within altered epiclastic and possible fragmental rhyolitic volcanic rocks.

On the available information Ten Mile Creek has several features similar to the porphyry-epithermal type of hydrothermal systems. In the Fire Tower prospect, the mineralisation seems to be similar to that associated with volcanic-hosted massive sulphide deposits.

The Central Volcanic Complex of the Mount Read Volcanics is known to have a range of pyroclastic and epiclastic rocks including welded ignimbrites with flattened pumice clasts, coarse to fine breccias of polymictic to monomictic composition, massive to well-bedded crystal tuffs, crystal-lithic tuffs, crystal-vitric tuffs and chert-like vitric ashes (Corbett, 1989).

The Thomas Creek or Timbertops prospect, south of Macquarie Harbour, exhibits possible porphyry copper style mineralisation in Cambrian intrusive rocks. This is a mineralisation style often associated with epithermal mineralisation, enhancing the potential of this area for epithermal mineralisation.

Some extrusive rocks have also been recorded in the St Marys district of eastern Tasmania where a felsic quartz porphyritic body is known to contain extrusive rocks associated with Devonian magmatism. The St Marys Porphyrite contains a thick sheet of predominantly dacitic, welded ash-flow tuff together with a high-level, vesicular part of the volcanic feeder. The St Marys porphyrite is interpreted to be co-magmatic with both dykes which belong to the early I-phase magmatism in the Blue Tier Batholith (Turner *et al*., 1986).

Within Tasmania both Cambrian and Devonian magmatism could have created conditions favourable for the generation of epithermal systems.

Assessment criteria

1. Distribution of intrusive/extrusive complexes represents a predominantly subaerial complex of volcanic and volcaniclastic rocks of silicic to mafic composition.
2. Presence of favourable structures such as caldera with ring fractures and zones of brecciation.
3. Presence of alteration types such as silicification, propylitic, chloritic, sericitic and argillic.
4. Presence of mineral prospects having features similar to epithermal precious-metal deposits.

Assessment: Tract Au6a/M/C

There are two major areas for epithermal gold-silver potential. The area in the Northeast Tasmania Element is drawn based on the presence of ignimbrite sheets in the St Marys Porphyrite. The ignimbrite sheet is part of a Devonian magmatic complex which is interpreted to be co-magmatic with the I-phase magmatism. Although dacitic ignimbritic rocks constitute favourable hosts for this type of mineralisation, no significant wall-rock alterations, favourable structures and mineral occurrence of epithermal gold and silver are reported in the area. The area has moderate potential for epithermal gold-silver deposits with a certainty level of C.

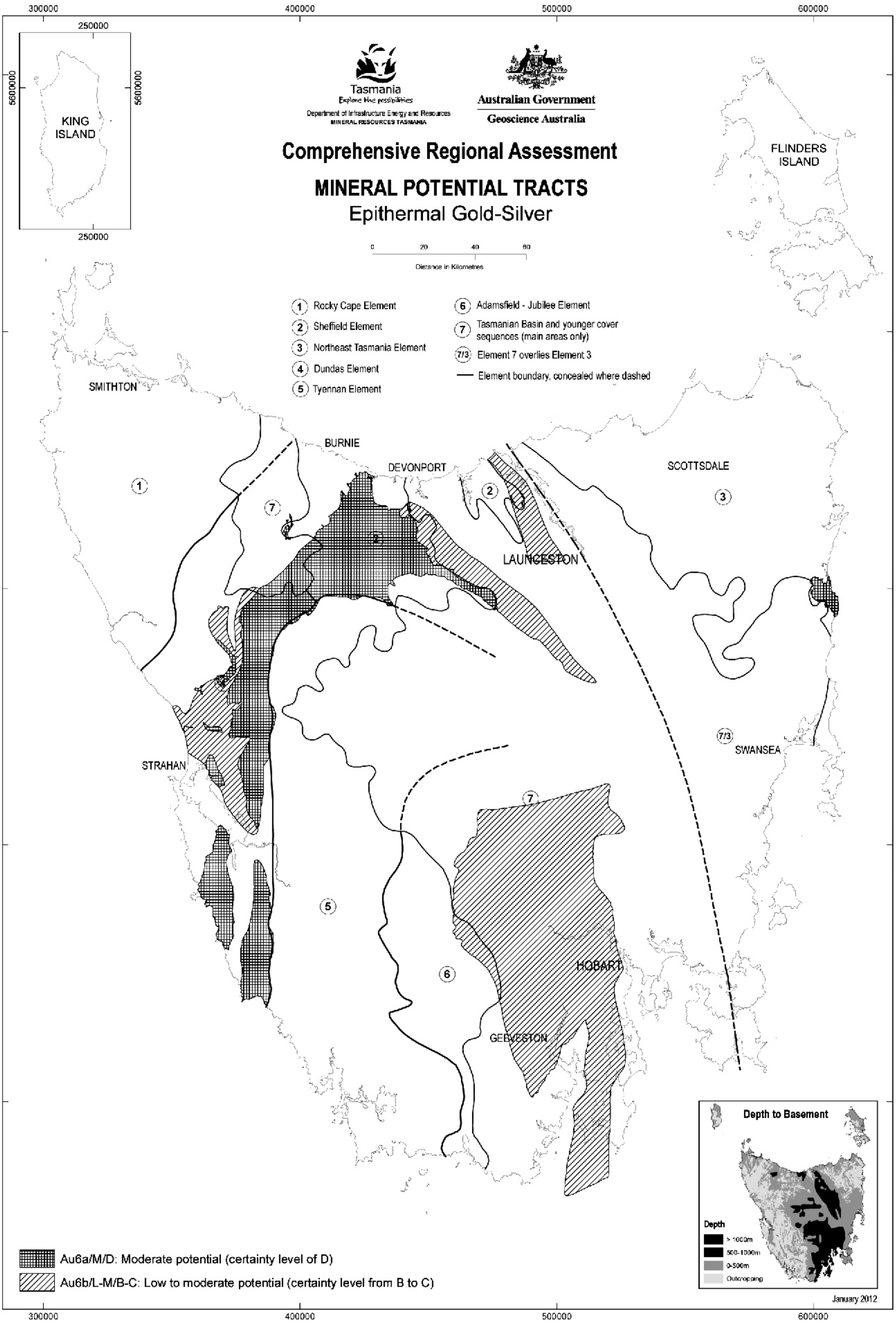
The second part of the tract has been delineated based on the presence of epiclastic rocks including welded ignimbrites in the Central Volcanic Complex of the Cambrian Mount Read Volcanics. Although the presence of ignimbrites is reported by many workers in the area it is not certain to what extent they were deposited in subaerial conditions. Although the Mount Read Volcanics and associated Cambrian granitoids are responsible for several types of gold mineralisation, the presence of strictly epithermal systems and related mineral occurrences have not been reported in the area. Based on the above information it is concluded that the tract has moderate potential for epithermal gold-silver deposits with a certainty level of C.

Assessment: Tract: Eastern Tasmania: Au6b/L-M/B

The presence of a number of rock units, which crop out in western Tasmania, is inferred from the 3-D model of Tasmania in the basement of central and southeastern Tasmania, areas which are largely covered by Parmeener Supergroup and younger rocks. A number of concealed bodies of felsic volcanic rocks, which may be a continuation of the Mount Read Volcanics rocks, are postulated to occur widely in eastern Tasmania and these are considered to have low to medium potential for this deposit style with a certainty level of B.

Economic significance

Epithermal gold-silver deposits are important sources for gold and silver. Grade/tonnage models for deposits of this type (Cox and Singer, 1986) indicate that 90% of deposits contain more than 0.065 million tonnes of ore, 50% more than 0.77 million tonnes and 10% contain more than 9.1 million tonnes. In 90% of these deposits ores have at least 2.0 g/t gold and 10 g/t silver. The ores in 50% of these deposits have at least 7.5 g/t gold and 110 g/t silver. In 10% of these deposits the ores have at least 27 g/t gold and 1300 g/t silver.



Map 12 — Model M12

MODEL M13: Layered mafic-ultramafic bodies with basal segregations of Ni-Cu-Co sulphides (Model 7A of Cox and Singer, 1986)

Model description

Description of the model after Norman J. Page.

Approximate synonyms

Synorogenic-synvolcanic Ni-Cu, Ni-Cu in mafic rocks; stratabound sulphide-bearing Ni-Cu; gabbroid associated Ni-Cu.

Description

Massive lenses, matrix and disseminated sulphide in small to medium-sized gabbroic intrusions in fold belts and greenstone belts.

General references

Ross and Travis, 1981; Marston *et al*., 1981.

Geological environment

Rock types:

Host rocks include norite, gabbro-norite, pyroxenite, peridotite, troctolite and anorthosite forming layered or composite igneous complexes.

Textures:

Phase and cryptic layering sometimes present, rocks usually cumulates.

Age range:

Archaean to Neogene, predominantly Archaean and Proterozoic; Cambrian in Tasmania.

Depositional environment:

Intruded synvolcanically or tectonically during orogenic development of a metamorphosed terrane containing volcanic and sedimentary rocks.

Tectonic setting(s):

Mobile belts, metamorphic belts, greenstone belts.

Associated deposit types:

Stratiform mafic-ultramafic Ni-Cu (Stillwater); stratiform mafic-ultramafic PGE (Merensky Reef, Bushveld Complex); placer chromite-PGE.

Deposit description

Mineralogy:

Pyrrhotite + pentlandite + chalcopyrite   pyrite   Ti-magnetite   Cr-magnetite   graphite; with possible by-product Co and PGEs.

Texture/structure:

Predominantly disseminated sulphides in stratabound layers up to 3 m thick; commonly deformed and metamorphosed so primary textures and mineralogy may be modified.

Alteration:

Alteration (serpentinisation, etc.) can be marked in this deposit type.

Ore control:

Sulphides may be near the basal contacts of the intrusion but are generally associated more with gabbroic dominated rather than basal ultramafic cumulates.

Weathering:

May be recessive if altered; may form nickeliferous laterites over the ultramafic portions in low latitudes.

Geochemical signature:

Ni, Cu, Co, PGE, Cr.

Geophysical signature:

Strong magnetic signature where not extensively serpentinised.

Examples

Sally Malay, AUWA (*Thornett, 1981*)
Munni Munni Complex AUNSW (Williams *et al*., 1990)
Rana, NRWY (*Boyd and Mathiesen, 1979*)
Moxie pluton, USMA (*Thompson and Naldrett, 1984*)

Tasmania

Cuni deposits (Five mile), Zeehan.

Known deposits and mineral prospects in Tasmania

Cuni (Five Mile) deposits near Zeehan. Includes Genets Winze/North Cuni–South Cuni–Blowfly/Mosquito/Vaudeau shafts and the Nickel Reward shafts area. Virtually all Tasmanian nickel production (only 237 tonnes) came from this field, intermittently between 1894 and 1938. Other nickel prospects in Tasmania (e.g. Lord Brassey in the Heazlewood Complex) appear to be serpentine-hosted, but may be granite-related (see Avebury-style nickel model).

Assessment criteria

1. Presence of mafic rocks or altered mafic rocks in the area (Cuni is hosted by an altered fine-grained gabbro sill comprising epidote, chlorite and actinolite).
2. Presence of stratabound nickel copper sulphide mineralisation in gabbro/dolerite sills associated with ultramafic complexes.

Assessment Tract: NiCu1a/H/C

Dolerites within the Neoproterozoic Crimson Creek Formation in the Cuni area, east of Zeehan, are assessed as having high potential due to the presence of comparable mineralisation and have a certainty level of C.

Assessment Tract: NiCu1b/M/B-C

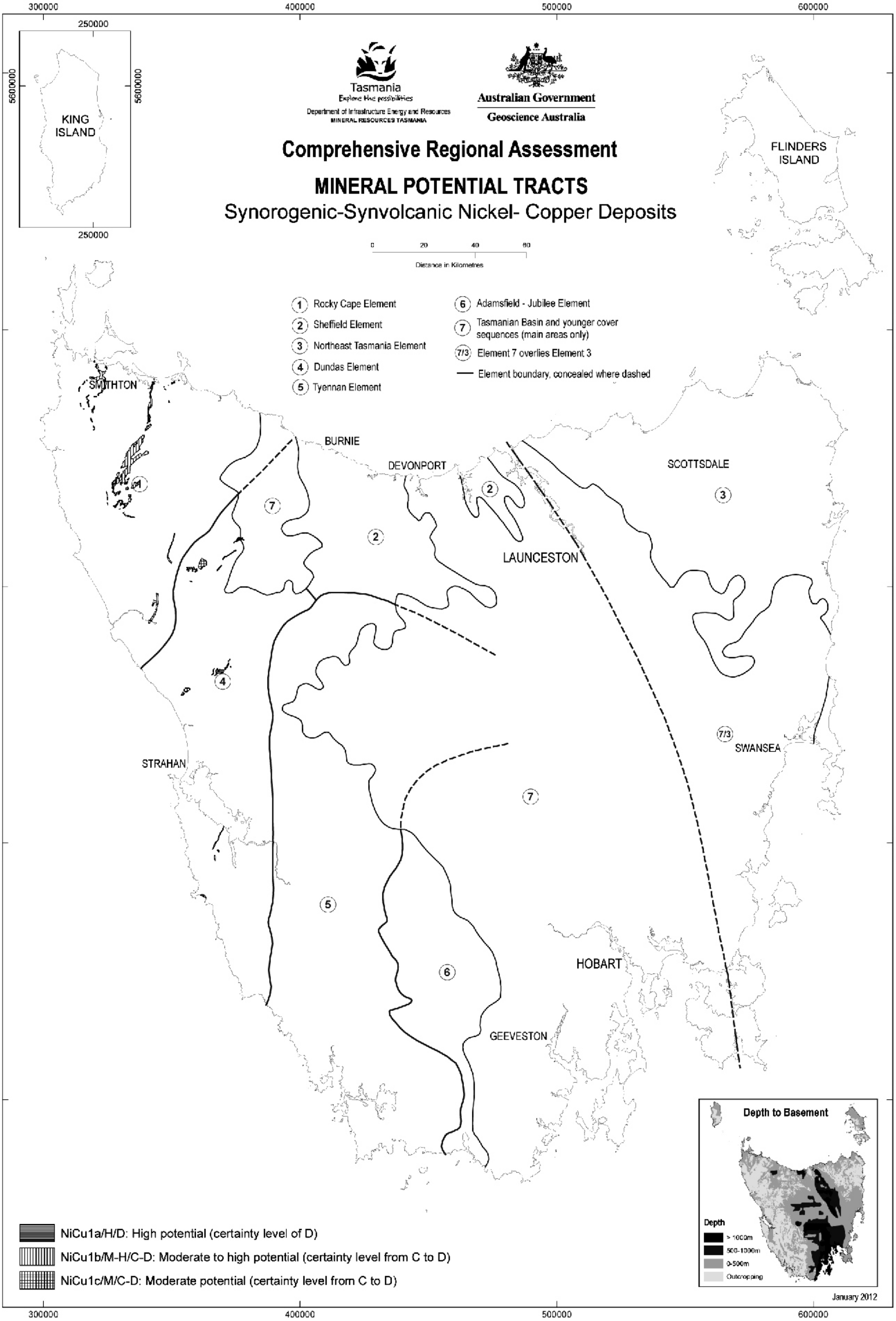
Gabbro bodies within the Heazlewood, Mt Stewart and Trial Harbour ultramafic complexes and at Luina, Magnet, Wandle River and on the Cape Sorell peninsula are rated as of moderate potential. Certainty is rated as C to B depending on the detail of geological mapping. The Luina, Magnet and Cape Sorell peninsula bodies in particular are not well known.

Assessment Tract: NiCu1c/M-H/B-C

Neoproterozoic basaltic rocks, including picritic basalt, are currently being explored for magmatic Ni-Cu deposits and geochemical anomalies suggestive of potential for discoveries of this style of mineralisation have recently been announced in the Kannunah Subgroup basalt near Smithton. Correlative rocks, the Bernafai Volcanics near Corinna and basalt south of Macquarie Harbour, are included in the tract.

Economic significance

The gabbroid associated Ni-Cu stratabound nickel copper sulphide deposit type has been of minor commercial importance in Tasmania in the past. However this deposit type is of world significance overseas as an important source of nickel and as a source of of strategically important PGEs.



Map 13 — Model M13

Model description

Model and assessment prepared by Alison Kirkby, Tony Meixner and Ed Gerner.

Approximate synonyms

Enhanced geothermal systems.

Description

Regions of elevated temperatures in the crust from which heat can be extracted and used either directly or for electricity generation.

Geological environment

Variable. Hot rock geothermal systems are commonly found in areas of elevated heat flow, caused by (for example) high heat producing granite rocks or recent magmatism, or areas where there is strong thermal insulation (for example sedimentary basins).

Examples

Cooper Basin, Australia;
Soultz, France;
Landau, Germany.

Exploration

At present there is one geothermal exploration project in Tasmania. It is held by KUTh Energy and is located in central/eastern Tasmania, covering a region of 14 300 km^2 which includes Launceston and Hobart. At present there are no geothermal projects in Tasmania producing electricity.

Geothermal potential in Tasmania

Datasets:

Two factors are important in controlling the hot rock potential of a region: thermal conductivity of rocks in the top five kilometres, and heat sources at depth. If the distribution of these properties is known it is possible to model the crustal temperature distribution. For this assessment a 3D geological map has been attributed with heat production and thermal conductivity values, and used to model the crustal temperature distribution in Tasmania.

Geological framework:

An existing 3D geological map of Tasmania (project T3 of the pmdCRC, Murphy *et al.*, 2006) was used as a framework for temperature modelling in this assessment. The map covers the main island of Tasmania but excludes King, Cape Barren and Flinders islands. It extends from the topographic surface to 10 km depth. For the purposes of temperature modelling the geological map was simplified into 14 units, and converted into voxet format with resolution 2 km x 2 km horizontally and 200 m in depth.

There are several volumes in the pmdCRC 3D map for which no geological unit was assigned. Overall, these constitute a small proportion of the total volume considered in this assessment. In order to fill these volumes, the Tasmanian crust has been divided into five crustal blocks, following known geological subdivisions, and assigned these volumes to a geological unit on the basis of the crustal block in which they are located.

Thermal conductivity:

Thermal conductivity of formations has been estimated based on direct measurements (GA unpublished data) where available. Where unavailable, the abundance of each lithology (rock type) in a formation has been determined from the literature. A weighted harmonic mean has then been used on average thermal conductivity values for each lithology (Meixner *et al.*, 2011).

Heat sources:

Each unit within the model has been assigned a heat production rate. The heat production rate (in Wm^{-3}) was calculated using the following equation:

Heat Production (HP) = $*(K_2O * 2.91 \quad 10^{-5} + 9.67 \quad 10^{-5} * U + 2.63 \quad 10^{-5} * Th)$

where:
= density (in kg/m^{-3}); K_2O = concentration of potassium oxide (wt%); U and Th = concentration of uranium (ppm) and thorium (ppm) respectively.

Concentrations of U, Th and K_2O for granitic rocks were obtained from Geoscience Australia's OZCHEM database. Concentrations of U, Th and K for supracrustal rocks were obtained from the *Radiometric Map of Australia* (Minty *et al.*, 2010), following the methodology of Goodwin and van der Wielen (in prep.). Density values for granites were assumed to be 2670 kg/m^{-3}, values for other rocks were taken from the literature (see Goodwin and van der Wielen, in prep.). Calculated HP rates for the granitic rocks are variable at the regional scale. To capture this within the 3D model, granite volumes were subdivided into eight subregions based on the distribution of surface HP data. As discussed by Goodwin and van der Wielen (in prep.), HP rates calculated from radiometric data generally underestimate true values. To overcome this, HP rates for supracrustal rocks were increased (by a factor of 2.1), to make the average HP of these units equivalent to that of average upper continental crust (HP = 1.71, using values of Rudnick and Gao, 2003).

Surface heat flow and borehole temperature data were used to help constrain the thermal modelling. The data have been drawn from both open file sources and also proprietary data from a geothermal exploration company. Open file data from the OzTemp Borehole Temperature Database provided nine boreholes with either temperature measurements or heat flow determinations. Data from a further 35 boreholes were made available by KUTh Energy on a confidential basis, which allowed them to be used to constrain the assessment, but not displayed in the results.

Thermal modelling

Each lithology in the 3D model was assigned thermal properties as calculated above. Boundary conditions were set for the thermal modelling such that no heat enters or leaves the sides of the model. A constant temperature of 13°C was set for the topographic surface, while the bottom boundary condition was set by applying a constant heat flow of 50 mW/m^2 into the base of the model. An initial thermal model was produced that predicts the temperature at depth, as well as the surface heat flow. The thermal model accounts for heat transport by conduction only. The resulting surface heat flow and 3D temperature distributions were compared to the measured surface heat flow and bottom-hole temperatures.

Heat production values of geological units were modified for subsequent iterations of the thermal model in order to minimise differences between the observed and modelled heat flow. Because heat flow determinations are not evenly distributed across Tasmania, this means that this assessment has a higher degree of certainty in areas where heat flow data are present. Because of the shallow nature of the temperature measurements in Tasmania (all <510 m depth and all but three <300 m), no attempt was made to match temperatures.

On average the modelled heat flow values match measured values, although there are some areas in the model where there are moderately large differences. These differences are due to the consequences of attempting to model a complicated geological region using a relatively simplistic 3D model. Improvements could be achieved in the match between the modelled and measured heat flow by further subdividing lithologies, particularly the granite lithologies. The regional scale nature of the model, as well as the limited heat production data, does not warrant further subdivisions.

Assessment criteria

The geothermal potential was determined based on the modelled temperature at 4 km depth slice as described below.

Modelled temperature at 4km depth (°C)	*Potential*
<120	Low
120–140	Low–moderate
140–165	Moderate
165–185	Moderate–high

Assessment

The regions of moderate to high potential are located in eastern Tasmania, 30 km southeast of Launceston, and in northwestern Tasmania, 20 km south of Burnie. These regions correspond to granite volumes which have been assigned high heat productions at depth in the 3D model. Predicted temperature at a depth of four kilometres in these regions is >165°C.

The areas of moderate and low to moderate potential mostly correspond to regions with granites which have been assigned moderate heat production values in the 3D model. Predicted temperature at four kilometres depth in these regions is between 120°C and 165°C.

Regions of low potential (predicted temperature at a depth of four kilometres less than 120°C) generally correspond to non-granite lithologies.

Heat production is, therefore, the major control on hot rock potential in Tasmania. The thermal conductivities of the youngest cover sediments (Parmeener Supergroup and Jurassic dolerite) are only marginally lower than the basement rocks and combined with their limited depth extent do not have a strong influence on modelled temperatures at depth.

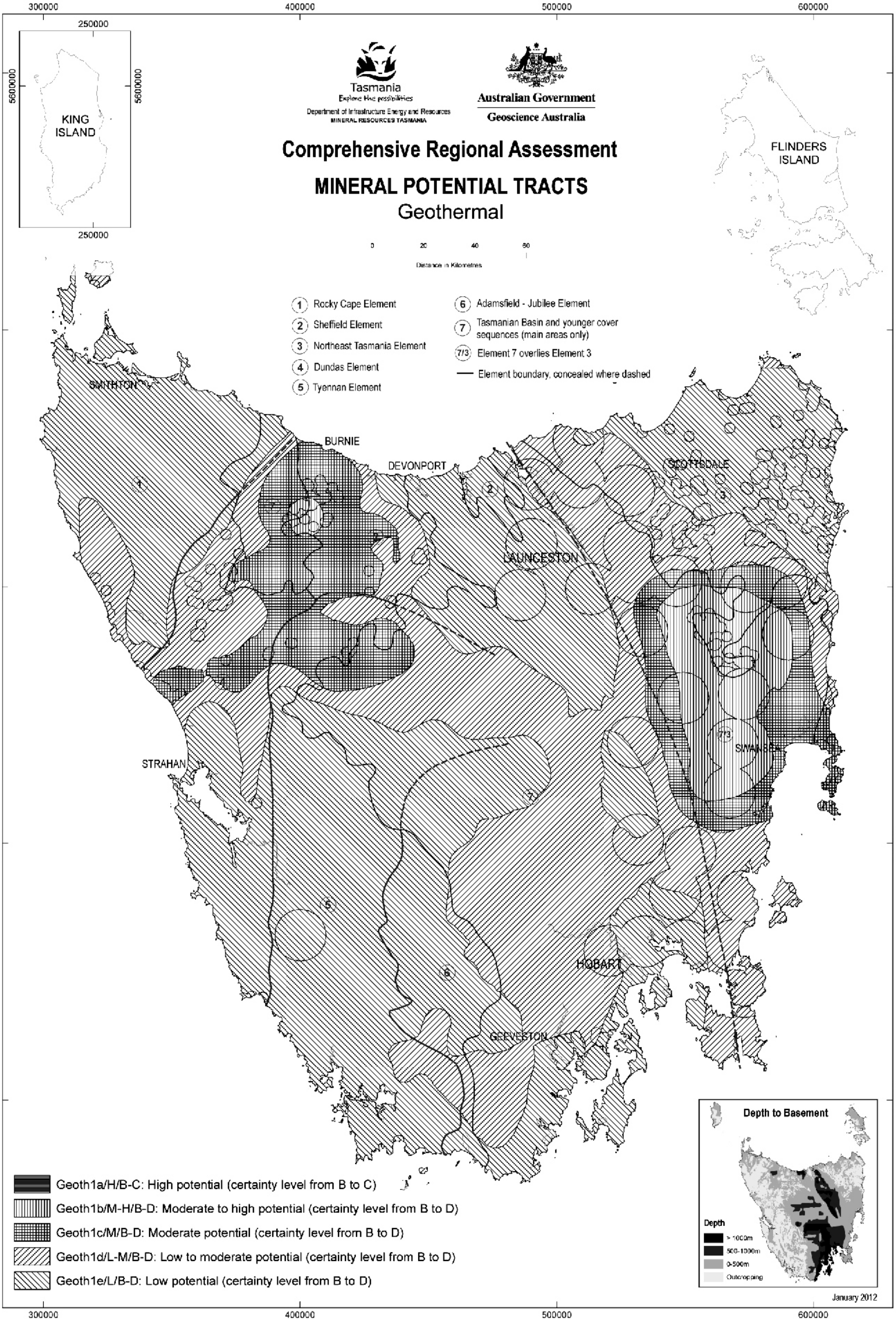
Certainty

In this assessment hot rock potential is dependant primarily on the 3D distribution of granites and their assigned heat production. The certainty of the assessment is, therefore, strongly dependant on how well the distribution of granite has been defined at depth, and to the accuracy of the heat production values assigned to these granites. The 3D granite distributions have been produced by gravity modelling constrained by outcrop geology and should be considered as interpretations of granite depth. Numerous heat production values exist in regions of outcropping granites. There is therefore a higher confidence in the assigned heat production in these locations. This confidence reduces with increasing depth and with distance from the nearest sampled outcrop. If heat flow determinations are available, then these can help better constrain the modelling, and therefore improve the confidence.

The thermal modelling performed in this assessment only incorporates heat transport via conduction. Heat transport may occur due to fluid flow within permeable sediments or fracture zones, which would change the prospectivity of the area. High permeability may also facilitate extraction of hot fluid, increasing the prospectivity of an area.

There is a known zone of high electrical conductivity within eastern Tasmania running broadly north–south through the Tamar Valley and extending south towards the Tasman Peninsula. KUTh Energy has interpreted this conductivity zone to be a potentially fluid-filled fracture zone and has identified it as a geothermal target. We have assessed the potential as moderate in this area, although the heat flow predicted by modelling is up to about 30% lower than that determined by KUTh's measurements. Therefore, this assessment has under predicted potential in this region. This disagreement reflects the fact that our assessment has been performed on a regional scale, and will not replicate local effects.

Three levels of certainty have been applied in this assessment: moderate in areas within a 10 km radius of a heat flow determination for which the modelled heat flow is within 14 mW/m^2 of the measured value; low to moderate within a 2 km radius of a surface geochemistry sample point; and low everywhere else. The moderate certainties reflect the lack of measured temperatures at great depths (>500 m) which could be used to further refine the thermal modelling. The moderate to low certainties reflect the difficulties in extrapolating surface geochemistry data to great depths.



Map 14 — Model E14

MODEL M15: Tungsten skarn deposits (Model 14a of Cox and Singer, 1986)

Model description

Description of the model after D. P. Cox.

Description

Scheelite in calc-silicate contact metasomatic rocks.

Approximate synonyms

Scheelite skarns of the tin-tungsten type (Solomon and Groves, 1994).

General references

Kwak, 1987; *Einaudi and Burt, 1982*; Meinert *et al*., 2005.

Geological environment

Rock types:

Tonalite, granodiorite, quartz monzonite; limestone.

Textures:

Granitic, granoblastic.

Age range:

Mainly Mesozoic, but may be any age. Tasmanian deposits are associated with Devonian–Early Carboniferous intrusions.

Depositional environment:

Contacts and roof pendants of batholith and thermal aureoles of apical zones of stocks that intrude carbonate rocks. Adjacent to fault zones which intersect the intrusion and the carbonate host rocks.

Tectonic setting(s):

Orogenic belts. Syn–late orogenic.

Associated deposit types:

Sn-W skarns, Zn skarns.

Deposit description

Mineralogy:

Scheelite molybdenite pyrrhotite sphalerite chalcopyrite bornite arsenopyrite pyrite magnetite traces of wolframite, fluorite, cassiterite, and native bismuth.

Alteration:

Diopside-hedenbergite + grossular-andradite. Late stage spessartine + almandine. Outer barren wollastonite zone. Inner zone of massive quartz may be present.

Ore controls:

Carbonate rocks in thermal aureoles of intrusions. Faults which intersect the intrusion and the carbonate beds have acted as conduits to the mineralising fluids, particularly faults which pre-date the intrusion.

Geochemical signature:

W, Mo, Zn, Cu, Sn, Bi, Be, As.

Geophysical signature:

May have strong magnetic anomaly depending on magnetite and/or pyrrhotite content.

Examples

King Island	
Pine Creek, USCA	*(Newberry, 1982)*
MacTung, CNBC	*(Dick and Hodgson, 1982)*
Strawberry, USCA	*(Nokleberg, 1981)*

Known deposits and mineral prospects in Tasmania

King Island–Dolphin and Bold Head ore bodies
Kara
Mount Youngbuck

Tungsten skarn deposits are associated with magnetite-bearing, I-type biotite-amphibole granodiorite (King Island) and granite (Kara), and occur along the flanks of the intrusion, often where there is a shelf in the granite contact. Host rocks for the King Island skarn are Neoproterozoic dolomite, limestone, siltstone and conglomerate.

The Kara deposit is the largest of several scheelite-bearing magnetite skarns developed in metasomatised Gordon Group limestone and the underlying transition beds to Denison Group sandstone on the margin of the Housetop Granite.

Assessment criteria

1. I-type granitoids — mostly Devonian–Early Carboniferous but could be Cambrian.
2. Carbonate rocks intruded by the granitoids.
3. Calc-silicate rocks (e.g. amphibolites, hornfels) intruded by the granitoids.
4. Commonly developed above a shelf in the granitoid contact.

Skarn related mineralisation is typically developed in close proximity to a granite intrusion and generally the majority of Tasmanian deposits of this type occur within the two kilometre subsurface granite contour (as determined from the modelling of gravity data). In general, this contour has been used as a primary controlling feature in defining the skarn-related mineralisation tracts. In some cases the boundary of the tract has been modified to reflect the known distribution of skarn-type mineralisation, the presence of potential geological structures which were active during granite emplacement, and the potential for buried carbonate units as predicted by the 3D geological model of Tasmania. It should be noted that in some cases the gravity data used in the modelling is not sufficiently detailed to indicate small shallow (<2 km) protrusions in the granite surface.

Because of the level of detail shown by the 1:250 000 scale geological maps used to make the assessment, a single tract map has been used for all the skarn-type deposits.

Assessment: Tract Skrn1a/H/B-D

This tract, with zones in northwest and southwest Tasmania, has been delineated based on the subsurface distribution of Devonian–Early Carboniferous granitoids, as determined by modelling of gravity data. Copper skarn deposits, as described above, occur in the northwest parts of this tract and are hosted by carbonate units within various Neoproterozoic and Ordovician sequences which are widespread in northwest Tasmania. Here the exposed granite bodies and known deposits strongly suggest that the subsurface granitoids are of the appropriate composition to be associated with copper skarn deposits and the potential is high. The certainty level varies from B to to D with the degree of geological mapping.

Assessment: Tract Skrn1b/M-H/B-C

This tract in northwest Tasmania has been delineated based on the subsurface distribution of the continuation of the Devonian–Early Carboniferous Interview and Pieman granitoids as determined by modelling of gravity data. The inferred subsurface granitoid is overlain, at the surface, by Neoproterozoic Rocky Cape Group rocks which contain only minor dolomite. An interpretation of the regional geology supported by recent geological mapping has suggested that these rocks have, in places, been thrust over Togari Group rocks which contain dolomite units. This tract has moderate to high potential and certainty ratings for this type of deposit partly due to the lack of geological mapping over much of the tract.

An outlying part of this tract in southwest Tasmania has also been delineated based on the subsurface distribution of Devonian–Early Carboniferous granitoids intruding an area of Ordovician limestone and Proterozoic rocks of the Tyennan and Jubilee elements. Granites belonging to the inferred subsurface body crop out at South West Cape and Cox Bight, where they are associated with alluvial tin deposits. The subsurface granite is thus also likely to include 'tin granite'. This part of the tract also has high potential as it is known to contain Ordovician limestone and Proterozoic dolomite in the New River, Picton River and Olga River areas. The level of certainty is moderate mainly because of the lack of detailed geological mapping in that area.

Assessment: Tract Skrn1c/M/B

This tract includes a zone in southwest Tasmania and another in northern Tasmania. It has been delineated based on the subsurface distribution of Devonian–Early Carboniferous granitoids, as determined by modelling of gravity data. In southwest Tasmania the granitoids are inferred to have intruded an area of Proterozoic rocks of the Tyennan Element. Granites belonging to the inferred subsurface body crop out at South West Cape and Cox Bight, where they are associated with alluvial tin deposits. The subsurface granite is thus also likely to include 'tin granite'. The tract is considered to have medium to high potential because, although outcropping rocks are dominantly quartzitic to pelitic, carbonate may be present. This is inferred from the presence of carbonate beds in similar Proterozoic rocks in the Lake Gordon area, and because due to structural complexity carbonate may occur at depth. As the major structures in the area are poorly known, it is not possible to discount the possibility that the Proterozoic rocks have been thrust over substantial Ordovician limestone units at comparatively shallow depth, which could act as host rocks for this type of deposit. In northern Tasmania the inferred subsurface granitoids intrude carbonate units within various Cambrian and Ordovician sequences.

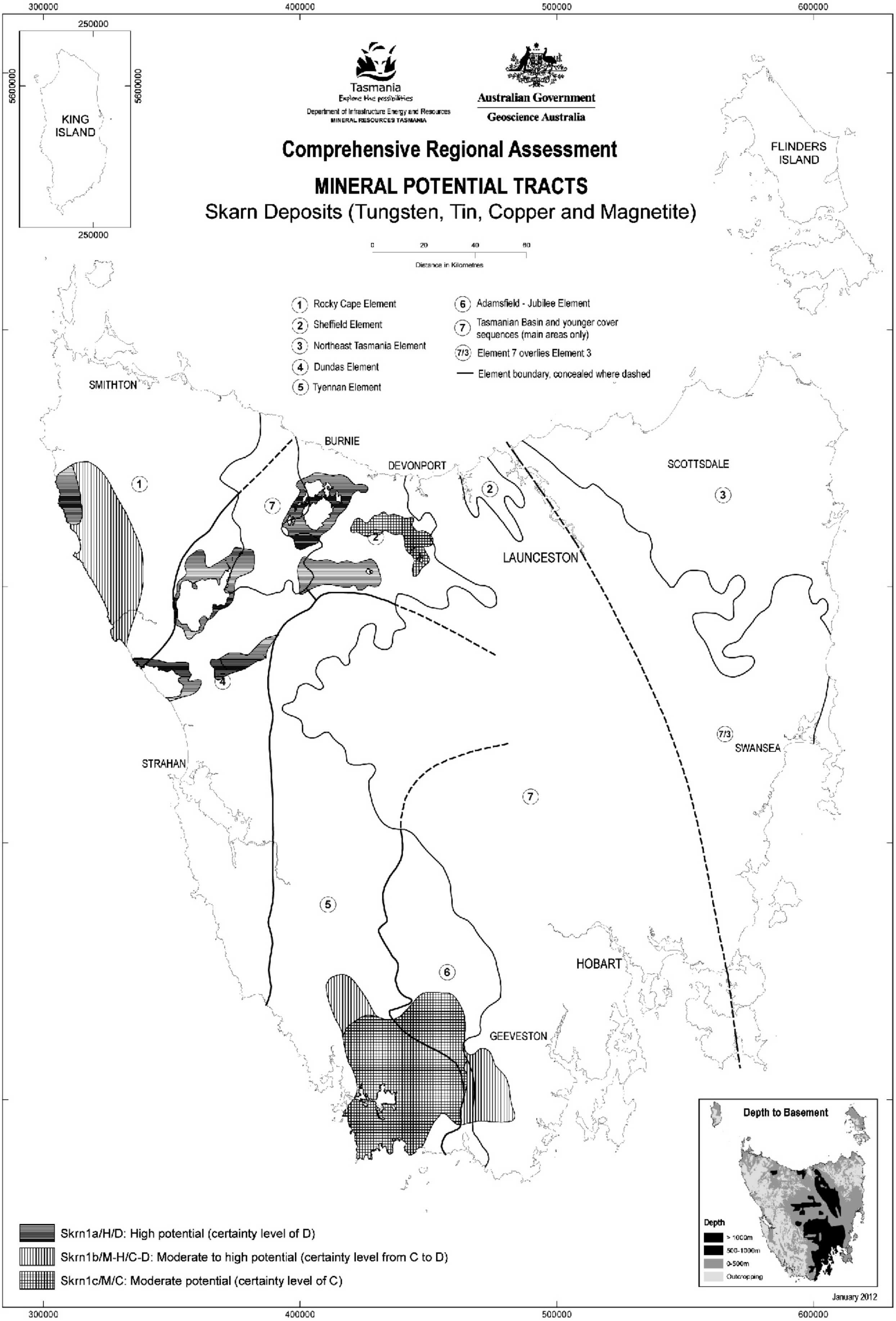
A second part of this tract, in northern Tasmania, is defined by the subsurface distribution of the Beulah Granite. This poorly known granite of possible Cambrian age has the potential to intrude Neoproterozoic carbonate-rich units at depth.

This tract has a moderate potential and certainty rating.

Economic significance

According to grade/tonnage models for tungsten skarn deposits, 90% of deposits contain at least 0.05 million tonnes of ore, 50% at least 1.1 million tonnes and 10% at least 22 million tonnes. In these types of deposits, 90% contain at least 0.34% WO_3, 50% at least 0.67% WO_3 and 10% at least 1.4% WO_3 (Cox and Singer, 1986).

King Island is one of the world's largest tungsten skarn deposits. Estimated pre-mining resources for King Island ore bodies are 16.9 Mt of ore averaging 0.78% WO_3. Total production to date has been 10.67 Mt of ore averaging 0.61% WO_3.



Map 15 — Model M15

MODEL M16: Descriptive model of tin greisen deposits (Model 15c of Cox and Singer, 1986)

Model description

Description of the model after B. L. Reed.

Description

Disseminated cassiterite, and cassiterite-bearing veinlets, stockworks, lenses, pipes, and breccia in greisenised granite.

General references

Reed, 1982; Solomon and Groves, 1994; Blevin, 1998.

Geological environment

Rock types:

Specialised biotite and (or) muscovite leucogranite (S-type); distinctive accessory minerals include topaz, fluorite, tourmaline and beryl. Tin greisens are generally post-magmatic and associated with late fractionated melt.

Textures:

Common plutonic rock textures, miarolitic cavities may be common; generally non foliated; equigranular textures may be more evolved; aplitic and porphyritic textures common.

Age range:

May be any age; tin mineralisation temporally related to later stages of granitoid emplacement. Tasmanian deposits are associated with Devonian–Lower Carboniferous granitoids.

Depositional environment:

Mesozonal plutonic to deep volcanic environment.

Tectonic setting(s):

Fold belts of thick sediments   volcanic rocks deposited on stable cratonic shield; accreted margins; granitoids generally post-date major folding.

Associated deposit types:

Quartz-cassiterite sulphide lodes, quartz-cassiterite   molybdenite stockworks, late complex tin-silver-sulphide veins.

Deposit description

Mineralogy:

Cassiterite, molybdenite, arsenopyrite, beryl, wolframite, bismuthinite, Cu-Pb-Zn sulphide minerals and sulphostannates. Gangue mineralogy includes quartz   fluorite, calcite, tourmaline, muscovite and topaz.

Texture/structure:

Exceedingly varied, the most common being disseminated cassiterite in greisens, and quartz veinlets and stockworks (in cupolas or in overlying wall rocks). Less common are pipes, lenses and tectonic breccia.

Alteration:

Incipient greisen (granite): muscovite   chlorite, tourmaline, and fluorite. Greisenised granite: quartz-muscovite-topaz-fluorite,   tourmaline (original texture of granites retained). *Greisen:* quartz-muscovite-topaz   fluorite   tourmaline   sulphides (typically no original texture preserved). Tourmaline can be ubiquitous as disseminations, concentrated or diffuse clots, or late fracture fillings. Greisen may form in any wall rock environment, typical assemblages developed in aluminosilicates.

Ore controls:

Greisen lodes located in or near cupolas and ridges developed on the roof or along margins of granitoids; faults and fractures may be important ore controls.

Weathering:

Granite may be 'reddened' close to greisen veins. Although massive greisen may not be economic as lodes, rich placer deposits form by weathering and erosion.

Geochemical signature:

Cassiterite, topaz and tourmaline in streams that drain exposed tin-rich greisens. Specialised granites may have high contents of Si_2O (>73%) and K_2O (>4%), and are depleted in CaO, TiO_2, MgO and total FeO. They are enriched in Sn, F, Rb, Li, Be, W, Mo, Pb, B, Nb, Cs, U, Th, Hf, Ta and most REE, and impoverished in Ni, Cu, Cr, Co, V, Sc, Sr, La and Ba.

Examples

Lost River, USAK	(*Dobson, 1982*; *Sainsbury, 1964*)
Anchor Mine, AUTS	(Solomon and Groves, 1994)
Erzgebirge, CZCL	(*Janecka and Stemprok, 1967*)

Known deposits and mineral prospects in Tasmania

Greisen tin deposits occur in the western and especially in the northeastern parts of Tasmania. These deposits are associated with biotite or muscovite-bearing alkali feldspar granites of Devonian–Early Carboniferous age.

In the northeast, the main deposits are Anchor, Royal George, Rex Hill and Cream Creek. At the Anchor mine, cassiterite occurs in irregular, flat-lying sheets of greisenised granite, located along the contact between an alkali granite and an overlying older porphyritic biotite granite (Groves and Taylor, 1973). At the Royal George mine, disseminated cassiterite occurs in sheeted tabular greisen bodies. At Rex Hill, disseminated cassiterite occurs in steeply-dipping breccia pipes, hosted by altered granite.

The main greisen deposits in the western part of Tasmania are those associated with the Heemskirk Granite. The greisens appear to have been formed as a result of alteration of pre-existing granitic dykes by magmatic fluids (e.g. Federation mine).

Assessment criteria

1. Distribution of 'tin granites' (highly fractionated alkali-feldspar granites) within Devonian–Early Carboniferous granitoids.
2. Distribution of greisenised granite.
3. Presence of alluvial tin.

4. Distribution of greisen minerals such as beryl and tourmaline.

Assessment: Tract Sn3a/H/C

The presence of highly fractionated phases of, or late minor intrusions within, major granite/adamellite plutons is possible. The tracts are therefore drawn to include all outcropping and near-surface Devonian to Lower Carboniferous granitoids, other than granodiorite and diorite.

In western Tasmania this includes all the major and minor granitoid intrusions. The Interview, Pieman, Meredith and Granite Tor plutons, the white S-type phase of the Heemskirk granite, the small Lone Pine and Birthday exposures in the upper Forth valley and the Mt Bischoff porphyries are assessed as having high potential on the basis of their mineralogy and geochemistry and their association with known mineralisation. The degree of uncertainty is rated as C except for the very poorly known and unmapped Granite Tor pluton.

In eastern Tasmania the Lottah, Mt Paris and Ben Lomond/ Royal George plutons are also considered to have high potential on the basis of geochemistry and known mineralisation which includes some of this style. The eastern Tasmanian granitoids are reasonably well mapped (except in the Bicheno–Coles Bay area) and geochemically well known, and the certainty level is C.

Assessment: Tract Sn3b/M/C

In western Tasmania the Housetop Granite and some other minor granite bodies are considered to have moderate potential with a certainty level of C. In eastern Tasmania, where a wider range of granitoid types is present, most of the Scottsdale Batholith and the Gardens, Pyengana, Georges River and Scamander Tier granodiorite phases of the Blue Tier Batholith were not considered to have the appropriate composition to have potential for this deposit type. The extrusive to hypabyssal St Marys Porphyry is also considered to be inappropriate for this model. The remaining granitoids in eastern Tasmania were considered to have moderate potential and the certainty level is C.

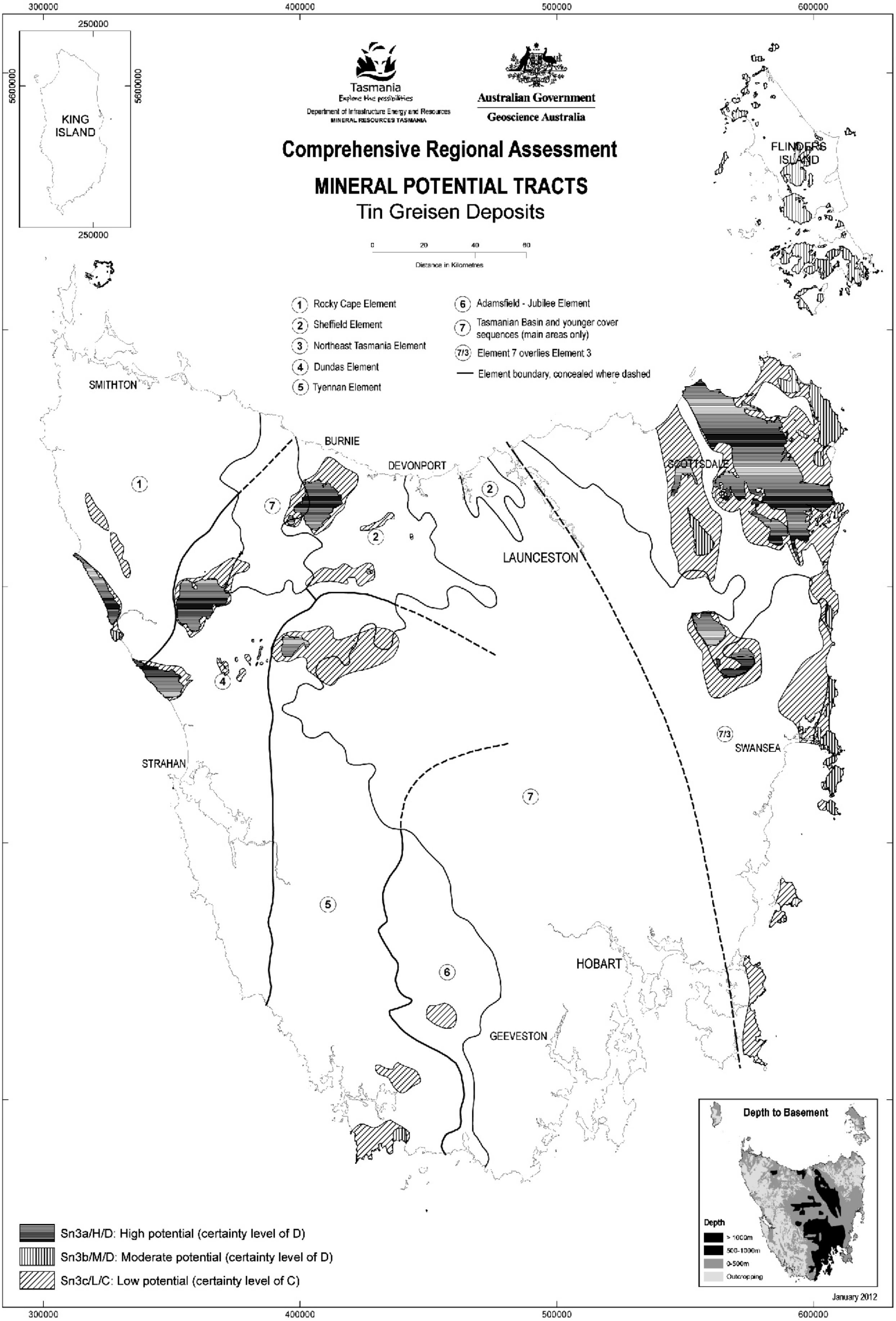
Assessment: Tract Sn3c/L-M/B

This tract is based on the distribution of shallow (<1 km) non-outcropping granites and is based on the 1 km granite depth contour as modelled from gravity data. It has a low to moderate potential with a moderate certainty.

Economic significance

According to grade/tonnage models for tin greisen deposits, 90% of deposits contain at least 0.8 million tonnes of ore, 50% at least 7.2 million tonnes and 10% at least 65 million tonnes. In these types of deposits, 90% contain at least 0.17% Sn, 50% at least 0.28% Sn and 10% at least 0.47% Sn (Cox and Singer, 1986).

The only greisen deposits in Tasmania which have recorded tin production are Anchor (2.09 Mt ore averaging 0.22% Sn), and Royal George (0.16 Mt ore averaging 0.4% Sn).



Map 16 — Model M16

MODEL M17: Gold in ironstones

Model description

Description of the model by S. Jaireth.

Approximate synonym

BIF-hosted gold; Starra-style gold.

Description

Stratabound to stratiform gold deposits in iron-rich chemical sediments.

General references

Davidson *et al*., 1989; Groves *et al*., 1987; Wedekind *et al*., 1989.

Geological environment

Rock types:

Iron-formation, banded or massive, hosted by regionally metamorphosed mafic and felsic metavolcanic rocks, komatiites, and volcaniclastic or turbiditic siliciclastic sedimentary rocks. Intruded by felsic plutonic rocks and locally by quartz porphyry and syenite porphyry.

Age range:

Mainly Archaean and Proterozoic but can be of any age.

Depositional environment:

Controversial. Submarine volcanic exhalative, and/or later epigenetic hydrothermal activity related to intrusive rocks.

Tectonic setting(s):

Archaean greenstone belts or younger metamorphic belts. Commonly greenschist-facies metamorphism, but locally relicts of high-pressure, prograde metamorphism (blue schist facies) may be preserved.

Associated deposit types:

Kuroko massive sulphide deposits, Algoma Fe, low-sulphide gold-quartz veins, copper   gold   bismuth replacement deposits in ironstones.

Deposit description

Mineralogy:

Native gold, pyrite, pyrrhotite, chalcopyrite, magnetite, hematite, chlorite, quartz, siderite, Bi minerals.

Texture/structure:

Disseminated.

Alteration:

Local sulphidation of iron oxides.

Ore controls:

Poorly understood, but there are probably at least three types: a syngenetic, exhalative style (e.g. Starra, Davidson *et al*., 1989), and epigenetic style (e.g. Tennant Creek, Wedekind *et al*., 1989); and a mixture of both (e.g. Mt Magnet, Groves *et al*., 1987). Beds may be cut by concordant or sharply discordant quartz-carbonate veins with gold in the veins and sulphidic selvages.

Weathering:

Gossans on sulphidic iron formation.

Geochemical signature:

Enrichment in Au, Cu,   Co   Bi   As in ironstones.

Geophysical signatures:

Strong magnetic anomalies.

Examples

Gecko, AUNT	(Wedekind *et al*., 1989)
Starra, AUQL	(Davidson *et al*., 1989)
Warrego, AUNT	(Wedekind and Love, 1990)
Selwyn, AUQL	(Kary and Harley, 1990)

Known deposits and mineral prospects in Tasmania

Alluvial gold has been recovered from a wide area in the Corinna–Savage River area. The source of much of this gold is thought to be the Precambrian Bowry Formation, which hosts the Savage River magnetite deposits. The Savage River magnetite deposits were first prospected for gold and grades up to 55 g/t were recorded (Twelvetrees, 1903). There is very little information about primary gold mineralisation associated with these magnetite bodies. In the nearby Long Plains prospect, gold is reported to be stratabound, as disseminations and small veins in various schists. In the Rocky River prospect to the south, gold is reported to be stratabound and hosted by magnetite-rich rocks with nickel, cobalt, copper and silver-bearing sulphides (Twelvetrees, 1903). In the Specimen Reef, north of Savage River, Twelvetrees (1903) reported quartz-carbonate-pyrite veins with gold values.

Based on very limited information it is difficult to outline geological factors responsible for the formation of gold mineralisation associated with ironstones.

A current view is that the ironstones are a variant of iron oxide-copper-gold deposits (Bottrill and Taheri, 2008).

Assessment criteria

1. Distribution of rocks belonging to the Bowry Formation in the Arthur Metamorphic Complex. These rocks host the Savage River magnetite-pyrite deposits.
2. Distribution of known gold occurrences.
3. Distribution of alluvial gold prospects.
4. Distribution of Devonian granitoids.

Assessment: Tract gold in ironstones: Au4a /H/B-C

The most important geological element for delineating this tract is the distribution of metamorphosed Neoproterozoic rocks of the Arthur Metamorphic Complex. These include chloritic schist, phyllite, dolomite, magnesite and amphibolites, and host the most important iron deposits including the Savage River deposit. The presence of several known occurrences of primary and alluvial gold also support the delineated tract. As mentioned earlier, Devonian granitoids might have played a significant role in the formation of these deposits but due to insufficient information their presence cannot be used to extend the tract beyond the limits of favourable rock units. The tract boundaries have been drawn so as to extrapolate the area of the target rock types under a thin unit of Cenozoic cover in parts of the tract.

The tract has a high potential for gold deposits associated with ironstones.

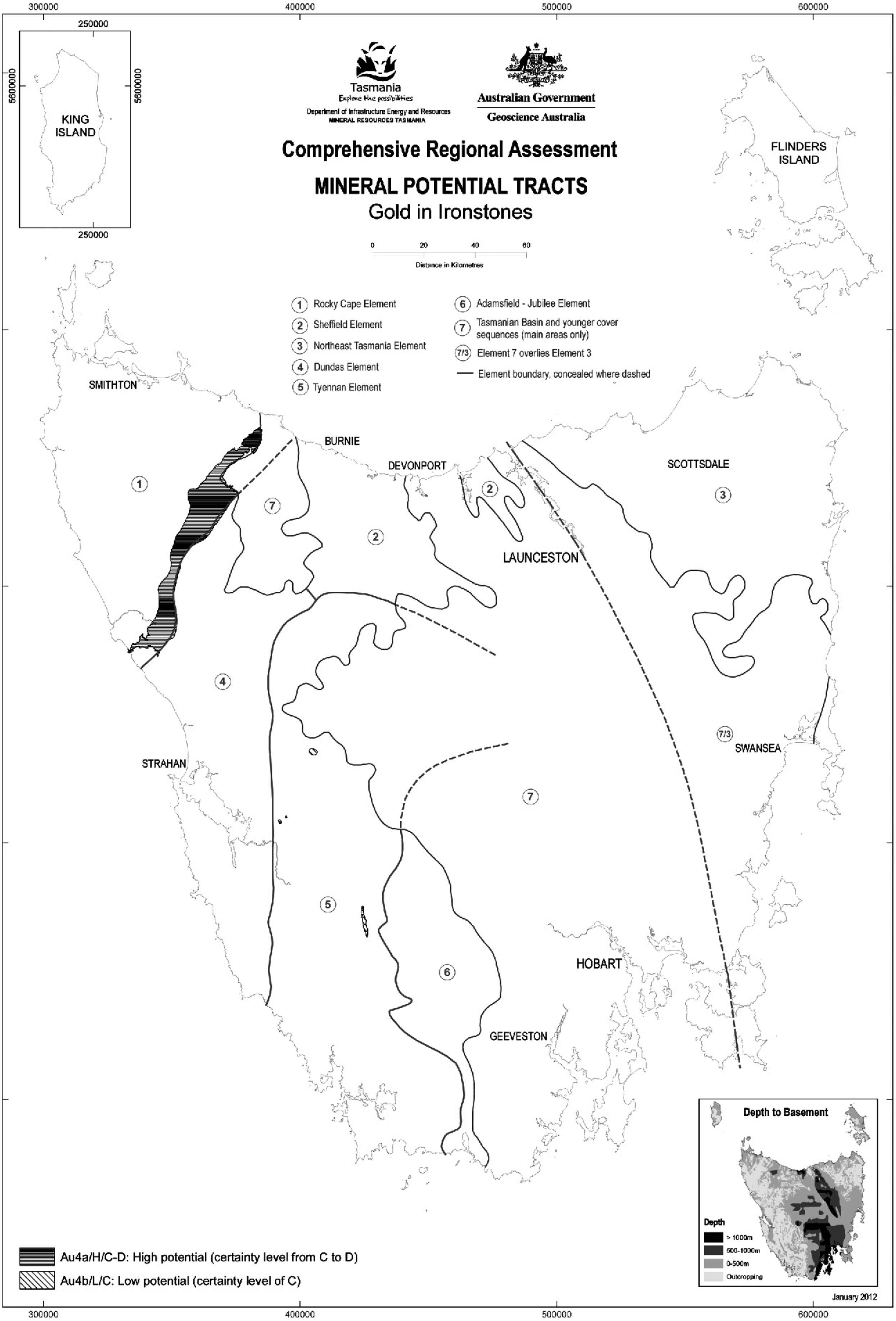
The southern (Savage River mine–Corinna) and northern (Arthur River area) segments of the Arthur Metamorphic Complex are fairly well known due to recent Geological Survey mapping and the tract in these areas has a certainty level of C, whilst most of the central segment is one of the most poorly known areas in Tasmania and has a certainty level of B.

Assessment: Tract Au4b/L/B

This tract consists of three small groups of outcrops of Neoproterozoic amphibolite in the Atkins Range, Mt McCall and Raglan Range areas. In the Atkins Range area the amphibolite is associated with a thin ironstone unit. There are no recorded gold occurrences in any of the areas and they have low potential for gold associated with ironstones, with a certainty level of B.

Economic significance

Deposits associated with ironstones contain significant amounts of copper and gold. The Selwyn copper deposit contained resources of 5.3 Mt of ore averaging 5.3 g/t Au and 1.98% Cu (Kary and Harley, 1990). Deposits in the Tennant Creek area are generally smaller in size, richer in copper but poorer in gold. An exception is the Warrego deposit that contained reserves of 5 Mt grading 7 g/t Au, 2.6% Cu and 0.3% Bi (Wedekind and Love, 1990).



Map 17 — Model M17

MODEL M18: Irish-style carbonate hosted base metal deposits (Model 31a of Cox and Singer, 1986)

Model description

Cox and Singer (1986) include the Irish-style base metal deposits in the model for the sedimentary-exhalative (Sedex) Zn-Pb deposits. Although Irish-style deposits have several similarities with sedimentary-exhalative deposits, they also have features which are similar to the Mississippi-valley type (MVT) deposits. Keeping this in view a descriptive model for the Irish-style deposit is thought necessary. The descriptive model is compiled based on a review by Hitzman and Large (1986).

Approximate synonyms

Carbonate-hosted stratabound deposits.

Description

Stratabound and cross-cutting accumulations of sulphide and sulphate minerals within sequences of carbonate and clastic rock.

General reference

Hitzman and Large, 1986.

Geological environment

Zones of active rifting. The onset of sudden rifting and local mafic volcanism. Collision-related environment with deposits formed in the interior of under-thrusting continents.

Rock types:

Mixed siliciclastic and carbonate rocks and locally evaporitic sediments in a shallow marine, moderate to high oxidising shelf environment. The sequence is succeeded by the deposition of shallow water shelf limestone and deeper water carbonate and argillite. Volcanic rocks of bimodal composition are locally present.

Textures:

Host rocks are commonly micritic, oolitic, pelloidal or slightly sandy carbonate beds.

Age range:

Commonly Palaeozoic. Deposits in Ireland are hosted in Lower Carboniferous rocks. The mineralisation is suggested to be formed in a short span of seven million years during the latest Courceya (approximately 353 my) and the Early Arundian (approximately 345 my). The latest Courceyan to Arundian corresponds to a period of tectonic activity including limited bimodal volcanism in Central Ireland.

Depositional environment:

Shallow marine shelf environment.

Tectonic setting:

Overall tectonic environment setting is similar to that of both the Selwyn Basin in Canada (which hosts the Sedex deposits) and the German Hercynian Basin (contains Meggen and Rammelsberg deposits). In all three areas large prisms of clastic sediments appear to have sharply abutted against well-developed carbonate shelves. Host rocks are formed during periods of limited volcanism, extensional tectonics followed by compression of one basin margin.

Associated deposit types:

Bedded barite deposits.

Deposit description

Mineralogy:

Sphalerite, galena, pyrite, marcasite, chalcopyrite, barite and carbonates. Minor to trace amounts of arsenopyrite, bornite, chalcocite, covellite, tennantite, semseyite, bournonite, freibergite, pyrargyrite, boulangerite, cylindrite, franckeite, argyrodite, jordanite, gratonite, enargite, geochronite, native antimony, and fluorite and gypsum.

Texture/structure:

Sulphides occur as inter-porosity fill, vein, irregular colloform bands replacing earlier bands of carbonates or sulphides and sulphates, coarse vug fillings, stylolites, and massive laminated bands. In cross-cutting close to the feeder mineralisation, sulphides form a stockwork of veins, breccia fillings and massive replacement zones.

Alteration:

Dolomitisation (often ferroan dolomite) and minor and local silicification. Alteration is lithologically controlled and argillaceous rocks are poorly dolomitised. Dolomitisation follows diagenetic infill cements by calcite. It is followed by the precipitation of sulphides and carbonate material. Minor carbonate followed mineralisation.

Ore controls:

Lithologically stratabound mineralisation is consistently restricted to non-argillaceous units and is generally best developed within micritic, oolitic, pelloidal or slightly sandy carbonate beds. Highest grade mineralisation occurs commonly within porous and permeable (?) oolitic, pelloidal or slightly sandy packstones and wackstones adjacent to less(?) permeable argillaceous carbonates, fine-grained calsiltite or micrite. Mineralisation adjacent to feeder structures cross cuts stratigraphy. The majority of mineral deposits are adjacent to structures (generally normal faults) that were active during mineralisation.

Geochemical signatures:

Zinc and lead geochemical anomalies in soil and stream sediments.

Geophysical signatures:

IP anomalies used for exploration.

Examples

Oceana?, Tasmania	(Taylor and Mathison, 1990)
Navan, Ireland	(Ashton *et al.*, 1986)
Silvermines, Ireland	(Andrew, 1986)
Tynagh, Ireland	(Banks, 1986)

Known deposits and mineral prospects in Tasmania

The only well known base metal deposit of this type is the Oceana lead-zinc-silver deposit in the Dundas Element. This deposit, and other base metal occurrences in the area, were interpreted as hydrothermal vein mineralisation associated with the Devonian Heemskirk Granite, although in recent years the mineralisation has been thought to show features similar to the Irish-style base metal deposits. Some of these features (Taylor and Mathison, 1990) are the presence of debris-flow breccia which can be viewed similar to carbonate breccia occurring in the immediate hanging wall of the Irish-style deposits; presence of ore texture indicative of syndiagenetic replacement; lead isotope determinations interpreted to indicate Ordovician age of mineralisation; the stratiform nature of mineralisation south of the mine fault; and the presence of pervasive dolomitisation, spatially and temporally associated with mineralisation.

Several other base metal occurrences in the Zeehan area, with features similar to the Oceana deposit, could possibly be grouped under Irish-style base metal mineralisation (Ellis, 1984). Recently, exploration in this area has recorded the presence of low-grade sub-economic mineralisation in three stratigraphic positions at the base, middle and top of the Gordon Group. In a number of these intersections the mineralisation is syndiagenetic, similar to the southern portion of the Oceana deposit (Taylor, 1989).

The predominant host of these mineral occurrences is the Ordovician sequence of the Gordon Group comprising most commonly micrite and dolomitic micrite deposited in supratidal, intertidal and subtidal shallow marine environments (Seymour and Calver, 1995).

Another setting that may be favourable for the Irish-style base metal mineralisation is the the Smithton Basin in the Rocky Cape Element. This area has been targetted by exploration companies for this style of mineralisation. The Neoproterozoic rocks of the Smithton Basin unconformably overlie the rocks of the Rocky Cape Group and comprise a sequence of dolomite, clastic sedimentary rocks, mafic volcanic rocks and chert (Seymour and Calver, 1995). Chert lithologies in the Black River Dolomite are apparently derived from silicification of carbonates, the oolitic textures in which are indicative of a shallow marine (shelf) depositional environment. Possible debris-flow units, and mapped lateral thickness changes of units, suggest mild syndepositional tectonism. The overlying Kanunnah Subgroup includes mafic volcanic rocks reflecting a regional rifting event. The Smithton Dolomite, the topmost unit of the sequence, also shows textures indicative of a shallow marine sedimentary environment (Seymour and Calver, 1995).

Assessment criteria

1. Distribution of carbonate rocks formed in a shallow marine environment.
2. Geological setting characterised by active tectonism with possible concurrent volcanic activity.
3. Distribution of occurrences similar to the Irish-style base metal deposits.

Assessment: Tract BM3a/H /C

The tract has been drawn on the basis of the distribution of the Gordon Group in the Zeehan district, including areas covered by surficial deposits. The district has a number of base metal occurrences, some of which have been shown to have features similar to the Irish-style base metal mineralisation.

Sawkins (1984) has noted that the Irish-style deposits are associated with a geotectonic environment with active rifting. Mineralisation in these deposits is localised near reef complexes adjacent to major faults in a shallow marine environment. The main feature of this environment is the sudden onset of rifting and local mafic and/or felsic magmatism.

Although rocks of the Gordon Group are formed in shallow marine conditions, there is some uncertainty regarding the tectonic setting during its formation. The presence of several base metal occurrences in the area indicates that some deep-level expulsion of hydrothermal fluids might have been active during deposition and diagenesis of these rocks.

The available information indicates that this tract has a high potential for Irish-style base-metal mineralisation with a certainty level of C.

Assessment: Tract BM3b/ M/B-C

This tract is considered to have moderate potential for Irish-style base-metal deposits; some areas with a certainty level of C, others with a lower certainty level B. The higher certainty area is based on the distribution of the Gordon Group outside the Zeehan district, including areas covered by surficial deposits and areas covered by thin or discontinuous Tertiary basalt.

The lower certainty areas comprise:

(i) an area in northern Tasmania where the presence of shallow subsurface distribution of rocks of the Gordon Group is uncertain.

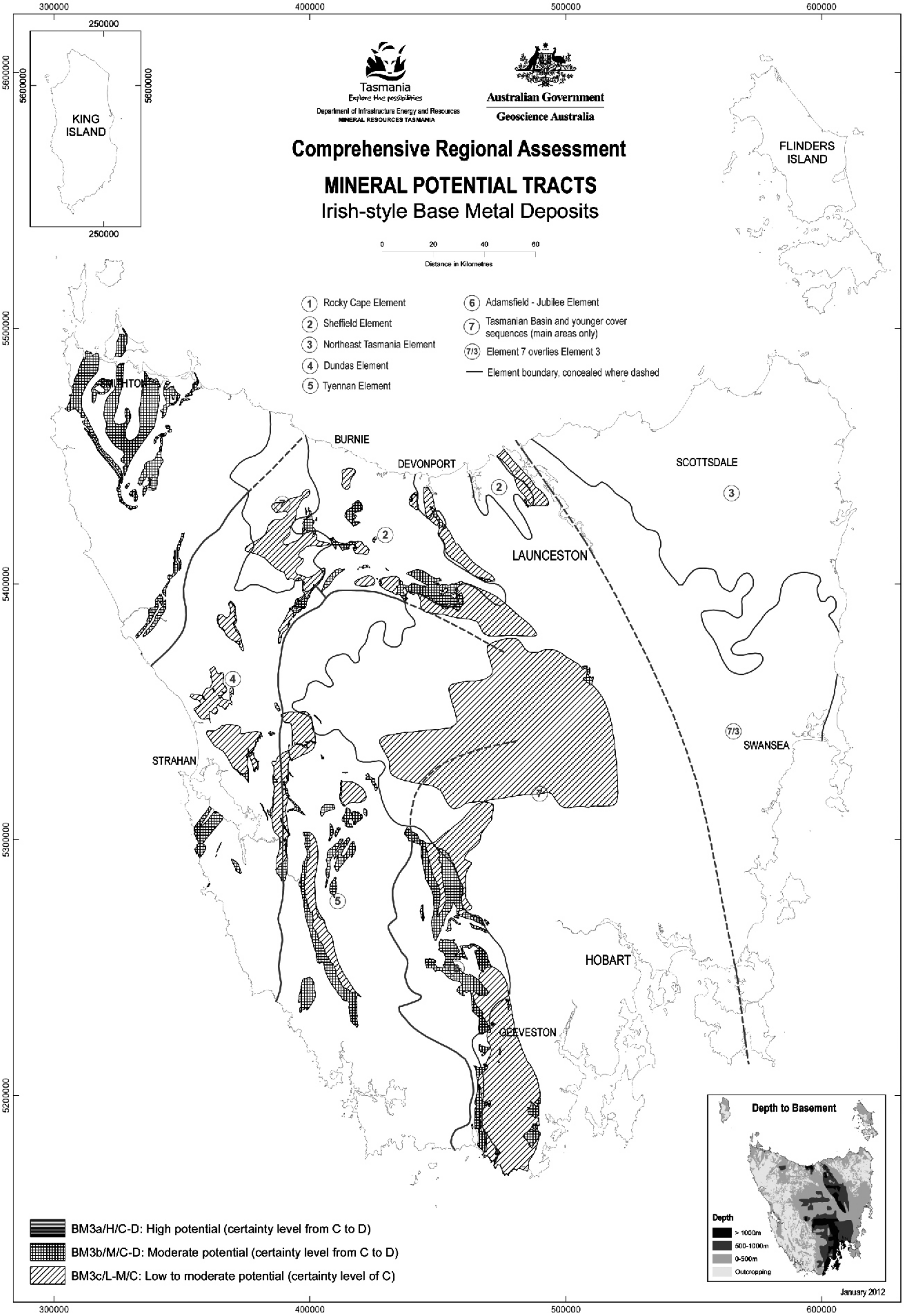
(ii) areas based on distribution of the Neoproterozoic carbonates of the Togari Group in the Smithton Basin, and correlatives in the Ahrberg Group along the western side of the Arthur Metamorphic Belt. These rocks are formed in shallow marine (shelf) environments, the deposition of which was interrupted by a major phase of mafic volcanism. Thus both depositional and tectonic environments are similar to that favoured for the generation of mineralising processes related to the formation of the Irish-style deposits. This is supported by the fact that exploration companies have also targeted this area for this type of deposit, although there are no known base metal occurrences of this type in this tract.

(iii) areas based on the distribution of Neoproterozoic carbonate rocks in central and southern Tasmania, which may be correlatives of the Togari Group. The Jane Dolomite in central Tasmania is poorly known. The Weld River Group in southern Tasmania includes shallow-marine dolomite and possible debris-flow units, but no volcanic rocks are known. There are some features consistent with this model but no comparable mineralisation is known although little exploration has been done.

This tract is based on the subsurface distribution (>1 km) of Ordovician and Neoproterozoic carbonate units as predicted by the 3D geological model of Tasmania. It has a low to moderate potential and a moderate certainly level.

Economic significance

Irish-style base metal deposits are important sources of base metals, as important as large volcanic-hosted massive sulphide deposits. The Navan deposit in Ireland has 90 million tonnes of ore with 2.3% lead and 10% zinc (Cox and Singer, 1986). The other two deposits are comparatively smaller (Silvermines 18 million tonnes with 2.8% lead and 7.4% zinc; and Tynagh 12 million tonnes with 0.4% copper, 4.9% lead and 4.5% zinc).



Map 18 — Model M18

MODEL M19: Nickel laterite deposits (Model 38a in Cox and Singer, 1986)

Model description

Description of the model by Donald A. Singer.

Description

Nickel-rich in situ lateritic weathering products derived from dunites and peridotites. Ni-rich oxides are most common. Some products are predominantly Ni silicates.

General reference

Evans et al., 1979.

Geological environment

Rock types:

Ultramafic rocks, particularly peridotite, dunite and serpentinised peridotite.

Age range:

Precambrian to Neogene source rocks, typically Cenozoic weathering.

Depositional environment:

Relatively high rates of chemical weathering (warm–humid climates) and relatively low rates of physical erosion.

Tectonic setting(s):

Convergent margins where ophiolites have been emplaced. Uplift is required to expose ultramafic rocks to weathering.

Associated deposit types:

Podiform chromite, PGE placers.

Deposit description

Mineralogy:

Garnierite, poorly defined hydrous silicates, quartz and goethite. Goethite commonly contains much Ni.

Texture/structure:

Red-brown pisolitic soils, silica-rich boxworks.

Alteration zoned from top:

(1) Red, yellow and brown limonitic soils;

(2) Saprolites — continuous transition from soft saprolite below limonite zone, hard saprolite and saprolitised peridotite, to fresh peridotite. Boxwork of chalcedony and garnierite occurs near bedrock-weathered rock transition.

Ore controls:

Upper limonite zone contains 0.5–2% Ni in iron oxides; lower saprolite and boxwork zone typically contain 2–4% Ni in hydrous silicates. The oxide and silicate ores are end members and most mineralisation contains some of both.

Weathering:

The profile from red pisolitic soil down to saprolite represents the products of chemical weathered ultramafic rocks.

Geochemical signature:

Enriched in Ni, Co, Cr; depleted in MgO relative to fresh peridotite (less than 40% MgO).

Geophysical signatures:

Regional airborne magnetics can be used to define high-Mg cumulate assemblage. Electromagnetics can assist in geomorphic interpretation.

Examples

Poro, NCAL	(*Troly et al., 1979*)
Cerro Matoso, CLBA	(*Gomez et al., 1979*)
Nickel Mountain, USOR	(*Chace et al., 1969*)
Greenvale, AUQL	(*Burger, 1979*)

Known deposits and mineral prospects in Tasmania

At Barnes Hill, the Neoproterozoic Andersons Creek Ultramafic complex has been deeply weathered during the Tertiary with an upper zone of secondary iron oxides overlying a clay-rich zone dominated by smectite, weathered serpentinite and chlorite. Indicated and Inferred resources are 6.6 Mt at 0.81% Ni and 0.05% Co, of which more than 5.6 Mt are Indicated (Proto Resources and Investments Ltd, Annual Report, 2011).

Assessment criteria

Presence of ultramafic units. Local evidence of Cenozoic weathering.

Assessment: Tract Andersons Creek area: M19/H/D

This tract is based on the outcropping distribution of the Andersons Creek Ultramafic complex. It has a high potential and certainty to host lateritic Ni mineralisation.

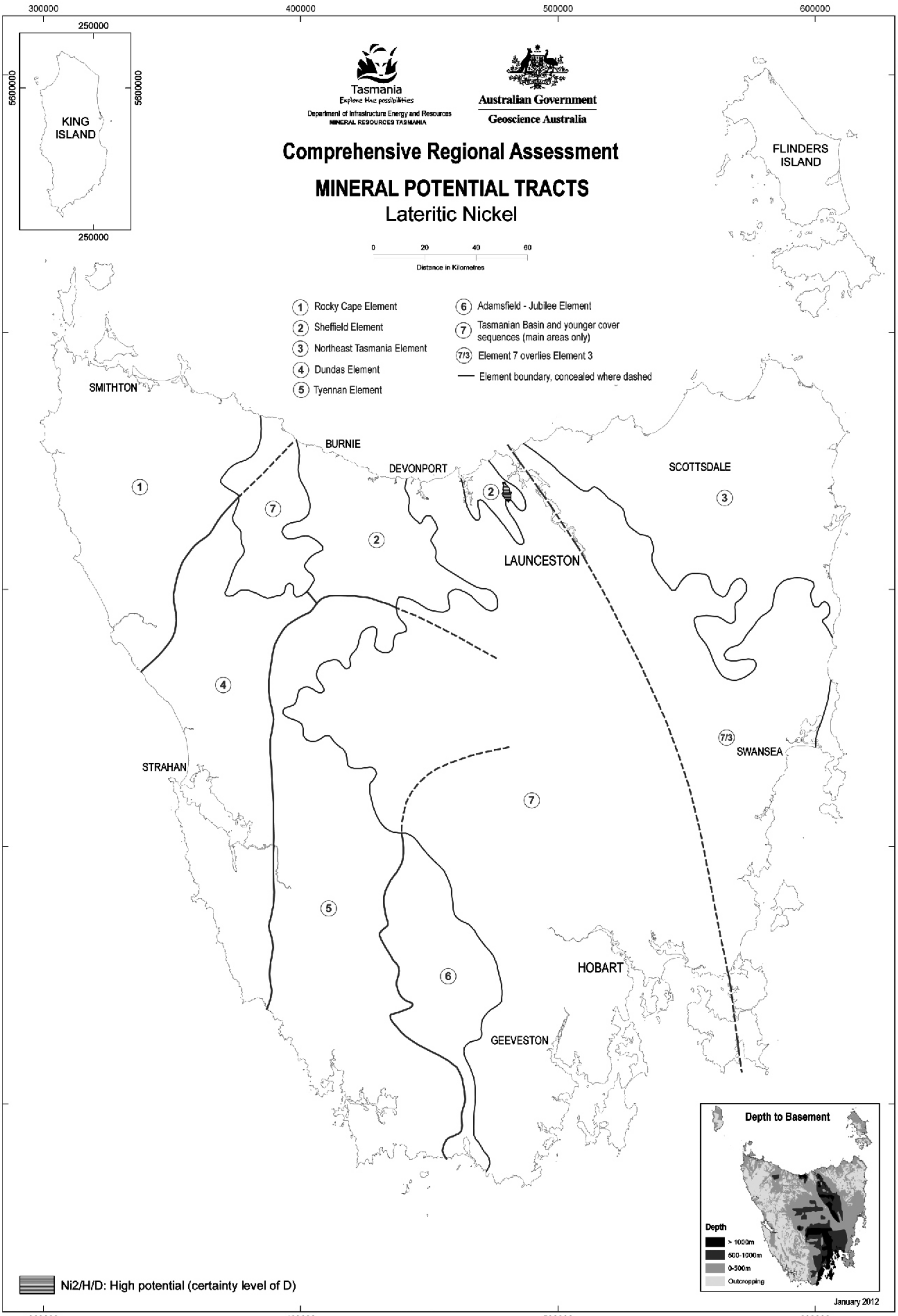
Assessment: Tract Western Tasmania: M19/L-M/B-C

Ultramafic rocks in western Tasmania, which have locally been exposed to deep weathering in the Tertiary and have been preserved from subsequent erosion, have the potential to host nickel laterites. Examples include the Riley Creek area where Venture Minerals is examining a potential deposit of Cr-rich direct shipping iron ore, and in the Dundas area where spectacular secondary mineral assemblages are developed in the contact zones of weathered serpentinite.

Economic significance

The Barnes Hill deposit is under full feasibility study to establish a mine and a mining lease has been granted over the deposit. There are pre-JORC resources at the nearby Scotts Hill and Mount Vulcan deposits.

Worldwide, nickel laterite deposits include the largest known resources of nickel and cobalt. For example, the Goro deposit, New Caledonia, contains 175 million tonnes of 1.48% Ni and 0.11% Co.



Map 19 — Model M19

MODEL M20: Gold associated with massive sulphide mineralisation (after Model 28a of Cox and Singer, 1986)

Model description

Description of the model after Donald A. Singer.

Approximate synonym

Gold-rich Noranda type, volcanogenic massive sulphide, felsic to intermediate volcanic type.

Description

Gold, copper, lead and zinc-bearing massive sulphide deposits in marine volcanic rocks of intermediate to felsic composition.

General references

Ishihara, 1974; *Franklin et al., 1981*; *Hutchinson et al., 1982*; *Ohmoto and Skinner, 1983*; Lydon, 1988; Hannington and Scott, 1989; Large, 1992.

Geological environment

Rock types:

Marine rhyolite, dacite, andesite and subordinate basalt and associated sedimentary rocks, principally organic-rich mudstone or shale. Pyritic, siliceous shale.

Textures:

Flows, tuff, pyroclastic rocks, breccia, bedded sediment, and in some cases felsic domes.

Age range:

Archaean through Cenozoic.

Depositional environment:

Hot springs related to marine volcanism, probably with anoxic marine conditions. Lead-rich deposits associated with abundant fine-grained volcanogenic sediments.

Tectonic setting(s):

Island arc, local extensional tectonic activity, rifts and graben following arc-continent collision, faults, or fractures. Archaean greenstone belt.

Associated deposit types:

Epithermal quartz-adularia veins in Japan are regionally associated but younger than Kuroko deposits. Volcanogenic Mn, Algoma Fe.

Deposit description

Mineralogy:

Upper stratiform massive zone (black ore) — pyrite + sphalerite + chalcopyrite pyrrhotite galena barite tetrahedrite-tennantite bornite; lower stratiform massive zone (yellow ore) — pyrite + chalcopyrite sphalerite pyrrhotite magnetite; stringer (stockwork) zone — pyrite + chalcopyrite (gold and silver). Gold in two mineral associations: gold-zinc (-lead-silver-barite), typical of lead-zinc rich deposits; and gold-copper. Gahnite in metamorphosed deposits. Gypsum/anhydrite present in some deposits.

Texture/structure:

Massive (>60% sulphides); in some cases, an underlying zone of ore stockwork, stringers or disseminated sulphides or sulphide-matrix breccia. Also slumped and redeposited ore with graded bedding.

Alteration:

Adjacent to and blanketing massive sulphide in some deposits — zeolites, montmorillonite (and chlorite?); stringer (stockwork) zone — silica, chlorite, and sericite; below stringer — chlorite and albite. Cordierite and anthophyllite in footwall of metamorphosed deposits, graphitic schist in hanging wall.

Ore controls:

Towards the more felsic top of volcanic or volcanic-sedimentary sequence. Near centre of felsic volcanism. May be locally brecciated or have felsic dome nearby. Pyritic siliceous rock (exhalite) may mark horizon at which deposits occur. Proximity to deposits may be indicated by sulphide clasts in volcanic breccias. Some deposits may be gravity transported and deposited in paleodepressions in the sea floor. In Japan the best deposits have mudstone in the hanging wall. In Tasmania the gold-zinc association is located in the higher parts of the massive sulphide ores whereas the gold-copper is located at the stratigraphic bottom of the massive sulphide ores and in the central portion of the copper-rich stringer zone.

Weathering:

Yellow, red, and brown gossans. Gahnite in stream sediments near some deposits.

Geochemical signature:

Gossan may be high in Pb and typically Au is present. Adjacent to deposit — enriched in Mg and Zn, depleted in Na. Within deposits — Cu, Zn, Pb, Ba, As, Ag, Au, Fe.

Examples

Rosebery, AUTS	Huston and Large, 1988; Large *et al.*, 2001
Mt Lyell, AUTS	Hills, 1990; Corbett, 2001; Huston and Kamprad, 2001
Hellyer, AUTS	McArthur and Dronseika, 1990; Gemmell and Fulton, 2001
Mt Morgan, AUQL	Taube, 1990
Brittania, CNBC	*Payne et al., 1980*
Buchans, CNNF	*Swanson et al., 1981*
Kidd Creek, CNON	*Walker et al., 1975*

Known deposits and mineral prospects in Tasmania

All the known deposits of this type are associated with the Cambrian Mount Read Volcanics in the Dundas Element, where the distribution of gold is closely related to the distribution of massive sulphide deposits. At the VHMS deposits at Hellyer, Rosebery and Que River gold mineralisation is concentrated in the stratigraphically higher parts of the massive sulphide ores and is commonly associated with high grades of zinc, lead and barium (Large, 1990). Deposits such as Mount Lyell are characterised by copper-gold association and the mineralisation is concentrated in the copper-rich stratigraphic bottom of the massive sulphide and also in the central portion of the copper-rich stringer zone (Large, 1990). The gold mineralisation at the Henty gold deposit (Callaghan, 2001) is of particular interest as it is the only known deposit of significant importance hosted by the Tyndall Group of the Mount Read Volcanics. The ore is characterised by a very high average gold grade of 32 g/t and is hosted by an intensively brecciated, highly silicified zone (Taheri and Green, 1990).

Gold mineralisation in these deposits is closely linked with the processes that formed volcanic-hosted massive sulphide ores with hydrothermal fluids selectively refining and enriching parts of the massive sulphide ores with gold.

The formation of volcanic-hosted massive sulphide deposits is attributed to hydrothermal systems that operated during the development of Mount Read Volcanics in the extensional rift formed after the arc-continental collision that took place in the lower to middle Cambrian. The presence of longitudinal faults, such as the Henty and Great Lyell faults, could have controlled the locations of mineralisation.

Recently the role of Cambrian granites in the genesis of VHMS and the associated gold mineralisation has been highlighted. It is suggested that two bodies of Cambrian granites (Murchison Granite and Darwin Granite), which intrude the eastern margin of the Central Volcanic Complex, could have played an important role in the formation of VHMS and gold mineralisation. This is supported by the presence of a series of copper-gold occurrences (e.g. Prince Darwin, Jukes Pty, Lake Selina) along the margins of the granite sheet. The Mount Lyell Cu-Au VHMS deposits are also located immediately west of the projected continuation of the subsurface granite (Large *et al.*, 1996).

Assessment criteria

1. Distribution of rocks belonging to the Mount Read Volcanics, in particular the rocks of the Central Volcanic Complex.
2. Presence of major fault zones such as the Henty Fault and the Great Lyell Fault.
3. Presence of Cambrian granites, and or basaltic-andesitic volcanic centres.
4. Distribution of known deposit type and occurrences.

Two tracts defining the mineral potential for gold associated with massive sulphide deposits have been defined. These are identical to the prospectivity tracts defined for Kuroko-style deposits.

Assessment: Tract AU2a/H/C-D

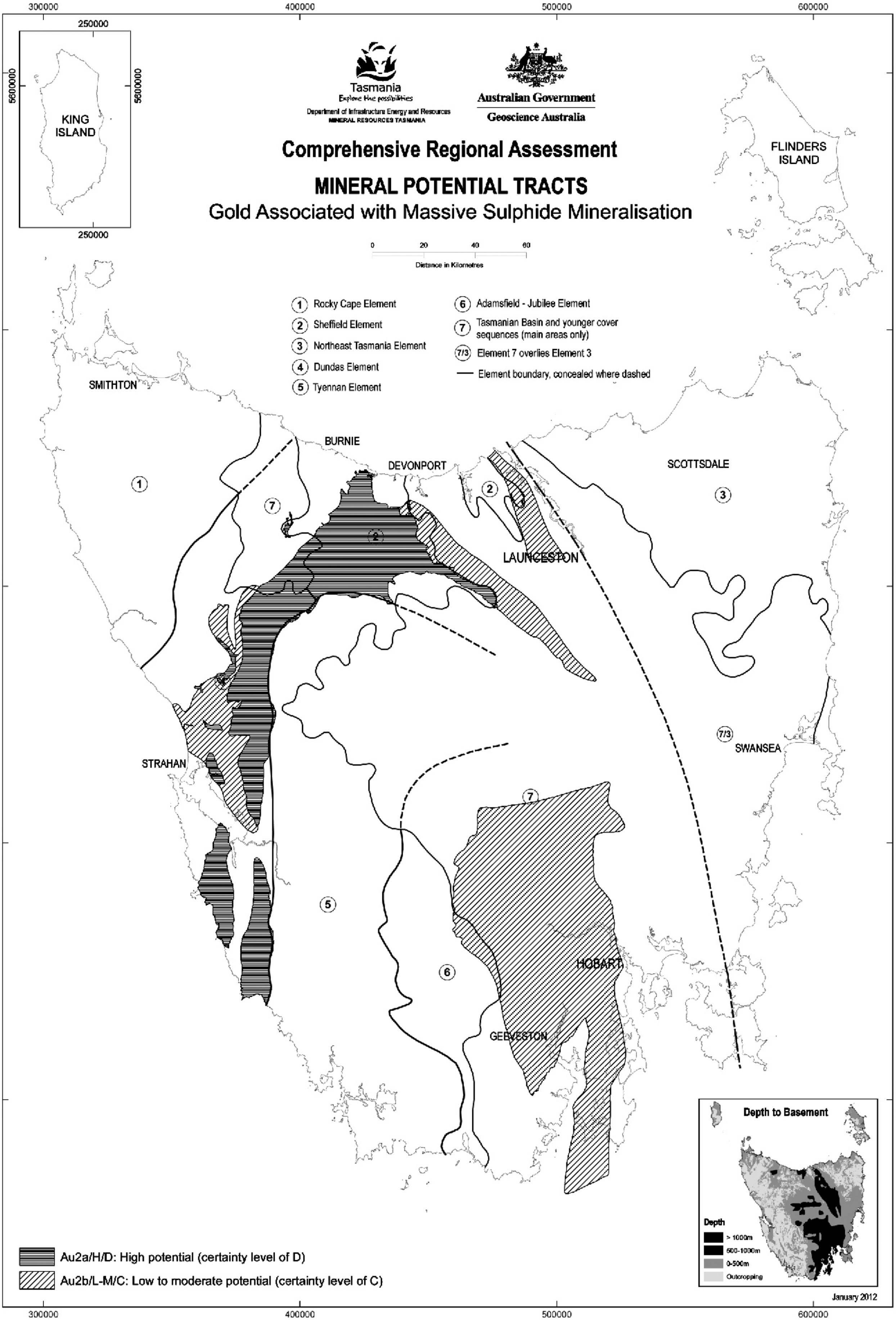
This tract is based on the surface distribution of the Mount Read Volcanics and associated rocks and includes some areas under shallow Ordovician–Cenozoic cover. It has a high potential and certainty level.

Assessment: Tract Au2b/L-M/B

This tract is based on the subsurface distribution of the Mount Read Volcanics and associated rocks as predicted by the 3D geological model of Tasmania. This tract is typically at depths of between 500–1000 m below the surface and has low to moderate potential with a moderate certainty level.

Economic significance

Volcanic-hosted massive sulphide deposits are an important source for gold and silver. Global grade/tonnage models for these types of deposit indicate that 90% of these deposits have more than 0.12 million tonnes of ores, 50% have more that 1.5 million tonnes and 10% have more than 18 million tonnes. Similarly in 50% of these deposits the ores have more than 0.16 g/t gold and 13 g/t silver, and 10 % have more than 2.3 g/t gold and 100 g/t silver. Major VHMS deposits in Tasmania also show similar concentrations of gold and silver ranging between 0.3 and 3.4 g/t gold and between 2 and 200 g/t silver (Large, 1992). The exception is the Henty gold deposit where the ore is characterised by a total pre-mining resource of 5.741 million tonnes at 8.29 g/t gold.



Map 20 — Model M20

MODEL M21: Polymetallic volcanic-hosted massive sulphide (VHMS) deposits

Model description

Description of the model after Donald A. Singer, modified by Michael Vicary and Geoffrey R. Green.

Approximate synonyms

Noranda type, Kuroko type (Model 28a of Cox and Singer, 1986), felsic to intermediate type volcanic-hosted massive sulphide deposits.

Description

Copper and zinc-bearing massive sulphide deposits in marine volcanic rocks of intermediate to felsic composition.

General references

Ishihara, 1974; *Franklin et al., 1981*; *Hutchinson et al., 1982*; *Ohmoto and Skinner, 1983*; Large, 1992; Allen and Barr, 1990; Large *et al*., 2001; Gemmell *et al*., 1998; Solomon and Groves, 1994, 2000.

Geological environment

Rock types:

Marine rhyolite, dacite, and subordinate andesite and basalt and associated sediments, principally organic-rich mudstone or shale. Pyritic, siliceous shale.

Textures:

Flows, epiclastic rocks, pyroclastic rocks, breccia, bedded sediment, and in some cases felsic domes.

Age range:

Archaean through Cenozoic.

Depositional environment:

Hot springs related to marine volcanism, in many cases with anoxic marine conditions or sub-sea floor replacement/ pore fillings. Lead-rich deposits generally associated with abundant fine-grained volcaniclastic sediments.

Tectonic setting(s):

Island arc, back-arc basin, epicontinental volcanic rift. Local extensional tectonic activity, faults, or fractures. Archaean greenstone belt.

Associated deposit types:

Epithermal quartz-adularia veins in Japan are regionally associated but younger than Kuroko deposits, hybrid VHMS-epithermal deposits, Mt Lyell-style Cu-Au deposits. Volcanogenic Mn, Algoma Fe.

Deposit description

Mineralogy:

Upper stratiform massive zone (black ore) — pyrite + sphalerite + chalcopyrite   pyrrhotite   galena   barite   tetrahedrite-tennantite   bornite; lower stratiform massive zone (yellow ore) — pyrite + chalcopyrite   sphalerite   pyrrhotite   magnetite; stringer (stockwork) zone — pyrite + chalcopyrite (gold and silver). Gahnite in metamorphosed deposits. Gypsum/anhydrite present in some deposits.

Texture/structure:

Massive (>60% sulphides); in some cases, an underlying zone of ore stockwork, stringers or disseminated sulphides or sulphide-matrix breccia. Also slumped and redeposited ore with graded bedding or matrix-supported breccia.

Alteration:

Adjacent to and blanketing massive sulphide in some deposits — zeolites, montmorillonite (and chlorite?); stringer (stockwork) zone — silica, chlorite and sericite; below stringer — chlorite and albite. Cordierite and anthophyllite in footwall of metamorphosed deposits, graphitic schist in hanging wall.

Ore controls:

Towards the more felsic top of volcanic or volcanic-sedimentary sequence. Near centre of felsic volcanism. May be locally brecciated or have felsic dome nearby. Pyritic siliceous rock (exhalite) may mark horizon at which deposits occur. Proximity to deposits may be indicated by sulphide clasts in volcanic breccias. Some deposits may be gravity-transported and deposited in paleo-depressions in the sea floor. In Japan the best deposits have mudstone in the hanging wall.

Weathering:

Yellow, red and brown gossans. Gahnite in stream sediments near some deposits.

Geochemical signature:

Gossan may be high in Pb and typically Au is present. Adjacent to deposit — enriched in Mg and Zn, depleted in Na. Within deposits — Cu, Zn, Pb, Ba, As, Ag, Au, Se, Sn, Bi, Fe.

Examples

Rosebery, AUTS	Lees *et al*., 1990; Large *et al*., 2001
Hellyer, AUST	Gemmell and Fulton, 2001
Benambra, AUVT	Allen and Barr, 1990
Furutobe, JAPN	Kuroda, 1983
Brittania, CNBC	*Payne et al., 1980*
Buchans, CNNF	*Swanson et al., 1981*

Known deposits and mineral prospects in Tasmania

Most known mineral deposits and occurrence of the Kuroko-type VHMS deposits are located within the Dundas Element in association with the Mount Read Volcanics and form a continuum with epithermal and porphyry-style mineralisation (Large *et al*., 2001). This continuum largely reflects the complex volcanic architecture of the Mount Read Volcanics during volcanism. The VHMS or Kuroko style Pb-Zn mineralisation reflects deposition at or near the sea floor in a moderate to deep water environment, although minor deposits have been recorded in shallow water facies. The Cu-Au mineralisation in the Mt Lyell area is generally associated with shallow water facies and has features typical of high sulphidation to low sulphidation mineralisation.

Field and chemical evidence suggests that both styles of mineralisation occurred during Cambrian volcanism, but there is debate whether the mineralisation occurred during one discrete period or occurs at two or more distinct stratigraphic levels in the volcanic pile. Within individual deposits ore bodies commonly occur at the contact between volcanic suites and are typically hosted by epiclastic rocks in sedimentary horizons deposited between the major volcanic episodes.

On a regional scale the presence of longitudinal faults (e.g. Henty Fault and Great Lyell Fault) is an important controlling factor. These faults are thought to control both the locations of mineralisation and the younger graben-fill volcanic sequence. Cross structures may be important in focussing fluids.

Most deposits are overprinted by deformation, metamorphism and remobilisation. Devonian deformation is also thought to have affected the Rosebery deposits where the disposition of ore lenses is attributed to this deformation (Solomon and Groves, 1994), but this is in some dispute (e.g. Huston and Large, 1988). The Hellyer and Que River deposits also show the effects of Devonian deformation; Hellyer sits on the crest of a broad anticline whereas Que River lies in an almost isoclinal synclinal structure. It has undergone substantial recrystallisation and transposition (Solomon and Groves, 1994).

All mineral deposits of this type are characterised by zones of alteration. Major conformable alteration zones occur in the immediate footwall of most ore bodies and are dominated by quartz-sericite pyrite alteration and patchy development of chlorite and carbonate (Gemmell and Large, 1992). Hanging wall alteration (sericite-chlorite-quartz) is of very low intensity, is commonly devoid of sulphides, and is best developed above the thickest parts of the massive sulphide body. In alteration pipes with significant copper stringer mineralisation, a central zone of intense chloritic alteration is typical. It is overprinted by silica alteration. The chloritic zone is surrounded by a sericite-rich envelope (Gemmell and Large, 1992). Carbonate alteration is a common feature in the footwall alteration zones.

Although the formation of these deposits is attributed to volcanic-hydrothermal systems associated with the Mount Read Volcanics the role of granitic magmas during the generation of massive sulphide deposits has been stressed by many workers (Solomon, 1976, 1981; Polya *et al*., 1981). In recent years Large *et al*. (1996) have drawn attention to the presence of Cambrian granitoids in the area, suggesting that these granitoids and hydrothermal systems generated by them might have played an important role in the formation of massive sulphide deposits.

Assessment criteria

1. Distribution of rocks belonging to the Mount Read Volcanics.
2. Presence of large fault zones such as the Henty Fault and the Great Lyell Fault.
3. Presence of Cambrian I-type granitoids, and or basaltic-andesitic volcanic centres.
4. Overprinting by deformation and metamorphism.
5. Distribution of known base metal deposits and mineral occurrences.

Two tracts defining the mineral potential for Palaeozoic VHMS deposits have been defined.

Assessment: Tract BM1a/H/B-D

This tract is based on the surface distribution of the Mount Read Volcanics and associated rocks and included some areas under shallow Ordovician–Cenozoic cover. It has a high potential and certainty level.

Assessment: Tract BM1b/M/B-C

This tract is based on the subsurface distribution of the Mount Read Volcanics and associated rocks as predicted by the 3D geological model of Tasmania. This tract is typically at depths of between 500–1000 m below the surface and has low-moderate potential with a moderate certainty level.

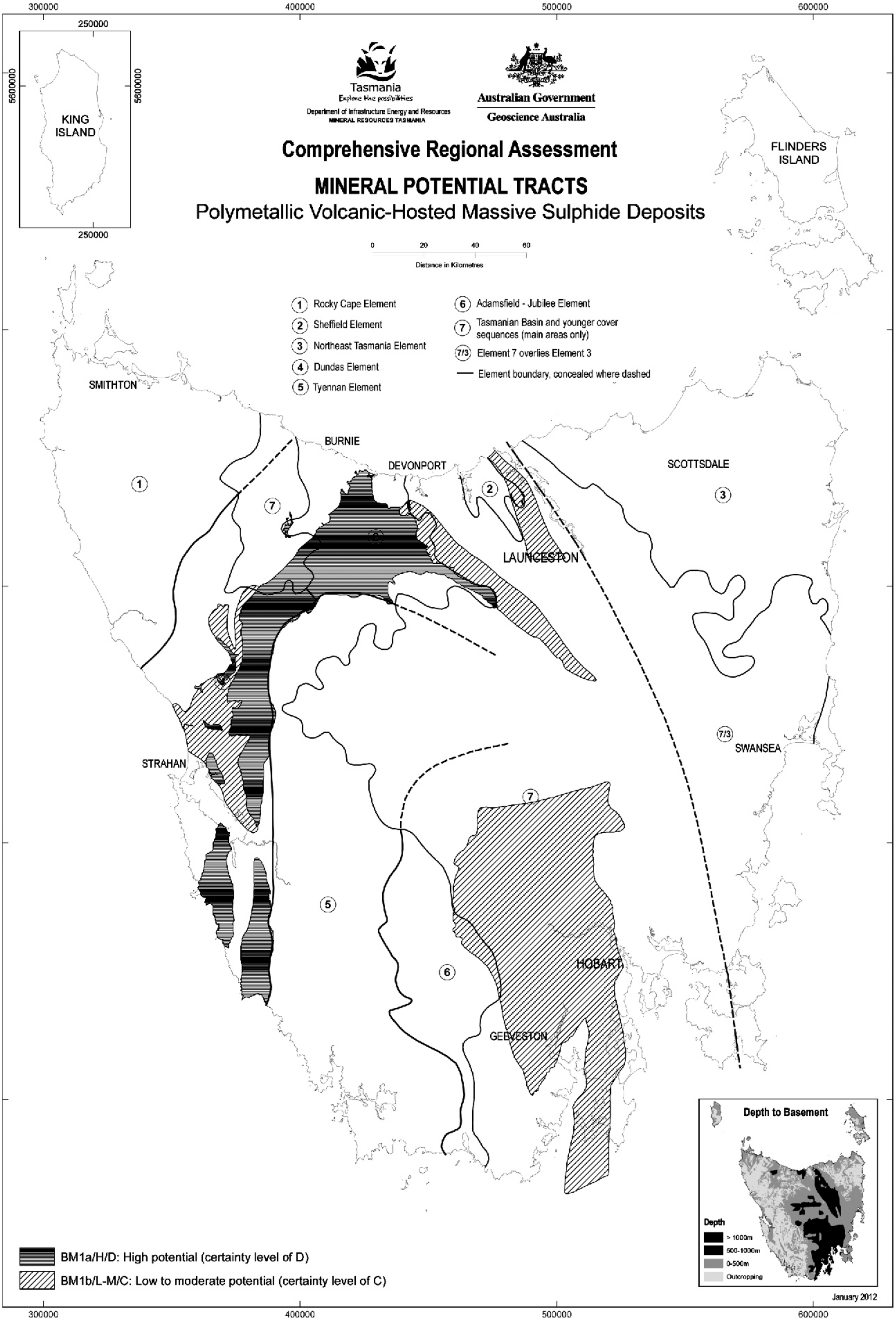
Associated deposit types

Apart from generating base metal massive sulphide deposits, volcanic hydrothermal systems are capable of forming several associated styles of mineralisation. Often overprinting of deformation and metamorphism can result in remobilisation of earlier mineralisation. Additionally weathering and oxidation of primary ores can form new styles of mineralisation. Some of the common known styles of mineralisation associated with VHMS deposits in the area are:

1. Disseminated chalcopyrite-pyrite mineralisation (e.g. Prince Lyell, Cape Horn, Western Tharsis, Lyell-Comstock, Jukes Pty, East Darwin, Garfield River).
2. Shallow water Au-rich stratabound deposits (e.g. Henty).
3. Bornite-chalcopyrite mineralisation (e.g. North Lyell, 12 West, Lyell Comstock) resulting from the reworking of Cambrian sulphide mineralisation during Devonian magmatism.
4. Barite mineralisation such as at Mount Charter, Hellyer, Rosebery, The Hummocks, Lower Beulah, Madam Howard.
5. Copper-clay deposits in altered limestone.

Economic significance

Volcanic-hosted massive sulphide deposits are significant sources for copper, lead and zinc. Some of these deposits can also have up to a few tens of ppm of gold and a few hundreds of ppm of silver. Global grade/tonnage models for this type of deposit indicate that 90% of these deposits have more than 0.12 million tonnes of ores, 50% have more than 1.5 million tonnes and 10% have more than 18 million tonnes. Similarly, in 90% of these deposits the ores have more than 0.45% copper, 50% have more than 1.3% copper and 2.0% zinc, and 10% have more than 3.5% copper, 8.7% zinc and 1.9% lead.



Map 21 — Model M21

MODEL M22: Mafic extrusive (flood basalt)-related Ni-Cu-PGE

Model description

Description of the model based on Naldrett (2004).

Approximate synonyms

Noril'sk Cu-Ni-PGE

Description

Massive to disseminated sulphides in tholeiitic complexes of mafic to ultramafic rocks.

Geological environment

Rock types:

Flood basalts, picritic intrusive rocks, picritic gabbro, norite, olivine gabbro, dolerite, intrusive and volcanic breccias. Often associated with evaporites or some external source of sulphur. Evaporites at Noril'sk are overlain by coal seams.

Age range:

Paleozoic, in particular Permian–Triassic.

Depositional environment:

Extensive basaltic flood volcanism (e.g. Siberian Traps) associated with intracontinental rift zones; sulphide deposits hosted by sub-volcanic differentiated tholeiitic sills (30 to 350 m thick) which acted as feeders to vast volumes of overlying basaltic magmas. Best mineralisation is usually developed in intrusions originally emplaced in the deepest part of the volcanic basin.

Tectonic setting:

Intracontinental rift zones. In Noril'sk region the Precambrian basement is different from the basement in the remainder of the Siberian Platform. In the latter the basement is Archaean, overlain by thin, relatively undisturbed Proterozoic and Paleozoic sediments, whereas in the Noril'sk region the north–south trending rift contains more than ~4 km of Paleozoic sediments.

Deposit description

Textures:

Aphyric, poikilophitic, porphyritic, glomeroporphyritic, intersertal, cumulate.

Mineralogy:

Pyrrhotite, pentlandite, chalcopyrite, cubanite, millerite, vallerite, pyrite, bornite, gersdorffite, sperrylite, PGE alloys, polarite, PGE tellurides, arsenides and antimonides.

Texture/structure:

Lenses, layers of massive, matrix and disseminated sulphides.

Alteration:

Contact metamorphic aureoles are well developed near main intrusive rocks. The presence of aureoles may be indicative of intrusions through which large volumes of magma could have flowed.

Ore controls:

Metals sourced from tholeiitic basaltic magma possibly related to mantle plume. Sulphur is sourced from non-magmatic rocks such as evaporites or sulphides. Deep crustal faults function as feeder zones for melt. Separation of sulphide melt is triggered by assimilation of crustal sulphur. Coal seams or other reductant could be important if the sulphur is sourced from evaporites. The presence of rocks with relatively primitive composition (Mg number ~0.55), such as picrites, is important as they indicate the parent magma to be sufficiently hot to initiate erosion and assimilation of country rocks. The role of contamination and assimilation is downplayed in another model (Arndt *et al.*, 2003) which suggests that mineralisation was formed from a second magma that was less contaminated. Channelised flow of melts is essential to create conditions of maximum scavenging of Ni, Cu and PGEs. Mineralisation is concentrated along hydrodynamic traps within the channels, such as feeder zones. Post-mineralisation tectonics is very critical to uplift of mineralised intrusive rocks formed in the deeper parts of a volcanic basin.

Geochemical and geophysical signatures:

Depletion in chalcophile elements (Cu, Ni, PGEs) in large pile of volcanic rocks in volcanic-intrusive complex.

Examples

Noril'sk (Russia), Duluth Complex (Lake Superior Region, North America), Insizwa Complex (Karoo Flood Basalt, South Africa).

No known deposits in Australia. Possible (unmineralised?) analogues in Australia are Antrim Plateau Volcanics and Hart Dolerite (Kimberley), Cooya Pooya Dolerite (Pilbara), Zamu and Oenpelli Dolerite (Pine Creek); Quaternary flood basalts (Victoria).

Jurassic dolerites in Tasmania

Jurassic dolerites in Tasmania were formed from a large volume of tholeiitic magma which intruded in the Tasmanian crust during the Middle Jurassic. The dolerites formed mainly as sills and are exposed over an area of 30 000 km^2. Most intrusions have the form of a flattened cone connected to a source(s) at the deepest point whereas the limbs are generally concordant sills (Seymour *et al.*, 2007). Contact metamorphic aureoles are confined to within a few metres of the intrusion contacts. The dolerites show geochemical affinities with similar rocks of the Ferrar Group in Antarctica and constitute part of a large magmatic province possibly related to interaction with mantle plume. Chilled margin dolerite samples range ~70–90 ppm for Ni, ~60–80 ppm Cu, ~80–120 ppm Cr and 0.05% S. Chilled margin sample composition is very uniform over the extent of outcrop (Hergt, 1987). The sulphide content in the vicinity of feeder conduits is not known.

The Sr, O and Os isotope data suggest continental contamination of mantle derived magmas. The data suggest that contamination could not have occurred during intrusion in the crust but the source from which the melt was derived was itself contaminated (Hergt and Brauns, 2001; Brauns *et al.*, 2000). The possibility of local-scale introduction of sulphur in the magma cannot be ruled out completely because the dolerites intruded sediments of the Lower Parmeener Supergroup which contain pyritic siltstone.

Leaman (1972, 1975) used detailed gravity surveys over an area of 2300 km^2 to locate numerous feeders to dolerite sills. Centres appear to be pipes up to 1.6 km in diameter up to 11–12 km in depth. The dolerite feeders occupy major fractures in the crust.

No known occurrence of Cu, Ni, and PGE has been reported in the area of Jurassic dolerites. The nickel in the Forster Au-Zn-Ni prospect (Calver *et al.*, 2007) in the Glovers Bluff inlier could have been sourced from Jurassic dolerite but it is unlikely to be directly linked to Jurassic dolerite.

Assessment criteria

1. A large volume of relatively primitive (Mg number ~0.55) magma including olivine-phyric magma (picritic rocks).
2. Evidence of depletion of Cu, Ni, and PGEs in some of the rocks/magmas.
3. Signs of sulphur saturation of magma (mafic-ultramafic rocks with >400 ppm sulphur). Sulphur saturation generally occurs late in the evolution of the volcanic-intrusive complex.
4. Source of sulphur in the country rock. If sulphur is from evaporites, a reductant (e.g. coal seams) is essential. Sulphur isotope composition of sulphides may indicate assimilation of crustal sulphur.
5. A structural setting which exposes intrusive rocks feeding the lavas and feeder zones.
6. Known deposits and/or occurrences of Cu, Ni and PGEs.

Suggestion for drawing mineral potential tracts

Two tracts can be delineated. The first tract will coincide with the outline of Jurassic dolerites. It will have low level of potential with low level of certainty. The second tract can be drawn by outlining areas where feeder zones have been mapped. These areas will have low to moderate potential with low level of certainty.

Assessment: Tract Noril'sk CuNi/L-M/B

This tract includes the mapped extent of Jurassic dolerite in Tasmania. The dolerites represent a large volcanic-intrusive complex exposed over an area of 30 000 km^2. Sulphur concentration in the rock varies between 1100 ppm and 200 ppm. Some samples taken from the chilled margin show concentration greater than 400 ppm (varying between 500 ppm and 1100 ppm). This indicates that mafic rocks reached sulphur saturation levels (~400 ppm) and the saturation probably occurred late, which constitutes a favourable indicator of Cu-Ni-PGE mineralisation.

Available information does not report the presence of picritic rocks in the complex. The presence of these rocks is regarded as critical to form Noril'sk-style mineralisation. The Sr, O and Os isotope data suggest that contamination of mafic-ultramafic magma could not have occurred during intrusion in the crust. Assimilation of sulphur-rich country rocks is considered a critical factor of fertile systems of this type.

No known occurrences of copper, nickel and platinum group elements have been reported in the area.

The tract is assigned low to moderate level of potential with a low level of certainty.

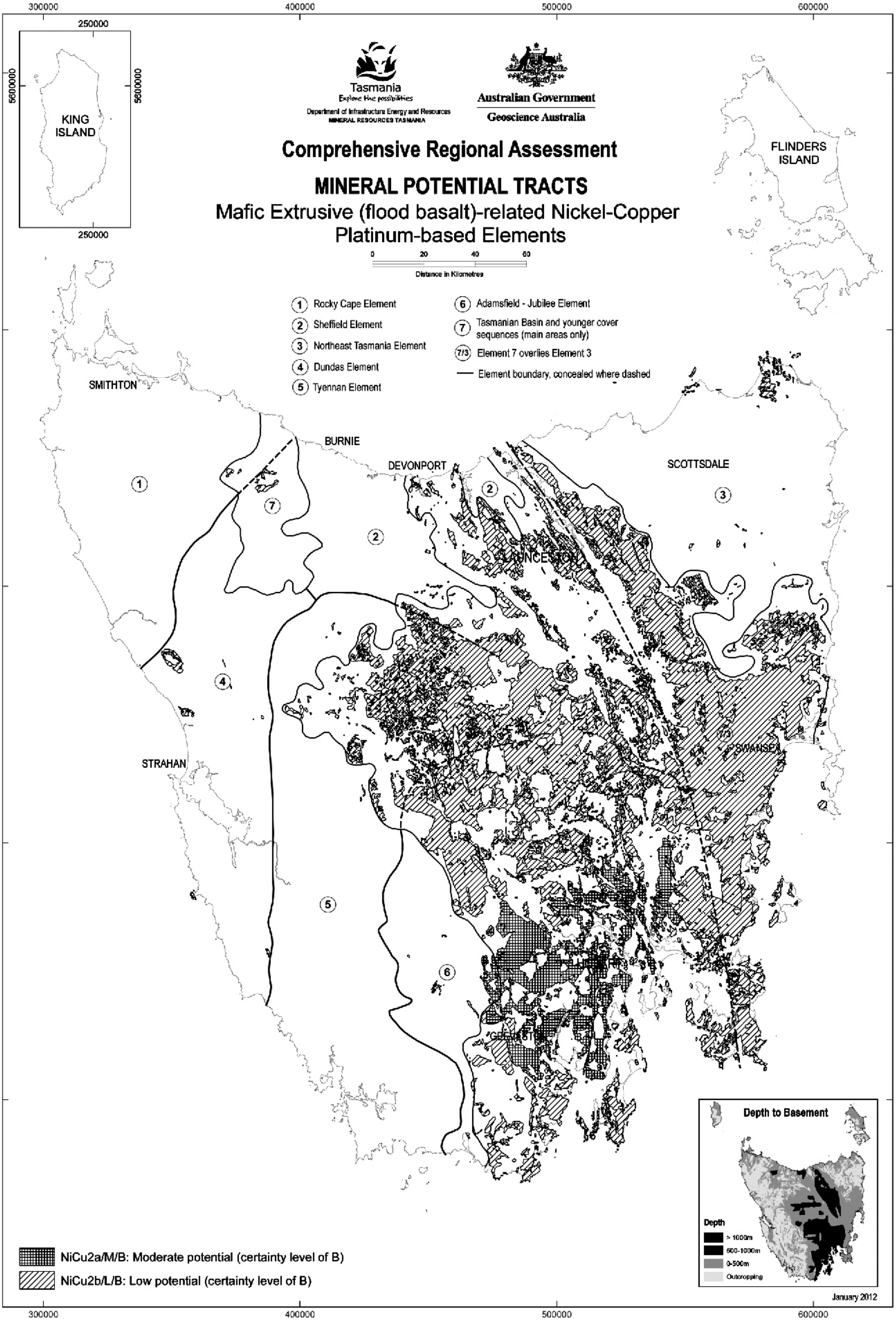
Assessment: Tract Noril'sk CuNi/M/B

This tract is delineated by selecting areas of Jurassic dolerite where feeder zones have been mapped. At this stage feeder zones have been mapped only in limited parts (Hobart 1:50 000 scale geological map sheet) of the area occupied by Jurassic dolerite. The presence of feeder zones is an essential feature of mineralised systems of this type because sulphide melt localised near the feeder zone is able to scavenge copper, nickel and platinum group elements from mafic melt passing through the feeder zones.

The tract is therefore assigned a moderate level of potential with a low level of certainty.

Economic significance

Flood-basalt type of mafic complexes have formed super-giant Ni-Cu-PGE deposits at Noril'sk. The size of deposit is controlled by several interconnected geological features (Naldrett, 2004).



Map 22 — Model M22

MODEL M23: Descriptive model of alluvial placer tin (Model 39e of Cox and Singer, 1986)

Model description

Description of the model after Bruce L. Reed.

Description

Cassiterite and associated heavy minerals in silt to cobble-size nuggets concentrated by the hydraulics of running water in modern and fossil stream beds.

General references

Hosking, 1974; *Taylor, 1979*; *Sainsbury and Reed, 1973*.

Geological environment

Rock types:

Alluvial sand, gravel and conglomerate indicative of rock types that host lode tin deposits.

Textures:

Fine to very coarse clastic.

Age range:

Commonly late Tertiary to Holocene, but may be any age.

Depositional environment:

Generally moderate to high-level alluvial, where stream gradients lie within the critical range for deposition of cassiterite (for example, where stream velocity is sufficient to result in good gravity separation but not enough so the channel is swept clean). Stream placers may occur as offshore placers where they occupy submerged valleys or strandlines.

Tectonic setting(s):

Alluvial deposits derived from Paleozoic to Cenozoic accreted terranes or stable cratonic fold belts that contain highly evolved granitoid plutons or their extrusive equivalents. Tectonic stability during deposition and preservation of alluvial deposits.

Associated deposit types:

Alluvial gravels may contain by-product ilmenite, zircon, monazite and, where derived from cassiterite-bearing pegmatites, columbite-tantalite. Economic placers are generally within a few (less than eight) kilometres of the primary sources. Any type of cassiterite-bearing tin deposit may be a source. The size and grade of the exposed source frequently has little relationship to that of the adjacent alluvial deposit.

Deposit description

Mineralogy:

Cassiterite; varying amounts of magnetite, ilmenite, zircon, monazite, allanite, xenotime, tourmaline, columbite-tantalite, garnet, rutile, gold, sapphire and topaz may be common heavy resistates.

Texture/structure:

Cassiterite becomes progressively coarser as the source is approached; euhedral crystals indicate close proximity to primary source. Where a marine shoreline intersects or transgresses a stream valley containing alluvial cassiterite the shoreline placers normally have a large length-to-width ratio.

Ore controls:

Cassiterite tends to concentrate at the base of stream gravels and in traps such as natural riffles, potholes and bedrock structures transverse to the direction of water flow. The richest placers lie virtually over the primary source. Streams that flow parallel to the margin of a tin-bearing granite are particularly favourable for placer tin accumulation.

Geochemical signature:

Anomalously high amounts of Sn, As, B, F, W, Be, W, Cu, Pb, Zn. Panned concentrate samples are the most reliable method for detection of alluvial cassiterite.

Examples

South East Asian tin fields (*Hosking, 1974*; *Newell, 1971*; *Simatupang et al., 1974*; *Westerveld, 1937*)

Known deposits and mineral prospects in Tasmania

Alluvial tin is widespread in western and northern Tasmania and is derived predominantly from primary deposits in the pre-Carboniferous rocks of the Dundas Trough and in the Northeast Tasmania Element. The most important area is in the Northeast Tasmania Element, where greisenised granites served as the primary source for numerous small to medium-sized deposits. In western Tasmania some alluvial tin was derived from veins, skarns and replacement-style deposits.

Most known alluvial tin prospects in Tasmania are thought to be Tertiary and Quaternary in age and the known workings are located within alluvium and eluvium in slopes and terraces. Some of the placer tin may be reworked from paleoplacers, from Permian to Tertiary in age.

Many of the major placer tin deposits worked in the northeast were also rich in gemstones and gold (e.g. the Boobyalla and Ringarooma rivers), whilst tin was associated with some gold and osmiridium-rich placers in western Tasmania.

Northeast Tasmania produced ~40 000 t of tin (to 1967). One of the largest alluvial fields was in the Ringarooma River, which produced about 21 000 t of tin.

Assessment criteria

1. Presence of granites.
2. Distribution of alluvial, eluvial and lacustrine deposits.
3. Distribution of rocks of Tertiary and Quaternary ages.
4. Distribution of alluvial tin deposits.

Assessment: Tract Sn5/M-H/B-C

This tract is drawn based on the distribution of known placer deposits, primary tin deposits and associated Tertiary and Quaternary sediments. Alluvial tin has been recovered from the Tertiary and Quaternary sediments and more deposits are present in areas where these sediments are not mapped in great detail.

The potential for placer tin is moderate to high with a moderate to high certainty level.

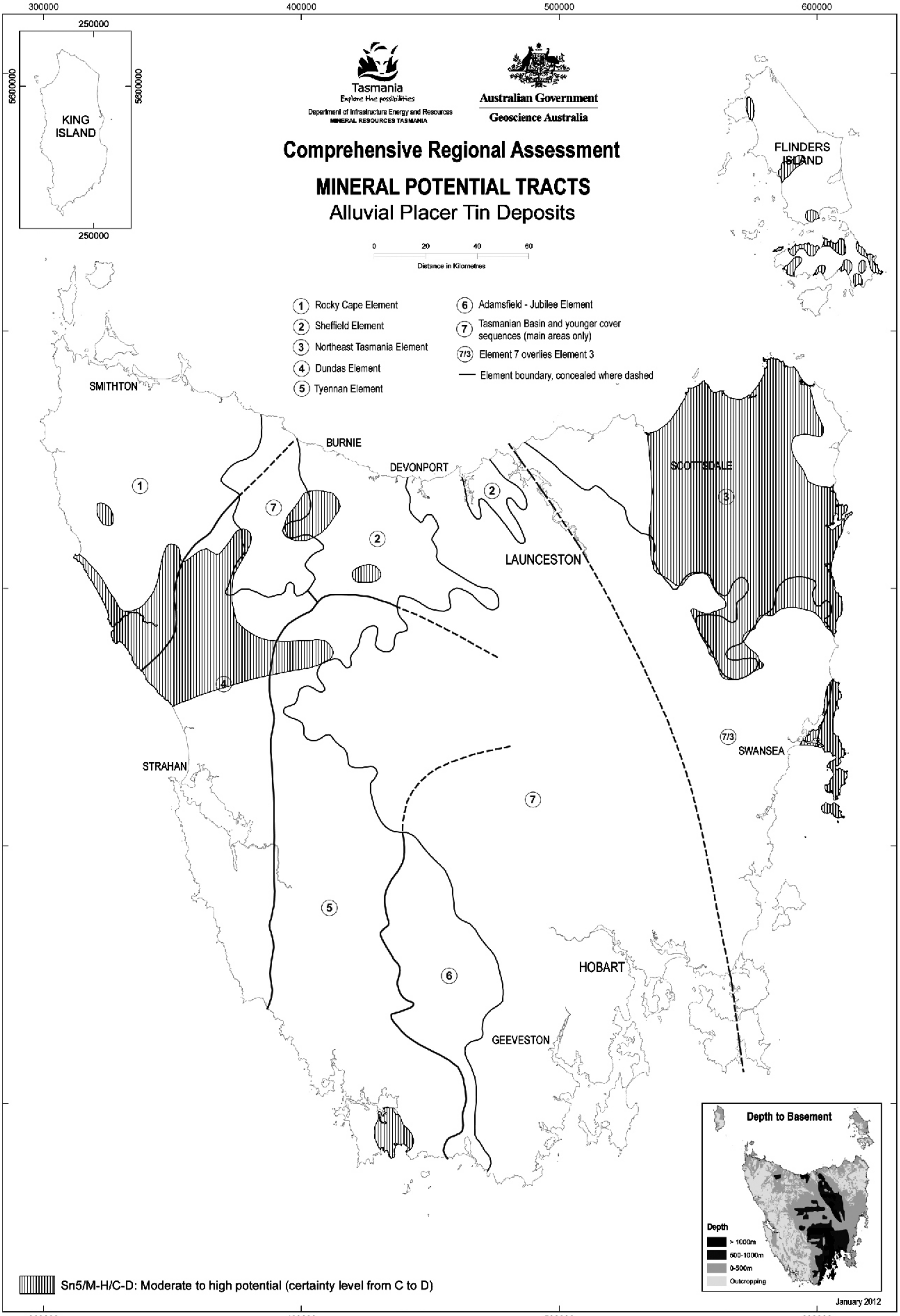
Some minor modifications to the boundaries of the tract as presented in the previous RFA assessment have been made to more accurately reflect the known distribution of these deposits.

Related deposits

Precious and semi-precious stones

Several small occurrences of precious and semi-precious stones are reported within Tasmania. Some of the important ones include sapphire, topaz, zircon, chrysoberyl, emerald, garnet and ruby, and these mostly occur in alluvial tin-bearing deposits in the Northeast Tasmania Element (Jennings *et al*., 1967). Amethyst and various other varieties of quartz have also been found in the same deposits. Devonian granitoids are important source rocks for alluvial accumulations of precious and semi-precious stones but some, including sapphire, are sourced from Eocene basaltic rocks (Yim, 1991).

Devonian granitoids, Tertiary basalt and alluvial deposits associated with them have a potential for forming accumulations of precious and semi-precious stones, but available information is not sufficient to assess the potential for these within Tasmania.



Map 23 — Model M23

MODEL M24: Mount Lyell style copper gold deposits

Model description

Description of the model by Michael J. Vicary and Geoffrey R. Green.

Approximate synonym

Porphyry copper-gold deposits; volcanogenic massive sulphide, felsic to intermediate volcanic type; high sulphidation epithermal deposits.

Description

Dominantly disseminated chalcopyrite in quartz-phengite-chlorite-pyrite-iron oxide altered felsic to intermediate volcanic rocks; significant bornite and chalcopyrite in cherty quartz pyrophyllite barite hematite or quartz-sericite altered volcanic rocks, significant massive pyrite-chalcopyrite tetrahedrite-tennantite; minor massive pyrite-galena-sphalerite-arsenopyrite-tennantite; minor native copper-cuprite-tenorite-digentite-covellite-bornite in clay ('copper clay deposits').

General references

Walshe and Solomon, 1981; Corbett, 2001; Huston and Kamprad, 2001; K. D. Denwer (pers. comm.).

Geological environment

Rock types:

Rhyolite and andesite flows and volcaniclastic rocks coeval with intrusive rocks.

Textures:

Intrusive rocks are porphyritic with fine to medium-grained groundmass.

Age range:

Middle to Late Cambrian. Copper clay deposits are hosted in Ordovician limestone and are of Ordovician or younger age.

Depositional environment:

In porphyry intruding coeval volcanic rocks. Porphyry bodies may be dykes. Associated with underlying bodies of magnetite-series granite.

Tectonic setting(s):

Post collisional rift-related volcanism.

Associated deposit types:

Porphyry Cu-Au-Mo; epithermal Ag-Au, volcanic-hosted massive sulphide deposits.

Deposit description

Mineralogy:

Chalcopyrite bornite; traces of native gold, electrum. Quartz + white mica biotite magnetite hematite chlorite.

Texture/structure:

Disseminations and veinlets.

Alteration:

Quartz magnetite biotite (chlorite) in interior of system, passing upward to quartz-chlorite-phengite with quartz pyrophyllite zunyite; quartz pyrophyllite barite hematite or quartz-sericite topaz quartz pyrophyllite barite hematite or quartz-sericite woodhouseite barite hematite or quartz-sericite at the top of the alteration system. Outer propylitic zone. Massive sulphide deposits appear to be early in the evolving hydrothermal history.

Ore controls:

Veinlets and fractures of quartz, sulphides, magnetite, hematite, biotite or chlorite are closely spaced. Ore zones have ellipsoidal bell shapes.

Weathering:

Hematite-goethite gossan above massive pyrite-chalcopyrite was the discovery outcrop.

Geochemical signature:

Central Cu, Au, Ag. System may have magnetic high over intrusion surrounded by magnetic low over pyrite halo.

Geophysical signature:

Magnetic signature associated with hydrothermal magnetite and magnetite series granite. IP and EM responses.

Examples

Mt Lyell, Tasmania (type example)
Garfield, Tasmania

Known deposits and mineral prospects in Tasmania

Recent research has revealed the potential of Cambrian granitoids for generating porphyry copper-gold systems (Large *et al.*, 1996). One of the two important areas is in the Cradle Mountain Link Road–Mt Tor region where there are a number of lead, zinc, copper and gold occurrences such as the Mt Remus, Anio Creek and Ten Mile Creek prospects. Most of these prospects are thought to be associated with the Cambrian Bonds Range Porphyry (Pemberton *et al.*, 1991).

The Bonds Range Porphyry is a sill-like body of quartz, feldspar, biotite and hornblende. The porphyry is locally intruded by several quartz porphyry dykes of Cambrian age. Both the dykes and the main porphyry sill show limited sericitisation and chloritisation. In the Mt Remus prospect several irregular veins of pyrite and quartz cross cut Precambrian schist. The veins also contain molybdenite with hematite, chlorite, epidote, zoisite and mica. In the Anio Creek prospect a mineralised breccia within the Cambrian sequence is reported to contain anomalous gold, silver, copper and tungsten. The breccia contains hydrothermal quartz, chlorite, tourmaline and sulphides. In the Ten Mile Creek prospect quartz-hematite-K feldspar veins, stockworks and breccias are noted in the Bonds Range Porphyry. The veins also contain pyrite and chalcopyrite with minor gold. The porphyry shows sericitic alteration of feldspars and chloritic alteration of biotite and hornblende.

Equivalents of the Bonds Range Porphyry are also exposed in the south of the Macquarie Harbour area and in the Elliott Bay area where some vein-type occurrences of copper, lead and zinc are reported. The Voyager 9 prospect in the Elliott Bay area is related to the Stony Creek granite porphyry and is characterised locally by chlorite-magnetite alteration (J. Pemberton, pers. comm.). A number of prospects in the area contain gold in quartz-carbonate veins within epiclastic rocks.

There are also Cu-Au deposits within the Mount Read Volcanics which have some features typical of high-sulphidation mineralisation and are typically associated with andesitic or dioritic-monzonitic intrusive complexes.

In the Cape Sorell area, a 2–3 km wide strip of rhyolitic to andesitic volcanic rocks, the Noddy Creek Volcanics, is associated with a series of dioritic intrusive rocks. The volcanic rocks are of the calc-alkaline type, similar to the Mount Read Volcanics, and represent a smaller, separate arc or sub-arc west of the of the main Mount Read Volcanics belt (McClenaghan and Corbett, 1989). The Cape Sorell area has a number of copper occurrences and in recent years been explored for porphyry copper style mineralisation (e.g. Thomas Creek, Reid, 2001).

At the Garfield prospect (Halley, 1996) Cu-Au mineralisation is associated with a stockwork zone of pyrite-chalcopyrite and magnetite-chalcopyrite-apatite veining and associated chlorite-sericite halo within an andesitic sill. It is considered to have similarities with the Prince Lyell deposit from the Mount Lyell field.

Assessment criteria

1. Distribution of Cambrian granitoids and/or andesitic intrusive complexes.
2. Presence of porphyry-related wall-rock alterations.
3. Magnetic highs on the aeromagnetic map.
4. Presence of geochemical anomalies.
5. Presence of mineral prospects having features similar to porphyry copper deposits

Assessment: Tract Au5a/H/D

This tract is based on the surface distribution of the Mount Read Volcanics and associated rocks and included some areas under shallow Ordovician–Cenozoic cover. It has a high potential and certainty level.

Assessment: Tract Au5b/L-M /B

This tract is based on the subsurface distribution of the Mount Read Volcanics and associated rocks as predicted by the 3D geological model of Tasmania. This tract is typically at depths of between 500–1000 m below the surface and has low to moderate potential with a moderate certainty level.

Mineral potential for associated deposits

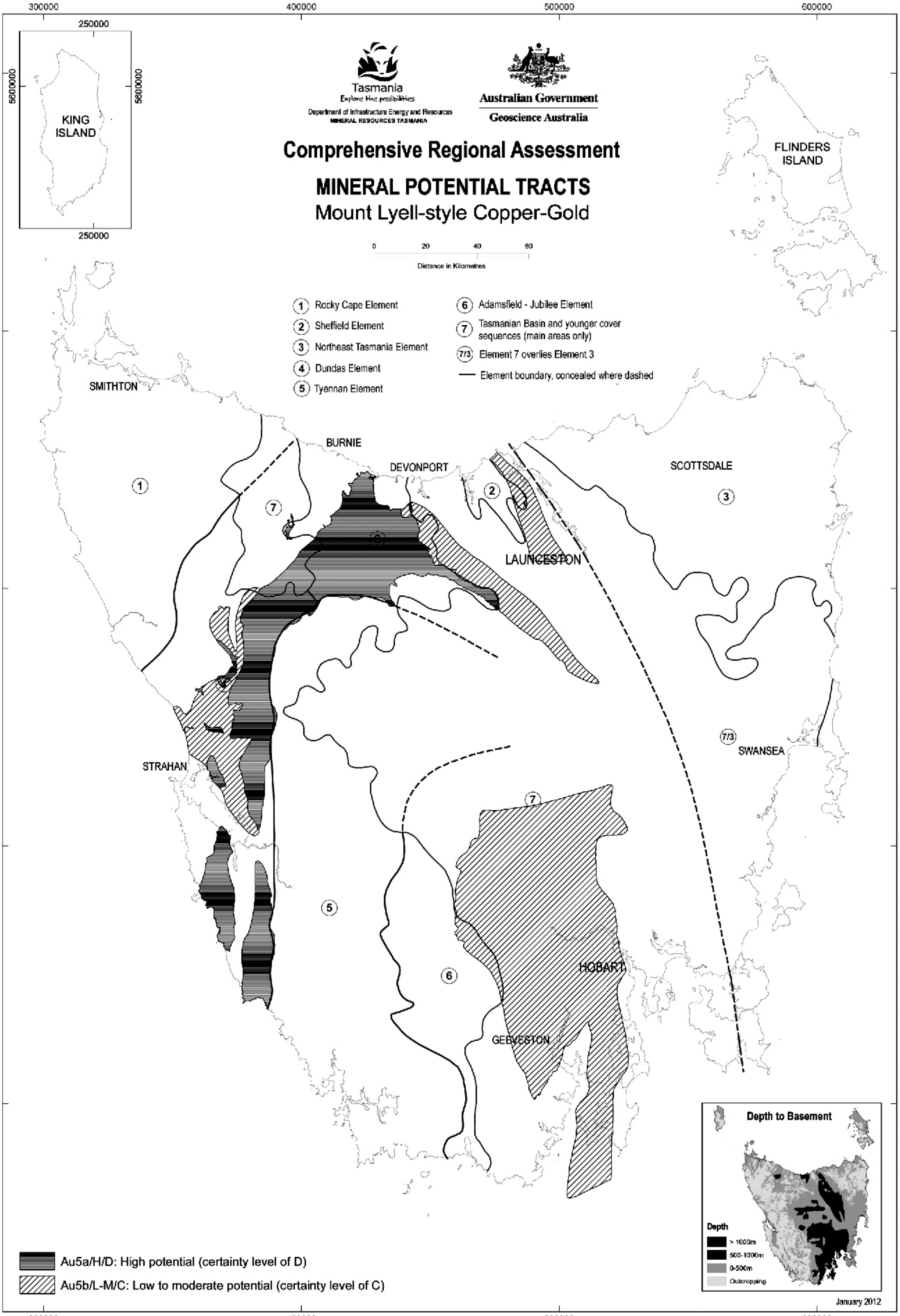
Often copper porphyry systems generate hydrothermal activity which is capable of forming several types of associated deposits. In the Mount Read Volcanics there is a close relationship between porphyry-style mineralisation, and Kuroko-style and epithermal style mineralisation (Large *et al*., 2001).

Epithermal deposits:

The two tracts have an unknown potential for epithermal gold-silver mineralisation.

Economic significance

Generally these deposits are important sources of copper and gold. The grade/tonnage model (Cox and Singer, 1986) for porphyry copper-gold deposits indicates that 90% of these deposits contain at least 25 million tonnes of ore, 50% contain at least 100 million tonnes and 10% contain at least 400 million tonnes. In 10% of these deposits ores contain at least 0.35 wt% copper and 0.2 ppm gold, in 50% of the deposits ores have at least 0.5 wt% copper and 0.38 ppm gold, and in 10% of the deposits the ores contain at least 0.72 wt% copper and 0.72 ppm gold. One of the largest deposits of this type is the Goonumbla group of deposits in NSW which contains 30 million tonnes of ore with 0.91 wt% copper and 0.63 ppm gold (Heithersay *et al*., 1990).



Map 24 — Model M24

MODEL M25: Rare earth element-bearing placers

Model description

Description of the model after Hoatson *et al.* (2011).

Approximate synonyms

Heavy mineral sands.

Description

Heavy minerals such as monazite, ilmenite, rutile, zircon, leucoxene, magnetite, garnet and xenotime concentrated by mechanical processes. Deposit types include beach, channel (fluvial), high-dune and offshore marine tidal placers. The REE are held in monazite and xenotime content of the heavy mineral concentrate.

Geological environment

Rock types:

Well-sorted medium to fine-grained sand in dune and beach deposits commonly overlying shallow marine sediments, and braided river sands.

Age range:

Miocene to Holocene but generally Pleistocene to Holocene. Some as old as Miocene. Mesozoic for fluvial sands.

Depositional environment:

Stable coastal region with efficient sorting and winnowing, receiving sediment from deeply weathered granitic terranes and metamorphic terranes of sillimanite or higher grade. Lower shoreface/inner shelf area with low energy conditions (for offshore shallow marine deposits). Transverse dune sands (for dune sand-type deposits). Braided river sands (for fluvial deposits).

Tectonic setting:

Margin of cratons. Crustal stability during deposition and preservation of deposits considered important for preservation.

Deposit description

Structure:

Elongate strandline deposits often parallel to coastal dunes and beaches. Dune deposits are often associated with transgressive dunes.

Ore controls:

REE-enriched minerals in the igneous and high-grade metamorphic rocks as essential source of mineral sands. In dune sands the REE-enriched minerals are sourced from beach sands. Structural/mechanical traps controlled by the topography of coastal regions. Zeta shaped shoreline preceding a headland which traps heavy minerals important for beach sands. Accumulation of sands caused by changes in wave and wind energy. For dune sands sorting by wind action of heavy minerals from previous beach heavy-mineral concentrations formed by wave action. For channel (fluvial) placer-type deposits, zones of changes in water flow in fluvial system.

Weathering:

Leaching of iron from ilmenite and destruction of labile heavy minerals can result in residual enrichment of deposits.

Geochemical and geophysical signatures:

High Ti, Zr, Th, U, rare earth elements; anomalously high concentrations of heavy minerals; gamma radiometric anomalies due to monazite content; induced polarisation anomalies due to ilmenite.

Examples

Beach sands:

Eneabba (Perth Basin), Jacinth-Ambrosia and Cyclone (Eucla Basin), Douglas and Ginkgo (Murray Basin).

Offshore sands:

WIM 150, Donald (WIM 250); Jackson (WIM 200), WIM 100 (all in Murray Basin).

Dune sands:

North Stradbroke Island, Queensland.

Channel (fluvial) sands:

Calypso (WA).

REE-bearing heavy mineral sands in Tasmania:

There are several known occurrences of heavy mineral sands in Tasmania, rich in titanium (ilmenite and rutile) and/or zirconium (zircon). Some of these sands are known to contain monazite. At Naracoopa on King Island these sands have been mined in the past, but principally for ilmenite.

Detrital monazite has also been recorded from most of the streams draining outcrops of Devonian granite and tin-tungsten fields in Tasmania. The mineral commonly occurs with cassiterite. Tourmaline, topaz, corundum and zircon accompany the monazite and cassiterite along the Ringarooma River and in the Scottsdale district. In the Scottsdale district, monazite was found in creeks draining north from Mt Stronach. Mining of alluvial monazite from the area was attempted in 1900. Partial analyses of monazite from Naracoopa and Stronach recorded about 60% total rare earth oxides and 6–7% ThO_2 (Bottrill, 2001).

The Briseis, Pioneer, Endurance and Echo alluvial tin mines all contained monazite. In 1945, 32.5 t of monazite concentrates were produced from the Endurance alluvial tin workings at South Mount Cameron (Barrie, 1966*a*). 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. 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 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.

Assessment criteria

1. Appropriate coastal deposits of sand along current or beach and dune sands inland along fossil shorelines.
2. Monazite-bearing alluvial heavy minerals in streams draining from outcropping Devonian granites.
3. Heavy mineral beach sands on the coastal plains downstream of monazite-bearing alluvial placers. In this case an alluvial placer can also serve as source of monazite in beach sands.
4. Known occurrences of monazite-bearing placers.
5. Presence of lineaments on radiometric images from airborne radiometric surveys.

Assessment: Tract REEHMS/M/B

This tract covers beach and dune sands and also older dune and swamp deposits on the coastal plain. In some area the extent of these sediments has not been mapped in detail and they may extend up to a few kilometres inland. The beach sands are known to host one or more occurrences of heavy mineral sands containing rutile, ilmenite or zircon, although the concentration of monazite in them has not been determined. Some of these areas are in proximity to granitoids (potential source of monazite and zircon). Alluvial sediments along streams also locally host occurrences of heavy minerals.

The tract is assigned a moderate potential with a certainty level of B because the heavy mineral sands have not been adequately sampled and analysed for monazite.

Assessment: Tract REEHMS/L-M/B

This tract includes alluvial sediments (mapped and/or unmapped). Streams in proximity (within two kilometres) of granitoids (potential source of zircon and monazite) were buffered (750 m on either side) to delineate areas where alluvial sediments have not been mapped. Several occurrences of alluvial sands with heavy minerals (ilmenite, rutile, zircon and locally cassiterite) have been reported in the tract.

The tract is assigned low to moderate potential with a certainty level of B.

Economic significance

REE are not currently extracted from monazite in Australia, with the material being returned back to the mine site. A systematic analysis of monazite concentration and of its REE-content is essential to evaluate the economic significance of these deposits.

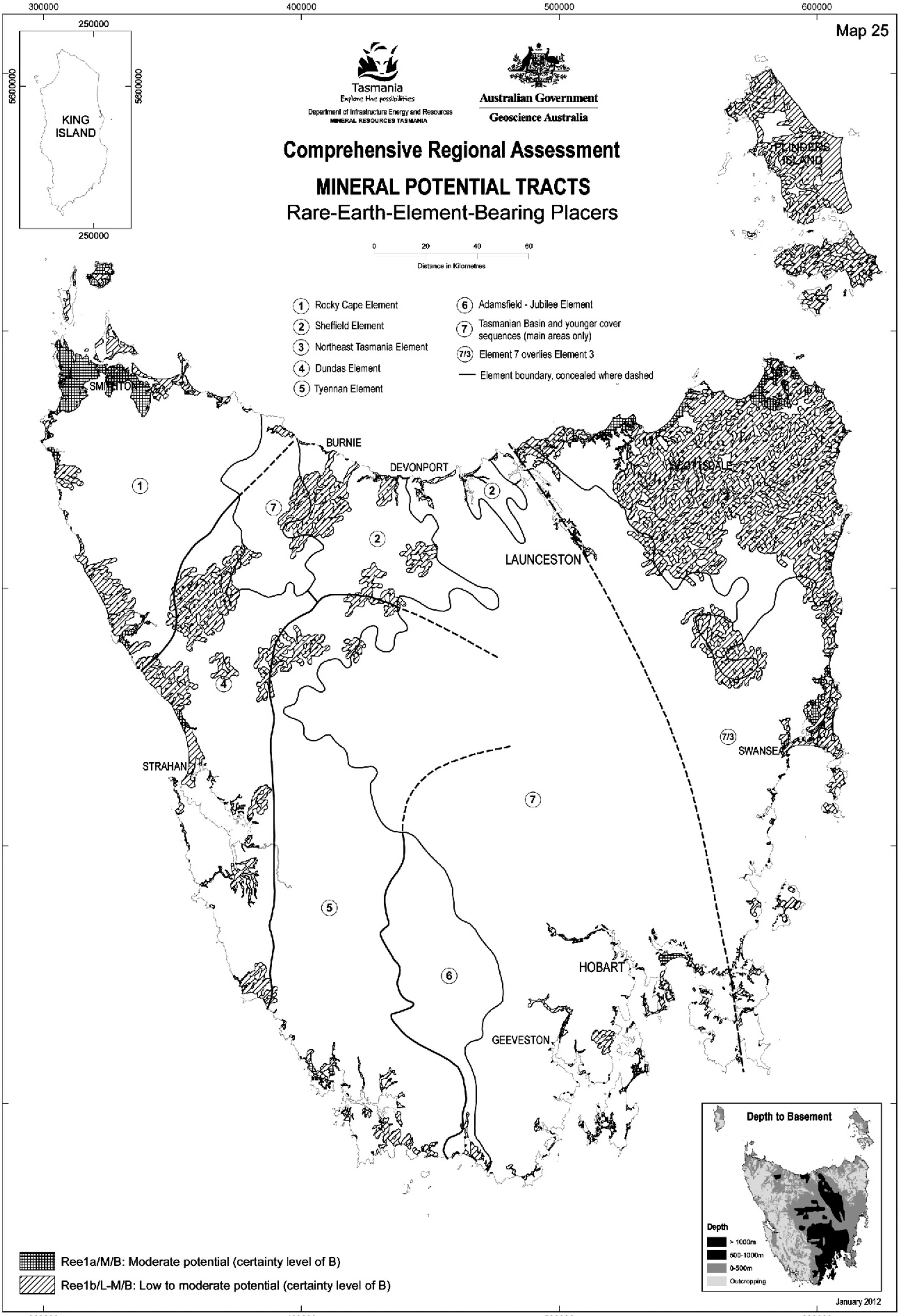
Potential of orthomagmatic and magmatic-hydrothermal deposits of rare earth elements.

REE-enriched melt of alkaline and peralkaline composition and carbonatites can form large deposits. These deposits either result from direct crystallisation from the melt and/or fluids predominantly derived from it (Hoatson *et al.*, 2011).

In Tasmania the onshore alkaline igneous intrusions of Cretaceous age have been mapped in the southeast (Cygnet–Oyster Cove area) and in the far northeast (Tomahawk River phonolite). They form part of a felsic, unfractionated felsic alkaline porphyry complex (Seymour *et al.*, 2007). The rocks do not show anomalous concentration of rare earth elements.

I-type highly fractionated granites can form REE-bearing pegmatites. In Tasmania these types of granites have been mapped in the east and northeast (Ben Lomond, Blue Tier and Scottsdale batholiths), and in the west (Heemskirk and Housetop granites). Small and rare pegmatites have been mapped in the Heemskirk Granite. Similar pegmatites may be present in other granites.

The mineral potential of REE deposits associated with magmatic rocks in Tasmania is at this stage unknown.



Map 25 — Model M25

MODEL M26: Magnesian skarn-hosted magnetite (Savage River magnetite)

Model description

Description of the model after Bottrill and Taheri (2008). Differs from normal skarns in being Ca-poor and more Mg and Fe-rich. Based on Savage River and other deposits along the Arthur Lineament.

Approximate synonyms

Iron skarns, Kiruna iron (iron oxide-apatite); IOCG variant.

Description

Massive concordant and discordant magnetite replacement bodies in magnesian skarns and carbonates interbedded with metamafic volcanic rocks, intrusive rocks and sedimentary rocks with talc, tremolite-actinolite and serpentine alteration. Fault bounded and strongly deformed.

General references

Bottrill and Taheri, 2008; *Einaudi et al., 1981*.

Geological environment

Rock types:

Stratabound magnesian skarns, dolostones and magnesite-stones in volcanosedimentary sequences usually including mafic lavas and sub-volcanic intrusions, volcaniclastic sandstone, schist, quartzite and granofels; albitites are locally prominent. The more highly metamorphosed zones include amphibolite and variable amphibole, chlorite, quartz, feldspar, almandine and mica-rich schists with minor graphite schist. Intrusive dolerite and gabbro dykes and sills are common. No obvious genetic association with felsic intrusive rocks.

Age range:

Probably Neoproterozoic in Tasmania.

Depositional environment:

Continental volcanic rocks and clastic sedimentary rocks intruded by sub-volcanic mafic (-intermediate) and felsic plutons.

Tectonic settings:

Ores and surrounding rocks are deformed and metamorphosed and occur in an allochthonous terrane. Possible original settings include volcanic-dominated continental margin or intra-continental rift.

Associated deposit types:

Magnesite and dolomite deposits.

Deposit description

Stratabound massive lenses of magnetite-rich ore enclosed in a mafic metavolcanic, carbonate and sedimentary package that occurs within an allochthon.

Ore mineralogy:

Magnetite is dominant, with mostly subordinate pyrite, minor apatite, ilmenite and rutile, and trace chalcopyrite and monazite.

Texture/structure:

Massive to disseminated, may include granoblastic textures, locally finely to coarsely banded; fine to coarse grained; brecciated to sheared in large part, may be folded and boudinaged. Minor magnetite, pyrite and hematite-bearing veins.

Alteration/gangue:

The primary skarns include diopside and Mg-rich silicates including amphiboles, serpentine, talc and chlorite that are the products of post-ore retrogression. Associated mafic rocks are usually also largely retrogressed to tremolite-actinolite, chlorite, albite and epidote assemblages. There may be minor biotite alteration of associated mafic and sedimentary host rocks. Partial to complete dolomitisation of magnesite-stones is common. Albitisation and tourmalinisation of footwall felsic intrusive and sedimentary rocks may be related to late-stage meta-evaporite fluid activity. Variable blueschist and greenschist-amphibolite metamorphic grade assemblages may occur in the mafic rocks, but there is evidence that high P assemblages occupy an early stage in the metamorphic evolution.

Ore controls:

Ore bodies are stratabound replacements of carbonate-rich sequences with associated mafic, sedimentary and felsic rocks, probably related to underlying felsic intrusive rocks, commonly unexposed (suggesting a link to IOCG deposits). Can include massive replacement magnetite, or less commonly in breccia filling and veins, possibly related to cupolas of deep plutons. The Savage River deposits are part of an allochthonous metamorphic complex in a major lineament formed during a Cambrian collisional Orogeny.

Weathering:

Magnetite oxidises to hematite and maghemite; sulphides oxidise to goethite; base of complete oxidation around 30–40 m depth.

Geochemical signature:

Fe, P, V, Ti and Cu.

Geophysical signature:

Strong magnetic anomalies.

Examples

Savage River	Bottrill and Taheri, 2008; Taheri and Bottrill, in prep.
Long Plains/Rocky River	Urquhart, 1966; Taheri and Bottrill, in prep.
Keith River	Taheri and Bottrill, in prep.
Russia & Mongolia	Aleksandrov, 1998; Pertsev, 1991

Known deposits and mineral occurrences in Tasmania

A number of magnetite-sulphide-silicate deposits are known in the Arthur Metamorphic Complex (AMC) portion of the Rocky Cape Element, especially in the Bowry Formation, the largest being the Savage River magnetite deposits. Many other smaller magnetite hematite iron sulphide-bearing occurrences are distributed throughout the AMC. Such deposits and occurrences are generally identifiable as magnetic anomalies on existing magnetic coverage of the area, some of which lie beneath Permian and Tertiary cover and remain to be confirmed. They are probably related to an unidentified intrusive body, possibly of at least Cryogenian (mid Neoproterozoic) age.

Assessment criteria

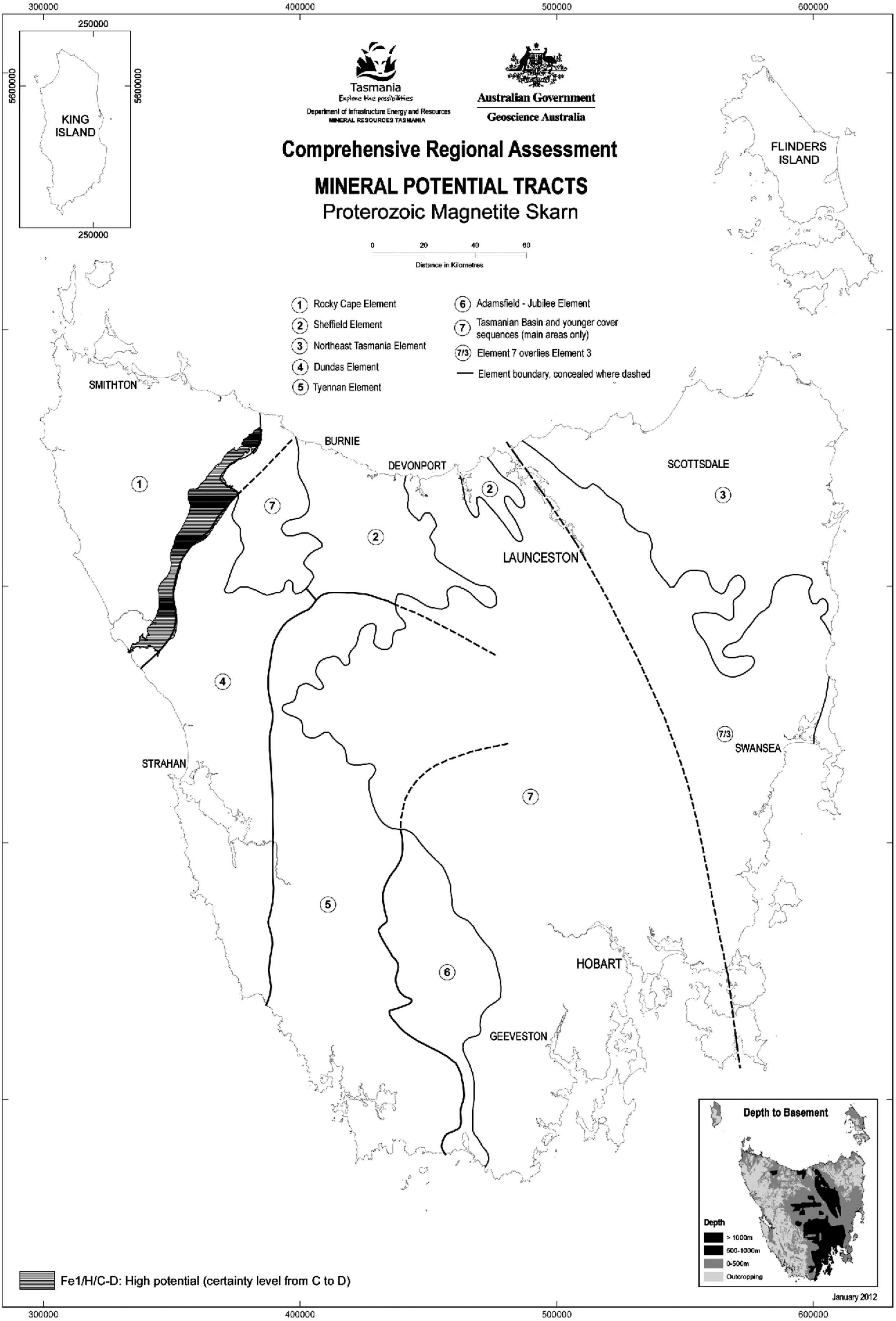
1. Presence of high amplitude magnetic anomalies.
2. Presence of magnetite pyrite apatite ores with Mg-silicate (amphiboles, serpentine, talc and chlorite) rich gangue.
3. Presence of Mg Fe Ca carbonate-rich rocks, especially magnesite.
4. Indications of a hydrothermal replacement origin.
5. Proximity to known iron oxide-sulphide-silicate deposits of this type.
6. Common presence of mafic to felsic or alkaline igneous rocks.

Assessment: Tract Arthur Metamorphic Complex Fe1/ H/B-C

The potential for Savage River-type iron ore deposits is highest in the carbonate-rich sequences within the Arthur Metamorphic Complex, essentially along strike from the Savage River deposit. This tract is defined by the mapped distribution of the Bowry Formation, together with its interpolated and extrapolated extensions beneath thin Permo-Carboniferous sedimentary and Tertiary basalt cover. The potential is rated as high and the degree of uncertainty varies with the detail of geological mapping and the amount of exploration done. The southern (Savage River mine–Corinna) and northern (Arthur River area) segments of the AMC are fairly well known due to relatively recent Geological Survey mapping and have a certainty level of C, whilst most of the central segment is one of the most poorly known areas in Tasmania and has a certainty level of B.

Economic significance

Magnetic iron ores of this type have the advantage of being amenable to cheaply and efficiently upgrading by magnetic methods, even when initial bulk magnetite grades are relatively low (>15%), thus producing much sought after high-grade fines which are pelletised. Such beneficiated ore (~68% Fe) is very high grade by world standards. Export revenues from this deposit type have been worth generally about $40 million to Australia annually.



Map 26 — Model M26

MODEL M27: Slate-belt gold deposits (Model 36a of Cox and Singer, 1986)

Model description

Description of the model after Byron R. Berger.

Approximate synonyms

Mesothermal quartz veins, mother lode veins, turbidite-hosted gold veins, slate-belt gold veins, low sulphide gold-quartz veins.

Description

Gold in quartz veins and silicified lode structures, mainly in regionally metamorphosed rocks.

General references

Forde and Bell, 1994; Hodgson *et al.*, 1993.

Geological environment

Rock types:

Greenstone belts, oceanic metasediments, regionally metamorphosed volcanic rocks, greywacke, chert, shale, and quartzite, especially turbidite-deposited sequences. Alpine gabbro and serpentine. Late granitic batholiths.

Age range:

Precambrian to Tertiary.

Depositional environment:

Continental margin mobile belts, accreted margins. Veins aged pre to post-metamorphic and locally cut granitic rocks.

Tectonic setting(s):

Fault and joint systems produced by regional compression.

Associated deposit types:

Placer Au-PGE, Homestake gold, Fosterville–Nagambie style gold (stockworks).

Deposit description

Mineralogy:

Quartz carbonates native gold arsenopyrite pyrite galena sphalerite chalcopyrite pyrrhotite sericite rutile. Locally tellurides scheelite bismuth tetrahedrite stibnite molybdenite fluorite. Gold-bearing quartz is greyish or bluish in many cases because of fine-grained sulphides. Carbonates of Ca, Mg and Fe abundant.

Texture/structure:

Saddle reefs, ribbon quartz, breccias, open-space filling textures commonly destroyed by vein deformation.

Alteration:

Quartz + siderite and (or) ankerite albite in veins with possible halo of carbonate alteration. Chromian mica dolomite talc siderite in areas of ultramafic rocks. Sericite disseminated arsenopyrite rutile in granitic rocks.

Ore controls:

Veins occur along regional high-angle faults, joint sets. Best deposits overall in areas with greenstone. High-grade ore shoots locally at metasediment-serpentine contacts. Disseminated ore bodies where veins cut granitic rocks. Carbonaceous shales may be important. Competency contrasts, e.g. shale/sandstone contacts and intrusive contacts may be important.

Weathering:

Abundant quartz chips in soil. Red limonitic soil zones. Gold may be recovered from soil by panning.

Geochemical signature:

Gold best pathfinder in general; As, Ag, Pb, Zn, Cu may be useful.

Geophysical signature:

Poorly defined generally, but magnetics may define important structures.

Examples

Bendigo goldfield, AUVT (Sharpe and MacGeehan, 1990)
Ballarat East gold deposits, AUVT (d'Auvergne, 1990)
Mother Lode, USCA (*Knopf, 1929*)
Goldfields of Nova Scotia, CNNS (*Malcolm, 1929*)

Known deposits and mineral prospects in Tasmania

Within Tasmania, most gold deposits of this type are located in the Northeast Tasmania Element. These deposits, including the largest known (the New Golden Gate deposit at Mathinna), lie within a 70 6 km NNW-trending corridor — the Mathinna–Alberton Gold Lineament — lying between the Scottsdale and Blue Tier batholiths (Bottrill *et al.*, 1992; Keele, 1994). They are hosted by the Ordovician–Early Devonian turbiditic sequence of the Mathinna Supergroup. These rocks are thought to be related to similar sequences in Victoria which also host slate belt gold deposits. The rocks have undergone deformation and syntectonic metamorphism (to lower greenschist facies) during the mid-Devonian to Carboniferous Tabberabbean Orogeny and are intruded by Late Devonian to Carboniferous granitoids. These granitoids generated local contact metamorphism of the host rocks and in some goldfields mineralisation overlies granodiorite ridges and rarely cuts granodiorite bodies and contact aureoles. The largest known deposit in the Mathinna Beds is the New Golden Gate deposit at Mathinna, which produced 7.2 t of gold. Gold-bearing quartz veins within this 'gold corridor' were deposited by fluids of deep-seated regional metamorphic origin (Taheri and Bottrill, 1994), and veins were genetically associated with wrench faulting associated with D_2 (Keele, 1994).

The gold veins usually have NNW or less commonly NE trends. The veins are mostly grey, laminated and brecciated, predominantly quartz with minor carbonates, sericite, arsenopyrite and pyrite and trace base metal sulphides.

Granitoid-related deposits (e.g. Lefroy, Lisle, Mt Horror) are more complex, with more Ag, As, Sb, base metals (Cu, Pb, Zn) and rarely Sn, Bi, Mo and W minerals. They mostly strike northeast and may be partly related to thrust faulting as proposed for similar deposits in Victoria and New South Wales (R. A. Glen, quoted in Bottrill *et al.*, 1992; Powell, 1991).

No single geological factor can be invoked to explain the formation and distribution of these deposits; a combination of several factors may be important, including crests and limbs of anticlines, zones of intensive cross folding, shear zones, suitable rocks and the presence of granitoids. It is probable that, like the slate-belt deposits in Victoria, processes of deformation and metamorphism played a predominant role in the formation of these deposits (Taheri and Bottrill, 1994).

The Beaconsfield area in the Sheffield Element hosts one of the largest gold mines in Tasmania, in which the gold reef was mined intermittently from about 1877. It is a current operation, but is due to close in mid 2012. The Tasmania reef is localised within conglomerate and arenite of the upper Cabbage Tree Formation of probable Early Ordovician age, a probable time equivalent of the Mathinna Supergroup (Bottrill *et al.*, 1992; Seymour *et al.*, 2011). In mineralogy and trend the reef is similar to the slate-belt type of gold deposits, but is larger and more continuous than most.

Assessment criteria

1. Distribution of the Mathinna beds turbidites and their metamorphic equivalents.
2. Presence of granodiorites.
3. Presence of fault zones.
4. Presence of primary and/or alluvial gold deposits and prospects.

Assessment: Tract Au1a/H/C

Part of the tract is drawn on the basis of the distribution of the Mathinna Supergroup rocks in northeastern Tasmania, which are the principal hosts of known slate-belt gold occurrences and deposits. The Mathinna Supergroup is interpreted to be similar to the turbiditic sequence in Victoria which hosts one of the largest deposits of this type. Some granodiorites are also gold hosts and are included.

This part of the tract has a high potential for the slate-belt gold deposits with a certainty level of C.

The part of the tract in the Beaconsfield area is drawn based on the distribution of rocks belonging to the Cabbage Tree Formation of Early Ordovician age. The tract also takes into account the presence of known, large and rich gold reefs in the Beaconsfield area. This part of the tract has a high potential for slate-belt gold deposits with a certainty level of C.

The part of the tract in the Lyell–Darwin area is drawn based on the distribution of known low-sulphide gold-quartz veins in pre-Carboniferous rocks, with no obvious link to granites. It has a high potential for slate-belt gold deposits with a certainty level of C.

Assessment: Tract NW Tasmania: Au1b/M-H/B

This tract, in the Penguin–Sheffield area and the Rocky Cape area, is drawn based on the distribution of known low-sulphide gold-quartz veins in pre-Devonian rocks, with no obvious link to granites. It has a high potential for slate-belt gold deposits with a certainty level of B.

Assessment: Tract Eastern Tasmania: Au1c/L-M/B

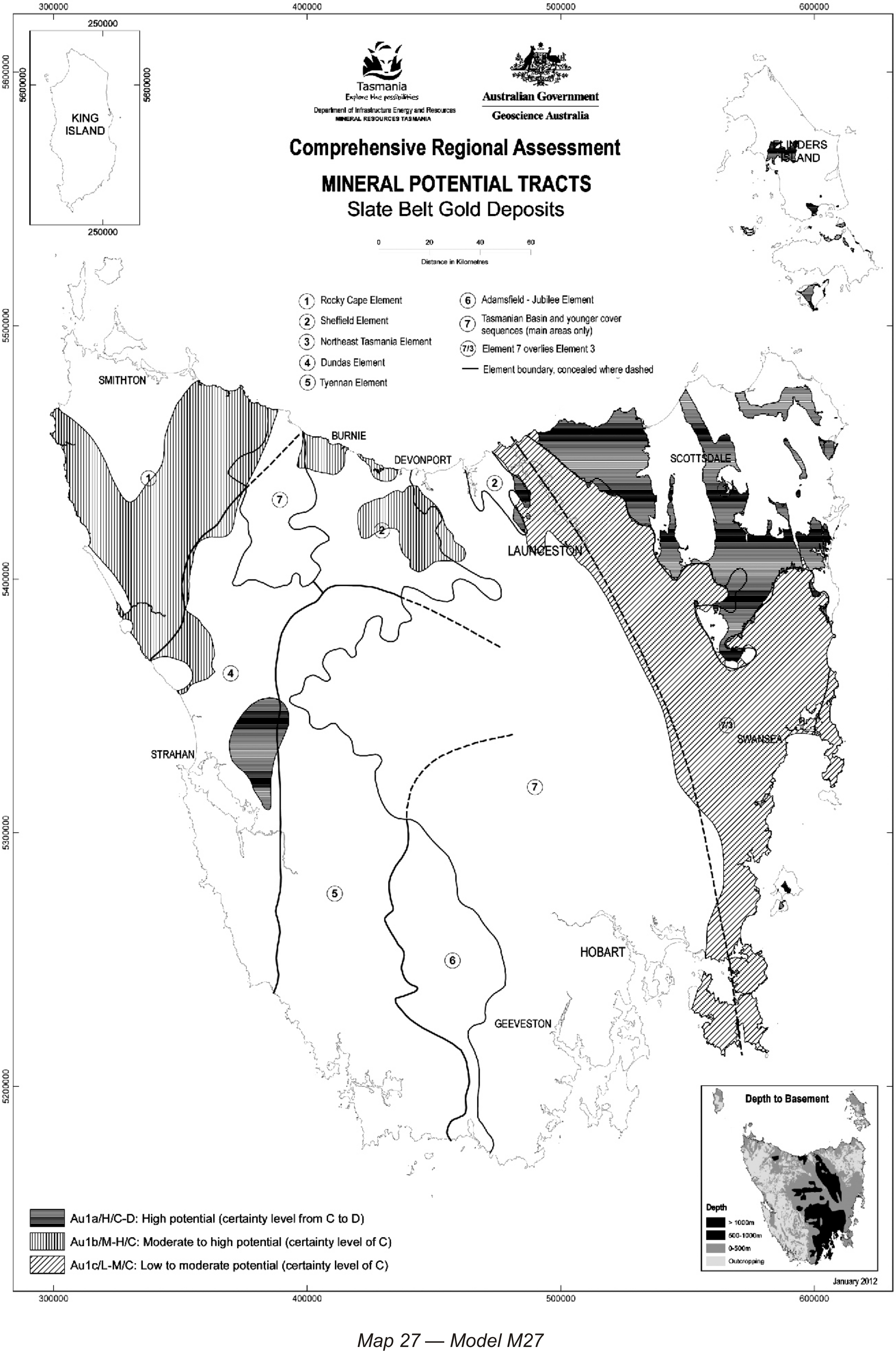
The 3D geological model of Tasmania postulates that a number of rock units outcropping in western Tasmania also occur in the basement rocks of eastern Tasmania which are largely covered by Parmeener Supergroup and younger rocks. A number of concealed bodies of Mathinna Supergroup rocks are postulated to occur widely in eastern Tasmania and these are considered to have low to medium potential for this deposit style with a certainty level of B.

Potential for related deposit styles

Low temperature, quartz poor, limonitic, slate-hosted stockwork-style gold mineralisation occurs in Victoria, as in the Fosterville and Nagambie deposits in very similar geological settings to the Mathinna Supergroup. Small stockwork zones at the Linton mine contain some anomalous gold and may be of this style (Taheri and Bottrill, 1994). The potential for this style must be considered high in the Mathinna Supergroup.

Economic significance

The slate-belt type of gold deposits are one of the largest type of gold deposits and are important source of gold and silver. According to the grade/tonnage models for the low-sulphide gold-quartz veins (Cox and Singer, 1986) 90% of these deposits contain at least 0.001 million tonnes of ore; 50% contain at least 0.03 million tonnes and 10% contain at least 0.91 million tonnes. In 90% of these deposits ores contain at least 6 g/t gold; 50% contain at least 15 g/t gold and 10% contain 43 g/t gold.



Map 27 — Model M27

MODEL M28: Replacement tin (Model 14c of Cox and Singer, 1986)

Model description

Description of the model after B. L. Reed.

Approximate synonyms

Massive cassiterite-bearing replacement; distal skarn tin (Solomon and Groves, 1994); Renison-style carbonate-replacement Sn deposits (Kitto, 1998).

Description

Stratabound cassiterite-sulphide (chiefly pyrrhotite) replacement of carbonate rocks and associated fissure lodes related to underlying granitoid complexes.

General references

Solomon and Groves, 1994; Morland, 1990; Patterson *et al.*,1981; Perkin, 1990; Kitto, 1998.

Geological environment

Rock types:

Carbonate rocks (limestone or dolomite); granite, monzogranite, quartz porphyry dykes generally present; quartz-tourmaline rock; chert, pelitic and iron-rich sediments, volcanic rocks and serpentinite may be present. 'Tin granites' are composed mainly of albite, K-feldspar and quartz together with a low mica content, and are commonly classed as alkali feldspar granites.

Textures:

Plutonic (equigranular, seriate, porphyritic).

Age range:

World-wide these deposits are Palaeozoic and Mesozoic; Late Devonian–Early Carboniferous in Tasmania.

Depositional environment:

Stratabound replacement (mainly by pyrrhotite and quartz) of calcareous rocks, dolomitic beds or altered magnesitic ultramafic rocks adjacent to dykes or mineralised fault structures.

Tectonic setting(s):

Late orogenic to post-orogenic passive emplacement of high-level granitoids in fold belts containing carbonate rocks. Deposits occur near the roof of granitic plutons or in the immediately overlying country rocks.

Associated deposit types:

Greisen-style mineralisation, quartz-tourmaline-cassiterite veins, Sn-W-Mo stockworks, Sn-W skarn deposits close to intrusions.

Deposit description

Mineralogy:

Pyrrhotite + arsenopyrite + cassiterite + chalcopyrite (may be major) + ilmenite + fluorite;
minor: pyrite, sphalerite, galena, stannite, tetrahdedrite, magnetite;
late veins: sphalerite + galena + chalcopyrite + pyrite + fluorite.

W minerals are usually absent from replacement tin deposits. Gangue minerals include quartz, siderite, talc and tourmaline.

Texture/structure:

Vein stockwork ores and massive ores with laminations following bedding in host rock, locally cut by stockwork veins, pyrrhotite may be recrystallised.

Alteration:

Greisenisation (cassiterite) near granite margins; sideritic alteration of dolomite near sulphide bodies; tourmalisation of clastic sediments; proximity to intrusions may produce contact aureoles in host rocks.

Renison deposit shows two types of alteration:
(1) sericite-fluorite-quartz alteration;
(2) localised greisens of tourmaline-quartz-muscovite.

Ore controls:

Replacement of favourable carbonate units; fault-controlled fissure lodes common. Isolated replacement ore bodies may lie above granitoid cupolas; faults provide channels for mineralising fluids.

Geochemical signature:

Sn, As, Cu, B, W, F, Li, Pb, Zn, Rb.

Geophysical signature:

Magnetic and EM anomalies.

Examples

Renison Bell	Patterson *et al.*, 1981; Kitto, 1992
Cleveland	Collins, 1981
Mount Bischoff	Groves *et al.*, 1972; Halley and Walshe, 1995
Queen Hill–Severn–Montana	
Razorback	

Known deposits and mineral prospects in Tasmania

These deposits are spatially and genetically related to the emplacement of Devonian–Lower Carboniferous granitoids, mostly occurring 500 to 1500 m above the upper surface of the underlying granites (Kitto, 1998). The deposits are hosted by various carbonate units within the Neoproterozoic Oonah Formation (Mount Bischoff, Queen Hill), the Neoproterozoic Success Creek Group and Crimson Creek Formation (Renison, Montana), and Terreneuvian to Cambrian Series 2 Cambrian allochthonous (?) sedimentary sequences (Cleveland). The Razorback deposit occurs in dolomite at a faulted contact between serpentinised peridotite of the Dundas Ultramafic Complex and sedimentary rocks of the Cambrian Series 3 to Furongian Dundas Group.

At the Mount Bischoff deposit, mineralisation is spatially related to Late Devonian porphyry dykes similar in age to the Meredith Granite which outcrops eight kilometres to the southwest. Gravity interpretation (Leaman and Richardson, 1989) shows that the deposit occurs above a shallow granitoid ridge extending from the Meredith Granite.

Assessment criteria

1. Highly fractionated 'ilmenite series' granites (both S-type and I-type) — these are referred to as 'tin granites' and show high Rb/Sr ratios. For Tasmania these granites are Devonian to Early Carboniferous in age.
2. Tin granites are mostly post-kinematic, steep-sided, flat-topped plutons with narrow thermal aureoles; tops are at shallow depths (<4 km) below fossil topographic surface.
3. Carbonate beds intruded by the granite or close to the upper surface of the intrusion. The 4 km subsurface granite contour (as determined by modelling of gravity data) has been used even though these sorts of deposit mostly occur 500 to 1500 m above the surface of the underlying granite. The deeper contour has been chosen because the gravity data used for the modelling is not sufficiently detailed to indicate that there are no small higher protrusions in the granite surface.
4. Fault zones which intersect carbonate beds and the tourmaline greisen zones at the top of the granite pluton.

Assessment: Tract Sn1a/H/B-D

This tract, with zones in the northwest, has been delineated from the subsurface distribution of Devonian–Early Carboniferous granitoids, as determined by modelling of gravity data. Major replacement tin deposits, as described above, occur in the northwest parts of this tract and are hosted by carbonate units within various Neoproterozoic and Cambrian sequences which are widespread in northwest Tasmania. The exposed granite bodies and the known deposits strongly suggest that the subsurface granitoids are of the appropriate composition to be associated with replacement tin deposits and the potential is high. The certainty level varies from C to D with the degree of geological mapping.

Assessment: Tract Sn1b/M-H/B

This tract in southwest Tasmania has also been delineated based on the subsurface distribution of Devonian–Early Carboniferous granitoids intruding an area of Ordovician limestone and Proterozoic rocks of the Tyennan and Jubilee elements. Granites belonging to the inferred subsurface body crop out at South West Cape and Cox Bight, where they are associated with alluvial tin deposits. The subsurface granite is thus also likely to contain 'tin granite'. This part of the tract also has high potential as it is known to contain Ordovician limestone and Proterozoic dolomite in the New River, Picton River and Olga River areas. The level of certainty is B mainly because of the lack of detailed geological mapping in the area.

Assessment: Tract Sn1c/M/B

This tract, in northwest Tasmania, has been delineated based on the subsurface distribution of the continuation of the Devonian–Early Carboniferous Interview and Pieman granitoids as determined by modelling of gravity data. These granitoids have the appropriate composition and are associated with tin mineralisation. The inferred subsurface granitoid is overlain, at the surface, by Neoproterozoic Rocky Cape Group rocks which contain only minor dolomite. An interpretation of the regional geology, supported by recent geological mapping, has suggested that these rocks have, in places, been thrust over Togari Group rocks which contain dolomite units. A second tract in the Sheffield area has been based on the subsurface distribution of the poorly known Beulah Granite. This granite, of Cambrian age, has the potential to intrude carbonate bearing Neoproterozoic units at depth.

This tract has moderate potential for replacement tin deposits with a certainty level of B due to the lack of geological mapping over much of the tract.

The tract in southwest Tasmania has been delineated based on the subsurface distribution of Devonian–Early Carboniferous granitoids, as determined by modelling of gravity data, intruding an area of Proterozoic rocks of the Tyennan Element. Granites belonging to the inferred subsurface body crop out at South West Cape and Cox Bight, where they are associated with alluvial tin deposits. The subsurface granite is also likely to contain 'tin granite'. The tract is considered to have medium to high potential because, although outcropping rocks are dominantly quartzitic to pelitic, carbonate may be present. This is inferred from the presence of carbonate beds in similar Proterozoic rocks in the Lake Gordon area. As the major structures in the area are poorly known, it is not possible to discount the possibility that the Proterozoic rocks have been thrust over substantial Ordovician limestone units at comparatively shallow depth, which could act as host rocks for replacement tin deposits.

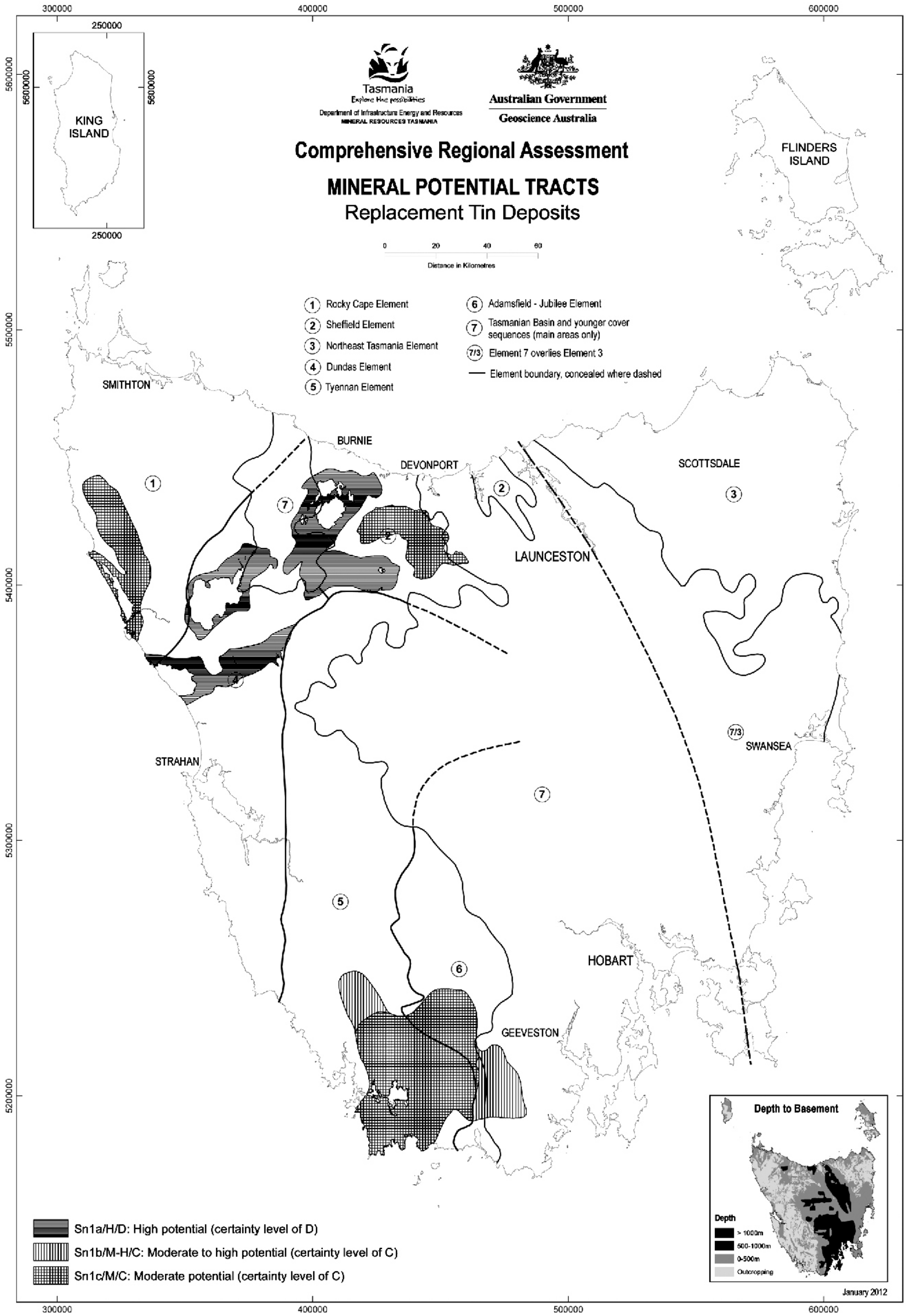
Economic significance

According to grade/tonnage models for replacement tin deposits, 90% of deposits contain at least 1.0 million tonnes of ore, 50% at least 5.2 million tonnes and 10% at least 27 million tonnes. In these types of deposits, 90% contain at least 0.56% Sn, 50% at least 0.8% Sn and 10% at least 1.2% Sn (Cox and Singer, 1986).

For the Tasmanian replacement tin deposits, ore tonnages range from 27 Mt to 2 Mt; grades range from 0.6–1.35% Sn, and average about 1% Sn. Copper contents range from 0.1–0.4% Cu.

Australia's largest concentrations of economic tin resources are of this deposit type. Worldwide, sizeable ore bodies of this type with average grade of 1% Sn are the largest repositories of hard-rock tin mineralisation known.

The estimated pre-mining resource for the Renison deposit was 27 Mt of ore averaging 1.35% Sn; and Mount Bischoff 10.3 Mt ore averaging 1.13% Sn. These are among the world's largest and richest tin deposits.



Map 28 — Model M28

MODEL M29A: Tungsten-molybdenum veins (Model 15a, Cox and Singer, 1986)

Model description

Description of the model after D. P. Cox and W. C. Bagby.

Approximate synonym

Quartz-wolframite veins (*Kelly and Rye, 1979*).

Description

Wolframite, molybdenite and minor base-metal sulphides in quartz veins.

Geological environment

Rock types:

Monzogranite to granite stocks intruding sandstone, shale, and metamorphic equivalents.

Textures:

Phanerocrystalline igneous rocks, minor pegmatitic bodies, and porphyroaphanitic dykes.

Age range:

Paleozoic to late Tertiary. Tasmanian veins of this type are associated with Late Devonian to Early Carboniferous intrusions.

Depositional environment:

Tensional fractures in epizonal granitic plutons and their wall rocks.

Tectonic setting(s):

Belts of granitic plutons derived from remelting of continental crust. Country rocks are metamorphosed to greenschist facies.

Associated deposit types:

Sn-W veins, pegmatites.

Deposit description

Mineralogy:

Wolframite, molybdenite, bismuthinite, pyrite, pyrrhotite, arsenopyrite, bornite, chalcopyrite, scheelite, cassiterite, beryl, fluorite; also at Pasto Bueno, tetrahedrite-tennantite, sphalerite, galena and minor enargite.

Texture/structure:

Massive quartz veins with minor vugs, parallel walls, local breccia.

Alteration:

Deepest zones, pervasive albitisation; higher pervasive to vein-selvage pink K-feldspar replacement with minor disseminated REE minerals; upper zones, vein selvages of dark-gray muscovite or zinnwaldite (greisen). Chloritisation. Widespread tourmaline alteration at Isla de Pinos.

Ore controls:

Swarms of parallel veins cutting granitic rocks or sedimentary rocks near igneous contacts.

Weathering:

Wolframite persists in soils and stream sediments. Stolzite and tungstite may be weathering products.

Geochemical signature:

W, Mo, Sn, Bi, As, Cu, Pb, Zn, Be, F.

Examples

Pasto Bueno, PERU	*Landis and Rye, 1974*
Xihuashan, CINA	*Hsu, 1943; Giuliani, 1985*
Isla de Pinos, CUBA	*Page and McAllister, 1944*
Hamme District, USNC	*Foose et al., 1980*
Round Mountain, USNV	*Shawe et al., 1984*
Chicote Grande, BLVA	

Tasmania

Storys Creek
Oakleigh Creek
Cleveland (Foley Zone)
All Nations
Other smaller veins containing tungsten and tin.

Known deposits and mineral prospects in Tasmania

In Tasmania, tungsten veins are related to Late Devonian to Early Carboniferous intrusions. These veins occur in single or sheeted quartz veins in granite, or in the country rock adjacent to these granites.

At Storys Creek, sheeted quartz veins occur in sedimentary rocks of the Mathinna Supergroup overlying the surface of the Ben Lomond granite, a coarse-grained, porphyritic biotite granite. The sheeted vein system is related to cupolas of greisenised granite.

At Lutwyche, the Battery vein contains mostly wolframite and occurs in the Mathinna Supergroup.

At the Oakleigh Creek deposit, the veins occur in Mesoproterozoic sandstone and shale of the Tyennan Region.

Assessment criteria

1. Distribution of syn to late orogenic, ilmenite series I-type and/or S-type fractionated granitoids.
2. The distribution of this type of vein mineralisation is related to the subsurface distribution of granitoids as determined by modelling of gravity data. They lie within the 4 km granite isobath, and many are within the one kilometre isobath (Green, 1990). The vein mineralisation may also occur in the granitoid.
3. Distribution of tungsten, molybdenum and bismuth prospects.

Assessment: Tract Vn1a/H/B-D

In northwest Tasmania all the major granitoids are relatively fractionated felsic types that fit the model. The subsurface extent of granitoid is much larger than that exposed. The Heemskirk pluton, the small Pine Hill exposure near Renison Bell, the poorly known Granite Tor pluton and the small Lone Pine/Birthday exposures are connected at a depth of less than 4 km to define a single large tract of high potential. Large tracts also surround and connect the Pieman and Interview plutons, the Meredith plutons and the Mount Bischoff porphyry dykes, and the Housetop and Dolcoath plutons. Because of the presence of known mineralisation, all are assessed as having high potential for tungsten (-molybdenum) veins, with certainty moderate to high depending on degree of mapping.

High potential zones also occur in areas of known mineralisation in northeast Tasmania in and surrounding the Ben Lomond/Royal George granite, within the Scamander mineral field, and in the Mt Paris, Blue Tier and Mount Cameron West areas. The certainty level in these areas is high.

Assessment: Tract: Vn1b/M-H/B-C

Gravity also defines a large area of shallow granitoid in southwest Tasmania. Small exposures at Southwest Cape and Cox Bight are associated with alluvial tin deposits and there are a few small tin, wolframite, copper and antimony lode deposits in the Port Davey area. This part of the tract is rated as having medium to high potential, but because of the lack of geological mapping over most of the area the certainty level is moderate.

A gravity low also suggests shallow granite in the Sheffield–Wilmot area, but the hornblende-bearing Beulah Granite which outcrops is not highly fractionated and has recently been dated as Cambrian in age. Because the evidence for shallow fractionated Devonian granite is ambiguous here, this part of the tract is rated as medium to high potential with a lower certainty level of moderate.

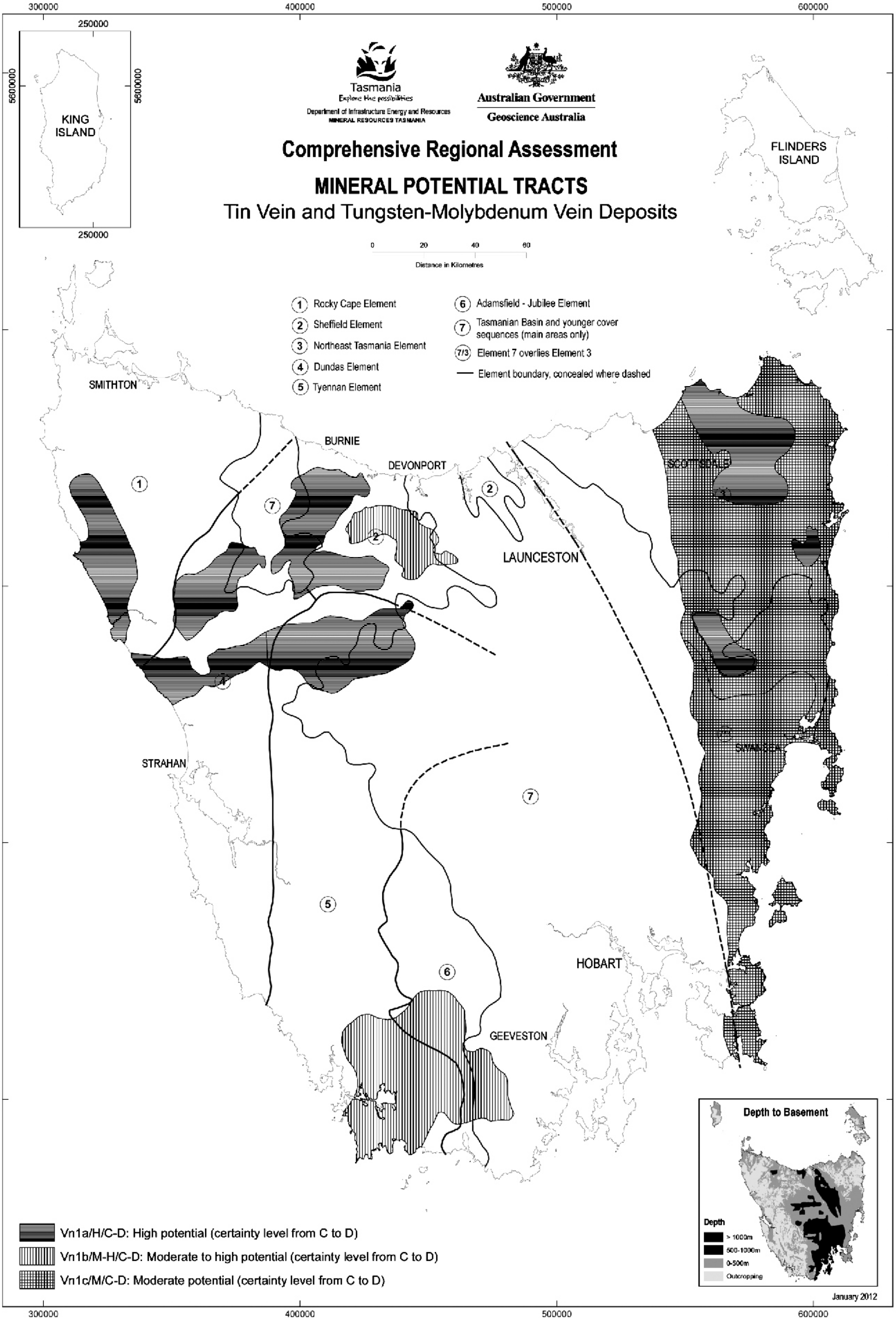
Assessment: Tract: Eastern Tasmania Vn1c/M/B-C

Much of northeast Tasmania is underlain by exposed or shallow granitoids, but in the western part of this area most of the Scottsdale Batholith is unfractionated, reduced, I-type granodiorite and is considered unprospective. In east and southeast Tasmania exposed and very shallow granitoid is restricted to a zone subparallel to the coast. The potential of this tract is rated as moderate with certainty levels of moderate to high depending on the detail of the geological mapping and depth to the underlying granite surface.

Economic significance

According to grade/tonnage models for tungsten deposits, 90% of deposits contain at least 0.045 million tonnes of ore, 50% at least 0.56 million tonnes and 10% at least 7 million tonnes. In these types of deposits, 90% contain at least 0.6 wt% WO_3, 50% at least 0.9 wt% WO_3 and 10% at least 1.4 wt% WO_3 (Cox and Singer, 1986).

Total production from the Storys Creek deposit was 1.1 Mt of ore averaging 1.09% WO_3 and 0.18% Sn.



Map 29 — Model M29A

MODEL 29B: Descriptive model of Sn veins (Model 15b of Cox and Singer, 1986)

Model description

Description of the model after B. L. Reed.

Approximate synonym

Cornish-type lodes.

Description

Simple to complex quartz-cassiterite wolframite and base-metal sulphide fissure fillings or replacement lodes in ore near felsic plutonic rocks.

General references

Solomon and Groves, 1994; *Hosking, 1974*; *Taylor, 1979*; Blevin, 1998.

Geological environment

Rock types:

Close spatial relation to multi-phase granitoids; specialised biotite and (or) muscovite; leucogranite common; pelitic sediments generally present.

Textures:

Common plutonic textures.

Age range:

Paleozoic and Mesozoic most common; may be any age.

Depositional environment:

Mesozonal to hypabyssal plutons; extrusive rocks generally absent; dykes and dyke swarms common.

Tectonic setting(s):

Fold belts and accreted margins with late orogenic to post-orogenic granitoids which may, in part, be anatectic; regional fractures common.

Associated deposit types:

Sn greisen, Sn skarn and replacement Sn deposits.

Deposit description

Mineralogy:

Extremely varied; cassiterite wolframite, arsenopyrite, molybdenite, hematite, scheelite, beryl, galena, chalcopyrite, sphalerite, stannite, bismuthinite. Although variations and overlaps are ubiquitous, many deposits show an inner zone of cassiterite wolframite fringed with Pb, Zn, Cu and Ag sulphide minerals.

Texture/structure:

Variable; brecciated bands, filled fissures, replacement, open cavities.

Alteration:

Sericitisation (greisen development) tourmalisation common adjacent to veins and granite contacts; silicification, chloritisation, hematisation. An idealised zonal relation might consist of quartz-tourmaline-topaz, quartz-tourmaline-sericite, quartz-sericite-chlorite, quartz-chlorite, chlorite.

Ore controls:

Economic concentrations of tin tend to occur within or above the apices of granitic cusps and ridges. Localised controls include variations in vein structure, lithologic and structural changes, vein intersections, dykes and cross faults.

Weathering:

Cassiterite in stream gravels, placer tin deposits.

Geochemical signature:

Sn, As, W, B are good pathfinder elements; elements characteristic of specialised granites (F, Rb, Be, Nb, Cs, U, Mo, REE).

Examples

Cornwall, GRBR	*Hosking, 1969*
Herberton, AUQL	*Blake, 1972*

Tasmania

Aberfoyle
Great Pyramid
Shepherd and Murphy
East Renison
Cooneys
Specimen Hill area south of Balfour

Known deposits and mineral prospects in Tasmania

Cassiterite veins (often with minor wolframite) are spatially related to Late Devonian to Early Carboniferous granitic intrusions (either outcropping or at shallow depth). Mineralisation occurs as either single or sheeted quartz veins in granite, or more commonly in adjacent country rocks. These veins are often above cupola-like protuberances of altered granite.

Distribution of tin veins is related to the subsurface distribution of granitoids as determined by modelling of gravity data. These veins are within the 4 km granite isobath, many being within the one kilometre contour (Green, 1990). An extensive, shallow subsurface ridge of granite extends from the Heemskirk Granite to the Granite Tor Granite, and many vein deposits are spatially related to this ridge. A concentration of veins occurs where major faults (e.g. Henty and Rosebery faults) intersect this ridge (Bamford and Green, 1986).

At Aberfoyle, the veins are within Mathinna Supergroup and are above a cupola of greisenised aplite. The veins at Great Pyramid are located along a Devonian fracture zone within silicified sandstone of the Mathinna Supergroup.

In the Moina area, sheeted quartz veins have been mined for tin, tungsten and bismuth at the Shepherd and Murphy mine. These veins cut the Moina skarn and are adjacent to a NW-trending fault zone.

In the East Renison area, a vein system is developed in sandstone, siltstone and shale of the Dundas Group. The veins occur immediately above a 700 m thick hornfels aureole of porphyritic adamellite.

Assessment criteria

1. Distribution of Late Devonian–Early Carboniferous granitic intrusions (either outcropping or at shallow depth).
2. Subsurface distribution of granitoids (as determined by modelling of gravity data) – veins are within the 4 km granite isobath, many being within the 1 km contour.

Assessment

The tracts for this model are the same as for the very similar W-Mo vein model (Model 29A).

Economic significance

According to grade/tonnage models for tin vein deposits, 90% of deposits contain at least 0.012 million tonnes of ore, 50% at least 0.24 million tonnes and 10% at least 4.5 million tonnes. In these types of deposits, 90% contain at least 0.7% Sn, 50% at least 1.3% Sn and 10% at least 2.3% Sn (Cox and Singer, 1986).

The production and estimated pre-mining resources for a number of tin and/or tungsten veins are shown below.

	Production			Pre-mining resources		
	Ore (Mt)	% Sn	% WO_3	Ore (Mt)	% Sn	% WO_3
Aberfoyle	2.1	0.91	0.28	2.1	0.91	0.28
Storys Creek	1.1	0.18	1.09	1.1	0.18	1.09
Great Pyramid	0.003	1.4	-	3.1	0.22	-
Shepherd and Murphy	0.2	0.23	0.11	0.28	0.23	0.18

MODEL M30: Ni-Cu-Cr-PGE: Early Cambrian ultramafic-related deposits (Models 5a,b; 8a,b,c, of Cox and Singer, 1986)

Model description:

Description of the models after Norman J. Page and John P. Albers.

Approximate synonyms

Duluth Cu-Ni-PGE; Noril'sk Cu-Ni-PGE; podiform chromite; alpine-type chromite; Limassol Forest Co-Ni; Alaskan-type complex.

Description

Sporadically distributed disseminated to sub-massive Ni-Cu sulphides associated with the basal portion of tectonically emplaced layered intrusions in rift environments (PGE mineral disseminations and chromite bands). Can include massive to disseminated sulphides in small shallow mafic to ultramafic intrusive rocks with an external source of sulphur or pod-like masses of chromitite in ultramafic of dismembered ophiolite complexes. Includes irregular veins, pods and lenses of Co-Ni sulphides associated with serpentinised peridotite and dunite.

General references

Hoatson and Glaser, 1989; Brown, 1992.

Geological environment

Rock types:

Island Arc–Ocean Island character: Peridotite, dunite, harzburgite, pyroxenite, norite, augite, troctolite, anorthosite and associated high magnesium boninitic and low titanium basalt lavas and associated gabbroic rocks.

Textures:

Cumulus textures, locally diabasic or ophitic textures.

Age range:

Early Cambrian (Tasmania); Precambrian to Tertiary (world).

Depositional environment:

Tectonically emplaced during Early Cambrian collision event within metasedimentary (black shale, argillite, greywacke, slate) and metavolcanic rocks. PGEs associated especially with Layered Dunite-Harzburgite association.

Tectonic Setting(s):

Rift environment; magma may accumulate in zones near unstable spreading plate boundaries, later exposed in accreted terranes, together with possible ophiolite associations.

Associated deposit types:

Podiform chromite, Ni-laterite, vein-type Co-Ni-Cu ophiolite sulphide. Placer chromite — PGEs (placer gold).

Deposit description

Mineralogy:

Pyrrhotite + pentlandite + chalcopyrite + cubanite   PGE minerals   graphite. Also can include millerite + vallerite + pyrite + bornite + gersdorffite + sperrylite + PGE alloys + polarite + PGE tellurides, arsenides, and antimonides. At different levels and layers may include chromite   ferrichromite   magnetite   Ru-Os-Ir alloys   laurite. Nickel-rich zones may include loellingite   niccolite   maucherite   skutterudite   gersdorffite   cobaltite   magnetite   mackinawite.

Texture/structure:

Disseminated, matrix, and ?rare lenses/layers massive sulphides; coarse grained to finely disseminated; irregular veins.

Alteration:

Often unaltered. Locally Ni-Cu sulphides may show evidence of hydrothermal remobilisation, serpentinisation, quartz-carbonate alteration.

Ore controls:

Zones of initial syn-intrusion faulting forming basins, in basal part of intrusion; source of external sulphur to contaminate magma causing immiscible Ni-Cu sulphides   PGEs in persistent basal layers or dyke-like intrusions into country rock. Chromitite layers are restricted to dunite bodies in lower portions of layered ultramafic rocks. Later intrusive rocks, fluid or country rock contamination   serpentinisation are also important.

Weathering:

Tends to be recessive and exhibit subdued topography where the ultramafic rock has been altered, strongly sheared or serpentinised although unaltered layered ultramafic differentiates tend to outcrop relatively strongly.

Geochemical signature:

Ni/Cu variable from approximately 1/3 to 2/1, + PGEs, Co, Cr. S sulphur isotopes can show non-magmatic sulphur. Can include Co/Ni = 1/16; Pt/(Pd/Ni) = 1/500:   As.

Geophysical signature:

Strong magnetic signature where not completely serpentinised.

Examples

Overseas

Duluth Complex, USMN (*Weiblen and Morey, 1980*)
Noril'sk, USSR (Krauss and Schmidt, 1979);
High Plateau, Del Norte County, USCA (*Wells et al., 1946*)
Limmasol Forest, CYPS (*Panayiotou, 1980*)

Tasmania

Caudrys PGE prospect, Bald Hill
Loughnan Creek PGE workings, Mt Stewart
Lord Brassey Ni-Cu prospect, Heazlewood (Peck and Keays, 1990)
Bald Hill
Waratah–Zeehan region

Adamsfield
Glovers Bluff inlier.

Known deposits and mineral occurrences in Tasmania

Bald Hill/Heazlewood River: Lord Brassey Ni and Caudrys PGE prospects
Loughnan Creek PGE workings, Mt Stewart
Trial Harbour, Zeehan region
Halls workings, Adamsfield region
Glovers Bluff inlier.

Brown (1986, and *in* Burrett and Martin, 1989, p.71–74) grouped the ultramafic rocks of western Tasmania into 15 areas and three petrological associations, and briefly discussed the mineral potential of each. All are layered orthopyroxene-rich bodies tectonically emplaced in the Early Cambrian, and are thought to represent crustal cumulates rather than the basal parts of dismembered ophiolites.

The three associations identified by Brown are:

(1) the layered dunite and harzburgite (LDH) association, thought to represent cumulates from boninitic magmas. All the historical PGE (osmiridium) production is associated with this association.

(2) the layered pyroxenite, peridotite and gabbro (LPG) association, thought to represent cumulates from low-titanium tholeiitic magmas. This includes the Serpentine Hill Complex, samples of which have recorded the highest platinum values. Small amounts of platinum and palladium have been recorded associated with gabbro-related nickel mineralisation at Cuni, in turn related to the Serpentine Hill Complex.

(3) the layered pyroxenite and dunite (LPD) association, the affinities and PGE potential of which are poorly understood.

The ultramafic/mafic complexes occur at Andersons Creek (Beaconsfield); Forth; Heazlewood (LPG + LDH); Mt Stewart (LDH); Huskisson River (LDH + LPD); Wilson River (LDH + LPD); Colebrook Hill (LPD); Serpentine Hill (LPG); McIvors Hill (LPG); Dundas (LPD); Trial Harbour; the Hibbs Melange Belt (Cape Sorell area); Spero Bay; Adamsfield (LDH + LPD); Boyes River (LDH + ?LPD); Rocky Boat Harbour (LDH) and a few other small fault emplaced slivers in western Tasmania.

All the bodies probably have some potential for chromite, both in the ultramafic rocks themselves and locally in fossil placers within overlying sedimentary sequences, such as the siliciclastic Denison Group adjacent to the Adamsfield Ultramafic Complex. (Cainozoic placer deposits are treated elsewhere in a separate model). The LDH association contains more refractory chromites with higher Cr/Cr + Al contents than the other associations.

Similarly there is some potential for related nickel-(copper) with all the bodies, and some nickel mineralisation is known in or near the Andersons Creek, Heazlewood, Trial Harbour, McIvors Hill, Serpentine Hill, Dundas, Hibbs Melange Belt and Adamsfield bodies. Most of the nickel prospects in Tasmania are in the Cuni area near Zeehan. These are gabbro-related and, although associated with the Serpentine Hill Ultramafic Complex, are treated separately.

The Lord Brassey Ni deposit contains arawuite, heazlewoodite and millerite. It is poorly understood but may have resulted from granite-related metasomatic serpentinisation of nickel-bearing ultramafic rocks and is included in discussion on Avebury-style Ni mineralisation.

Mineralisation is known or could occur within other fault-bounded ultramafic blocks and complexes at Andersons Creek (Beaconsfield), Huskisson River/Wilson River, Serpentine Hill, McIvors Hill, Cape Sorell, Boyes River, Maydena, Rocky Boat Harbour and South Cape.

Assessment criteria

- ☐ Presence of mafic-ultramafic complexes in the area.
- ☐ Presence of nickel-copper minerals, PGEs, or layered chromites in ultramafic and mafic rocks in the area.
- ☐ Presence of PGEs, or chromites as placer accumulations in streams or in paleoplacers in an area.

Assessment: Tract Adamsfield PGE1a/H/C

Ultramafic rocks in the Adamsfield area have produced most of Tasmanian PGE and are rated as having high potential for this deposit type with a high certainty level.

Assessment: Tract Western Tasmania and other areas: PGE1b/M/B-C

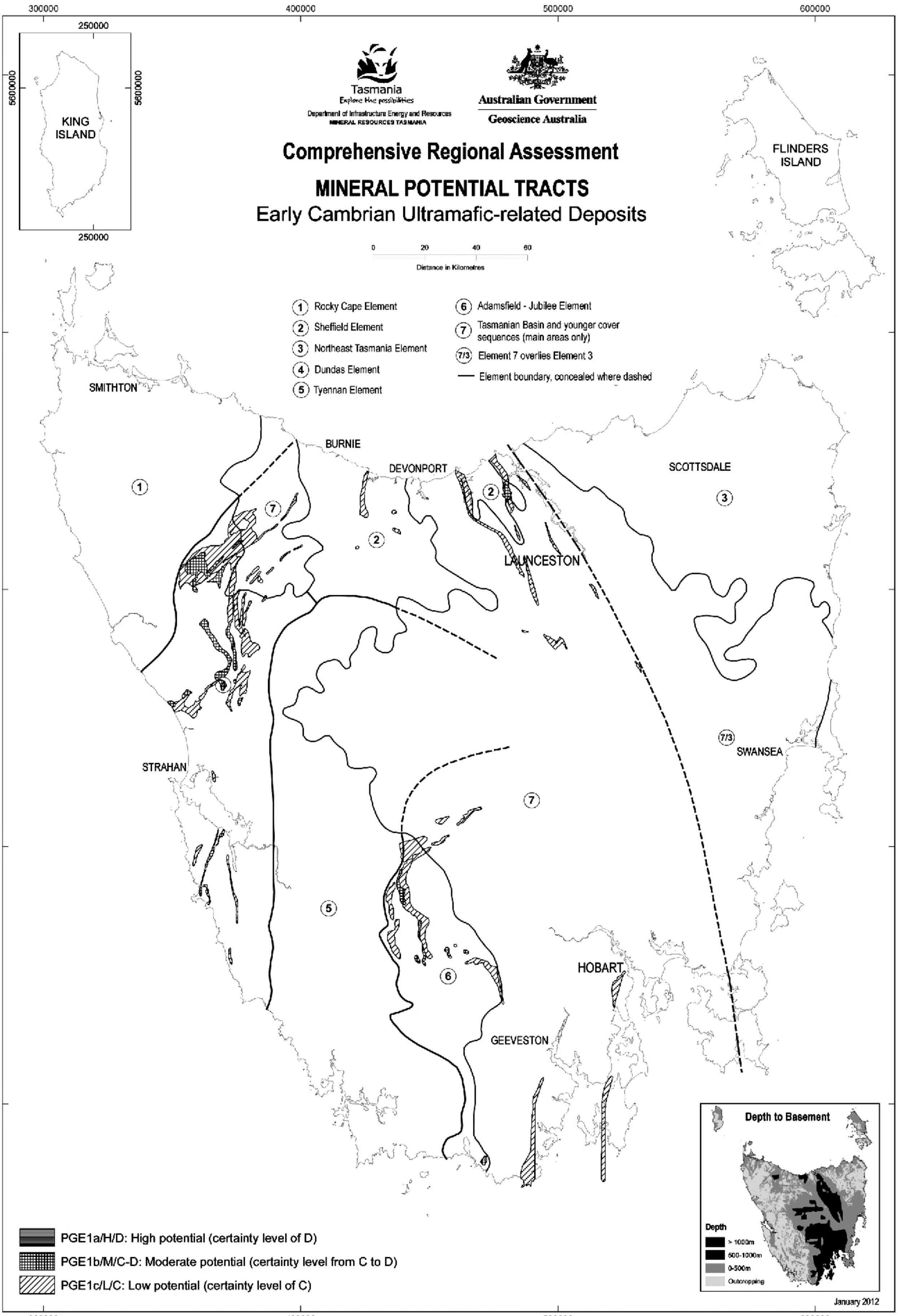
Based on the presence of ultramafic rocks in the areas of this tract there is moderate potential for deposits of this type. The certainty level is rated as moderate to high depending on the standard of geological mapping, geochemical data and exploration.

Assessment: Tract Eastern Tasmania and other areas: PGE1c/L-M/B

This tract is based largely on the distribution of Cambrian Series 2 mafic–ultramafic sequences as predicted by the 3D geological model of Tasmania. In most cases this tract is concealed beneath a cover of Parmeener Supergroup and younger rocks. This tract is considered to have low to medium potential with a moderate level of certainty.

Economic significance

Historically, placer 'osmiridium' (a mixture of various PGMs) has been the most economically significant product of the ultramafic-related deposit types in Tasmania, although demand and therefore price is not as strong as it once was. If grades and tonnages of potentially ore-bearing material were sufficiently high, mining of osmium-iridium-ruthenium alloys would be economic at today's prices for these elements which are about half on average of the prices for palladium-platinum and rhodium. Layered chromitites and vein nickel sulphides have not been mined in great quantities from Tasmania in the past.



Map 30 — Model M30

Descriptive model of sandstone-hosted uranium (Model 30c of Cox and Singer, 1986)

Model description

Description of the model after Christine E. Turner Peterson and Carroll A. Hodges.

Approximate synonyms

Tabular U ore, roll front U.

Description

Microcrystalline uranium oxides and silicates deposited during diagenesis in localised reduced environments within fine to medium-grained sandstone beds; some uranium oxides also deposited during redistribution by groundwater at interface between oxidised and reduced ground.

General references

Turner-Peterson and Fishman, 1986; *Granger and Warren, 1969*.

Geological environment

Rock types:

Host rocks are feldspathic or tuffaceous sandstone. Pyroclastic material is felsic in composition. Mudstone or shale commonly above and/or below sandstones hosting diagenetic ores.

Textures:

Permeable medium to coarse grained; highly permeable at time of mineralisation, subsequently restricted by cementation and alteration.

Age range:

Most deposits are Devonian and younger. Secondary roll-front deposits mainly Tertiary.

Depositional environment:

Continental-basin margins, fluvial channels, braided stream deposits, stable coastal plain. Contemporaneous felsic volcanism or eroding felsic plutons are sources of U. In tabular ore, source rocks for ore-related fluids are commonly in overlying or underlying mud-flat facies sediments.

Tectonic setting(s):

Stable platform or foreland-interior basin shelf margin; adjacent major uplifts provide favourable topographic conditions.

Associated deposit types:

Sediment-hosted V may be intimately associated with U. Sediment-hosted Cu may be in similar host rocks and may contain U.

Deposit description

Mineralogy:

Uraninite, coffinite, pyrite in organic-rich horizons. Chlorite common.

Texture/structure:

Stratabound deposits. Tabular U — intimately admixed with pore-filling humin in tabular lenses suspended within reduced sandstone. Replacement of wood and other carbonaceous material. Roll front U — in crescent-shaped lens that cuts across bedding, at interface between oxidised and reduced ground.

Alteration:

Tabular — Humic acid mineralising fluids leach iron from detrital magnetite-ilmenite leaving relict TiO_2 minerals in diagenetic ores. Roll front — Oxidised iron minerals in rock up-dip, reduced iron minerals in rock down-dip from redox interface.

Ore controls:

Permeability. Tabular — Humin or carbonaceous material the main concentrator of U. Roll front — S species, 'sour' gas, FeS_2. Bedding sequences with low dips; felsic plutons or felsic tuffaceous sediments adjacent to or above host rock are favourable source for U. Regional redox interface marks locus of ore deposition.

Weathering:

Oxidation of primary uraninite or coffinite to a variety of minerals, notably yellow carnotite as bloom in V-rich ores.

Geochemical and geophysical signature:

U, V, Mo, Se, locally Cu, Ag. Anomalous radioactivity from daughter products of U. Low magnetic susceptibility in and near tabular ores.

Examples

Colorado Plateau	(*Fischer, 1974*)
Grants, USNM	(*Turner-Peterson and Fishman, 1986*)
Texas Gulf Coast	(*Reynolds and Goldhaber, 1983*)

Known deposits and mineral prospects in Tasmania

Granite-hosted deposits:

Uranium mineralisation occurs in granites in several areas in the northeast, particularly at the Rossarden, Royal George and Anchor tin mines. These are probably the sources of the sediment-hosted uranium deposits described above. The mineralisation at Royal George consists of torbernite in fractures and joints in fine-grained granite, associated with weathered cassiterite-quartz veins. Torbernite was also reported from the Anchor tin mine. The primary mineral in these mines is unknown, but possibly uraninite.

There has also been exploration for uranium mineralisation in granite at Storys Creek, near Rossarden (Blissett, 1959). The uranium minerals in the Tasmanian United Uranium or Chwalczyk prospect include torbernite, pitchblende (uraninite), 'gummite'-uranophane, autunite, carnotite and schoepite, and are associated with base metal sulphides and fluorite in fine-grained granite. Hughes Prospect, nearby, contains unidentified uranium mineralisation in a coarse grained, altered granite. Analyses indicate <2.2% U_3O_8, but usually <0.1%.

The potential for this style of mineralisation is unknown as it is poorly understood.

Shale-hosted deposits:

Uranium mineralisation occurs in Permian carbonaceous, pyritic black shale overlying granite in a prospect in Castle Cary Rivulet, in the Rossarden area (Blissett, 1959). Intercalated sandstones do not appear to be mineralised. This mineralisation (probably in thucolitic hydrocarbons) is probably sourced in the granite-hosted mineralisation described above. Analyses indicate <0.03% U_3O_8.

The potential for this style of mineralisation is unknown as it is poorly understood.

Assessment criteria

1. Presence of uranium-bearing source rocks.
2. Distribution of Devonian granites.
3. Distribution of rocks of Permian, Triassic and Cenozoic ages.

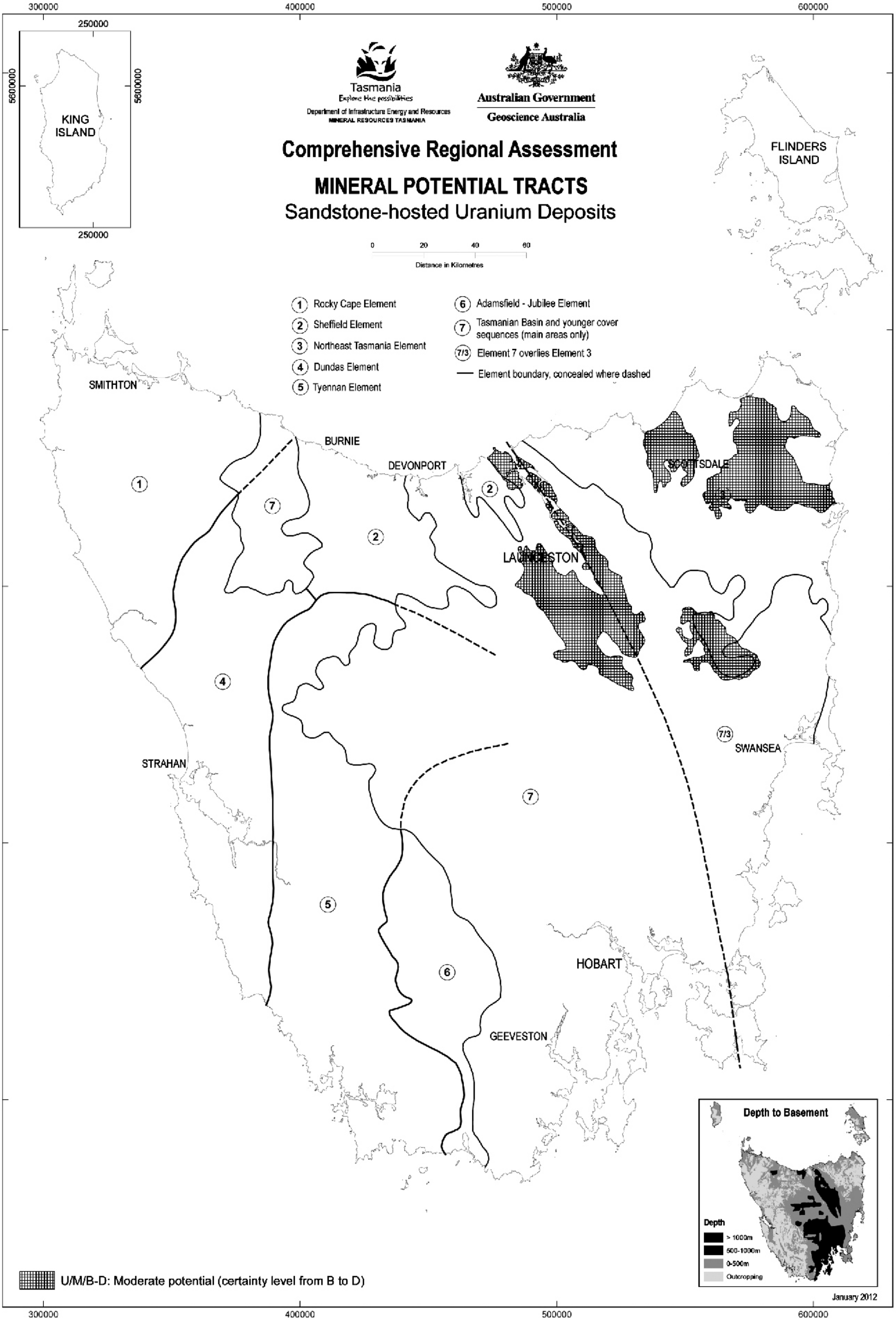
Assessment: Tract Ua/M/B-C

This tract is based on the distribution of U-rich Devonian granites and Permo-Triassic rock types in the Rossarden and Royal George areas. It has a moderate potential and moderate to high certainty. Minor Cenozoic sediments within this tract along the South Esk River and St Pauls River have moderate potential and moderate certainty.

Assessment: Tract Ub/M/B

This tract is drawn based on the distribution of Devonian granites, known sediment-hosted uranium deposits, primary uranium deposits and associated Cenozoic sediments. It is primarily defined about the tin-mineralised granites in northeast Tasmania, including Permo-Triassic and Tertiary cover. It also includes the Paleogene Longford Basin which has been explored for uranium.

On the available information the potential for uranium is moderate with a certainty level of B.



Map 31 — Model M31

MODEL F32: Coal deposits in the Tasmania Basin

Model description

Description of coal-bearing sedimentary sequences.

Approximate synonym

Coal measures.

Description

While coal measures of Early Permian, Late Permian and Triassic age are known from the Tasmania Basin, the economic deposits of coal are confined to the Late Triassic (Unit 4) sequence of the Parmeener Supergroup.

The Upper Parmeener Supergroup is of fluvial origin. The Late Triassic coal measure interval consists of interbedded lithic sandstone, with minor mudstone, siltstone, claystone, rare tuff bands and some coal seams (in turn banded with mudstone and claystone).

General reference

Bacon, 1991.

Geological environment

Rock types:

Permian and Triassic coal measures.

Age range:

Karnan–Norian

Depositional environment and tectonic setting:

The Upper Parmeener Supergroup is of fluvial origin and is composed of Late Permian to Late Triassic clastic rocks and overlies the largely marine sequence of the Lower Parmeener Supergroup. The sequence was extensively intruded by tholeiitic magma during the mid Jurassic. More than 8000 km^3 of magma formed a nearly continuous body through the Permian and Triassic sediments over almost the whole island. The dolerite occurs most commonly as discordant sheets or sills, although dykes are also seen. The sheets reach a maximum thickness of around 500 metres. From the cessation of Triassic sedimentation until recent times Tasmania has been subject to normal faulting with a NNW trend (horst and graben structures).

Structures of major dimensions developed during the Late Cretaceous and Early Tertiary. As a result of this faulting, the coalfields have been fragmented and dislocated.

Deposit description

Individual coal seams range from about 0.5 m to 4 m in thickness, most being 1–2 m in thickness, and lense out over distances of tens of kilometres. The seams which have been (and still are) mined are almost always banded; the coal must be washed to remove the unwanted mudstone/claystone material. In northeast Tasmania the seams are flat lying or dip to the southeast at 1–4°. The mined seams are frequently truncated by minor small scale faults (still a hindrance to extraction) which are frequently associated with the margins of overlying channel deposits. Some displacement may be due to differential compaction while other displacements are clearly the result of tectonic stresses.

Mineralogy:

The coal is an inertinite-rich coal of sub-bituminous rank suited for use as a steam raising fuel.

No coking coal deposits are known in Tasmania.

Examples

Mt Nicholas	Bacon, 1991
Fingal	Bacon, 1991
Harefield	Bacon, 1991
Merrywood	Bacon, 1991
Dalmayne	Bacon, 1991
Douglas River	Bacon, 1991
Seymour	Bacon, 1991
Langloh (Hamilton)	Bacon, 1991
Kaoota (Sandfly)	Bacon, 1991
Catamaran	Bacon, 1991

Many minor occurrences of coal are known from the three coal-bearing intervals of the Parmeener Supergroup. Coal has been found in 63 localities and Tasmania has at various times supported over 100 mines. The total production to date is around 20 million tonnes.

Assessment criteria

1. Presence of Unit 4, Upper Parmeener Supergroup.
2. Proximity to known coal deposits.

Assessment: Tract Langloh and Fingal areas: Coal1a/H/C

This tract is drawn based on the presence of Unit 4, Upper Parmeener Supergroup, and known deposits of coal, including operating mines and intersections in diamond drill holes from exploration programs. In northeast Tasmania the extent of the coalfields is known from an extensive diamond drilling program. High potential has been assigned, because of the presence of operating mines, with a certainty of C, based on moderate quality data.

Assessment: Tract Coal1b/M/C

This tract covers a number of smaller abandoned coalfields including Catamaran–Strathblane, Colebrook–Kempton, Preolenna, and Mersey–Don. It is drawn based on the presence of Unit 4, Upper Parmeener Supergroup, and known deposits of coal, including abandoned mines and intersections in diamond drill holes from exploration programs. In the Midlands the outcrop is assumed to be continuous with some areas confirmed as containing coal measures after diamond drilling. Elsewhere the coalfields are defined by detailed geological mapping. Moderate potential has been assigned, because of the presence of old mines with small reserves, and a certainty of C, based on moderate quality data.

Assessment: Tract Coal1c/L/C

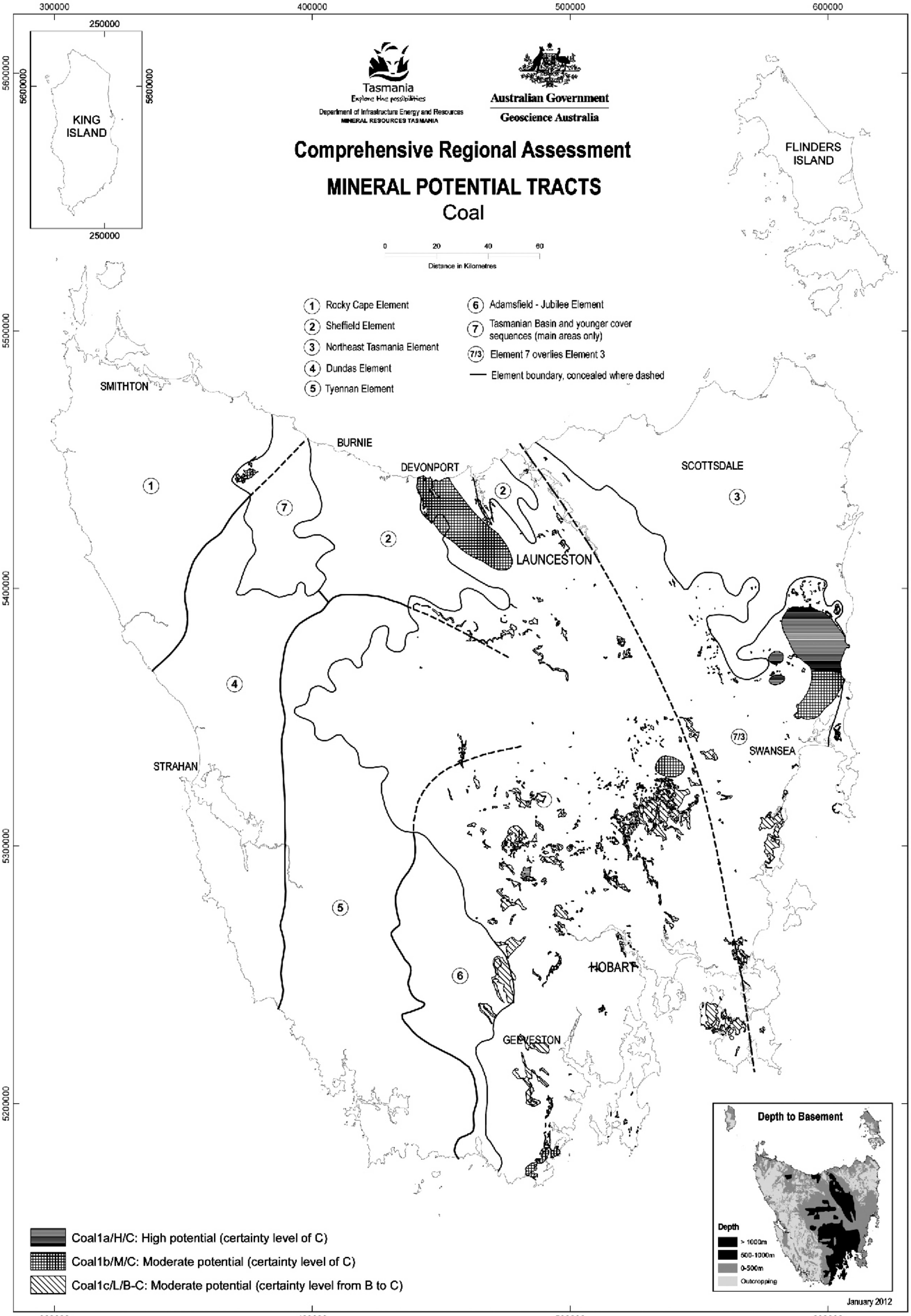
This tract, covering various areas in Tasmania, is drawn based on the presence of Unit 4, Upper Parmeener Supergroup, with few or no known deposits of coal. Low potential has been assigned, because of the lack of known deposits, and a certainty of C, based on moderate quality data.

Assessment: Tract Coal1d/L/B

This tract, covering various areas in Tasmania, is drawn based on the presence of Unit 4, Upper Parmeener Supergroup, with few or no known deposits of coal. Low potential has been assigned, because of the lack of known deposits, and a certainty of B, based on poor quality data.

Economic significance

Use of indigenous coal provides Tasmania with an industry which employs approximately 120 people and limits the reliance on imported coal. Total in situ black coal resources have been estimated at around 570 million tonnes (pre-JORC).



Map 32 — Model F32

MODEL I33: Dolomite

Model description

Description of the model after D. Hora/D. Perkin.

Approximate synonyms

Dolostone, magnesian limestone, dolomitic limestone, calcium-magnesium carbonate, double carbonate of calcium-magnesium ($CaCO_3.MgCO_3$ or $CaMg(CO_3)_2$).

Description

Dolomite deposits of economic importance comprise relatively pure carbonate-bearing sediments in which magnesium was co-precipitated with calcium. The depositional environment determines the size, shape and purity of the dolostone. Dolomite deposits are frequently of large areal extent and may be of considerable thickness (up to several hundred metres) of relatively impurity-free calcium-magnesium carbonate.

General references

McLeod, 1965.

Deposit description

Geological environment:

Rift/graben, in low latitudes associated with high evaporation rates; magnesium co-precipitated with calcium in generally hypersaline to saline conditions where detrital sedimentary influx was minimal; essentially a chemogenic sediment deposited in a quiet lagoonal, lacustrine or shallow-marine environment.

Rock types:

Dolostone, magnesian limestone, dolomitic limestone, calcium-magnesium carbonate.

Age range:

Commonly overlies clastic sedimentary sequences in the Neoproterozoic. Can occur at any stratigraphic horizon from the Archaean to the present day if conditions suitable.

Depositional environment:

Shallow hypersaline marine and non-marine (intra-continental and epi-continental) environments; graben, lagoons, lakes, epeiric seas.

Tectonic setting(s):

Continental shelf and subsiding marginal marine basins. Includes intra-continental rifts and closed basins.

Associated deposit types:

Limestone.

Deposit description

Mineralogy:

Dolomite (the mineral dolomite, when pure, theoretically contains 45.65% magnesium carbonate, equivalent to 21.7% MgO). Rarely are dolomites monomineralic containing 100% of the mineral dolomite. Common impurities include calcite, chert, clay, quartz sand, carbonaceous shale and pyrite.

Texture/structure:

Massive, or may be thick or thin bedded, fine to coarse grained. Coarsening of grain size is frequently due to recrystallisation because of replacement by later through-going fluids or because of exposure to a higher heat regime for an extended period.

Alteration:

Groundwater dissolution of dolomite is not as rapid as dissolution of limestone which results in dolines or karst cavities; dolines may be partly filled with clay.

Ore controls:

The degree of purity of quarry dolomite is a major factor in determining its quality; hence purity generally controls where dolomitic ore might occur. Cost limitations imposed by overburden thickness is variable depending on the end use.

Weathering:

Weathering can result in a variety of karst landforms in different climatic areas, but intensifies with warmer climate. Metamorphism may increase grain size through recrystallisation of carbonate minerals resulting in enhanced physical and chemical weathering.

Geochemical signature:

Ca, Mg.

Geophysical signature:

Resistivity has been used to identify karst features in covered terrain.

Examples

Ardrossan, Kadina (SA), Ipswich (Qld), Bungendore, Havilah, Barraba (NSW), Rum Jungle (NT).

Known deposits and mineral prospects in Tasmania

Neoproterozoic dolomite at Smithton (northwest), Brumbys Creek near Launceston, Maydena, Hastings; impure (calcitic) dolostones in parts of the Ordovician Gordon Group (e.g. western Tasmania; Hastings).

Assessment criteria

Known outcrop and shallow subsurface occurrence of high purity, thick dolomite units (Black River Dolomite, Smithton Dolomite, correlative dolomites of the Ahrberg Group, the Jane Dolomite, and the Weld River Group) in proximity to a potential market.

Assessment: Tract Dol/H/B-C

Mapped outcrop and shallow subsurface occurrence of the Smithton Dolomite, source of most of Tasmania's historical and present production, is assessed as high potential with a certainty level of C. All other areas of outcropping and shallow subsurface Neoproterozoic dolomite, including the Jane Dolomite and the Weld River Group in central and southern Tasmania, are assessed as having a high potential with a certainty level of B.

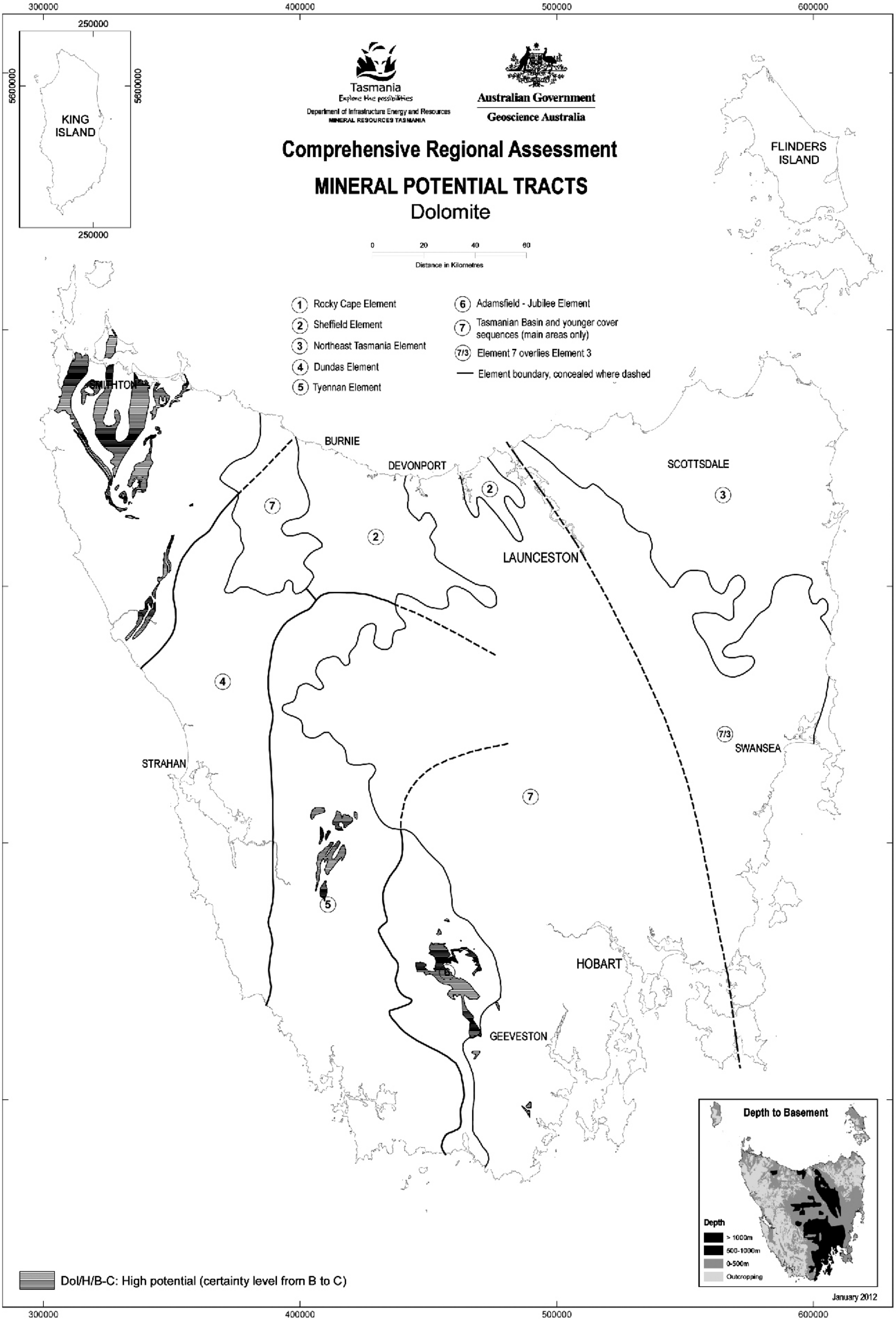
Economic significance

Some deposits may cover up to hundreds of square kilometres in area.

This deposit type accounts for most of the dolomite produced in Australia. Dolomite is used as a fluxing agent in steel manufacture. Crushed and powdered dolomite is used for agricultural purposes and spread as a soil conditioner in promoting alkalinity on pastures.

Physical/chemical properties affecting end use:

Chemical purity, absence of hard minerals like quartz or other silicates. Distance limitations to transportation, processing, end use/markets.



Map 33 — Model I33

MODEL I34: Limestone

Model description

Original description of the model after D. Hora.

Approximate synonyms

Lime rock, cement rock, calcium carbonate.

Description

Limestone deposits of economic importance were partly or wholly biologically derived from seawater and accumulated in a relatively shallow marine environment. Environment of deposition determines the size, shape and purity of the carbonate rock. Limestone deposits are frequently of large areal extent and may be of considerable thickness (several hundred metres).

General references

Threader, 1975.

Geological environment

Rock types:

Limestone.

Age range:

Late Proterozoic to Holocene.

Depositional environment:

Belts of shallow sea water sediments.

Tectonic setting(s):

Continental shelf and subsiding marginal marine basins.

Associated deposit types:

Deposits of dolomitic limestone and dolomite.

Deposit description

Mineralogy:

Limestone is a sedimentary rock consisting of 50% or more of calcite ($CaCO_3$) and dolomite ($CaMg(CO_3)_2$). There is a complete gradation from impure limestone to high calcium limestone (>95% $CaCO_3$). In dolomite the mineral dolomite is the major carbonate, which usually forms by replacement of calcite. Common impurities in carbonate rocks include clay, quartz sand, chert and organic matter.

Texture/structure:

Massive, bedded.

Alteration:

Groundwater dissolution results in karst cavities, frequently filled with clay.

Ore controls:

Highly sought white limestones for mineral fillers are usually a product of the contact or regional metamorphic process. The maximum limitation of overburden on mining is extremely varied depending on the end use. Limestones are known to be mined underground for uses like cement production.

Weathering:

Solution weathering results in a variety of karst landforms in most climatic areas, but intensifies with warmer climate.

Geophysical signature:

Resistivity has been used to identify karst features in covered terrain.

Examples

Silurian Marulan and Wombeyan limestones of NSW; Tertiary Eucla Basin limestones, e.g. Nullarbor Limestone of WA and SA; Tertiary Batesford Limestone and Gambier Limestone of Victoria and SA.

Known deposits and mineral prospects in Tasmania

The majority of the limestone produced in Tasmania comes from the Ordovician Gordon Group which contains by far the largest reserves of high-grade limestone in Tasmania. The Gordon Group consists of up to 1800 m of interbedded high-grade limestone, low-grade limestone and calcareous shale, and is widespread in south, west and northern Tasmania. Large volumes of moderate to high grade industrial limestone (80–95% $CaCO_3$) are present which are suitable for cement manufacture. The main production centres and recorded resources of Ordovician limestones are at Mole Creek, Railton, Flowery Gully and Ida Bay. Enormous resources of limestone are known to occur in the Maydena–Florentine Valley district. Limestone is also known to occur at New River and Precipitous Bluff.

Permian limestones occur in the southeast north of Hobart, on the east coast at Coles Bay and Maria Island, and in the Break O'Day Valley between Fingal and St Marys in the northeast. Grades are generally rather low, averaging about 60% $CaCO_3$. There is only one small-scale extant operation.

Cenozoic limestones occur mainly in the northwest, and tend to be thin, impersistent and impure. They have only been intermittently worked, as at Pulbeena for agricultural lime.

Assessment criteria

1. Presence of Ordovician Gordon Group limestone as indicated by geological mapping.

Assessment: Tract Lst1a/H/C

On a statewide broadscale assessment, there is a high potential in the Gordon Group for the presence of limestone resources suitable for industrial, agricultural and construction uses. In the vicinity of major extant or past operations (Mole Creek, Ida Bay, Flowery Gully, Railton) the potential is high with a certainty level of C.

Assessment: Tract Lst1b/H/B

All outcrop areas of Gordon Group rocks have high potential for limestone but in areas other than present or past operations the certainty level is only B.

Economic significance

This deposit type accounts for virtually all production of cement and lime in Australia.

Thickness of mineable limestone deposits range from ten to several hundreds of metres. Areal extent of some deposits covers hundreds of square kilometres.

Physical/chemical properties affecting end use:

Fillers: high brightness (over 90GE), chemical purity, absence of hard minerals like quartz and variety of silicates, absence of graphite. Flotation to remove deleterious components is routine.

Lime: High calcium carbonate (>97%), low MgO (<5%) — the specifications vary slightly. The rock must not decrepit in the kiln during calcination.

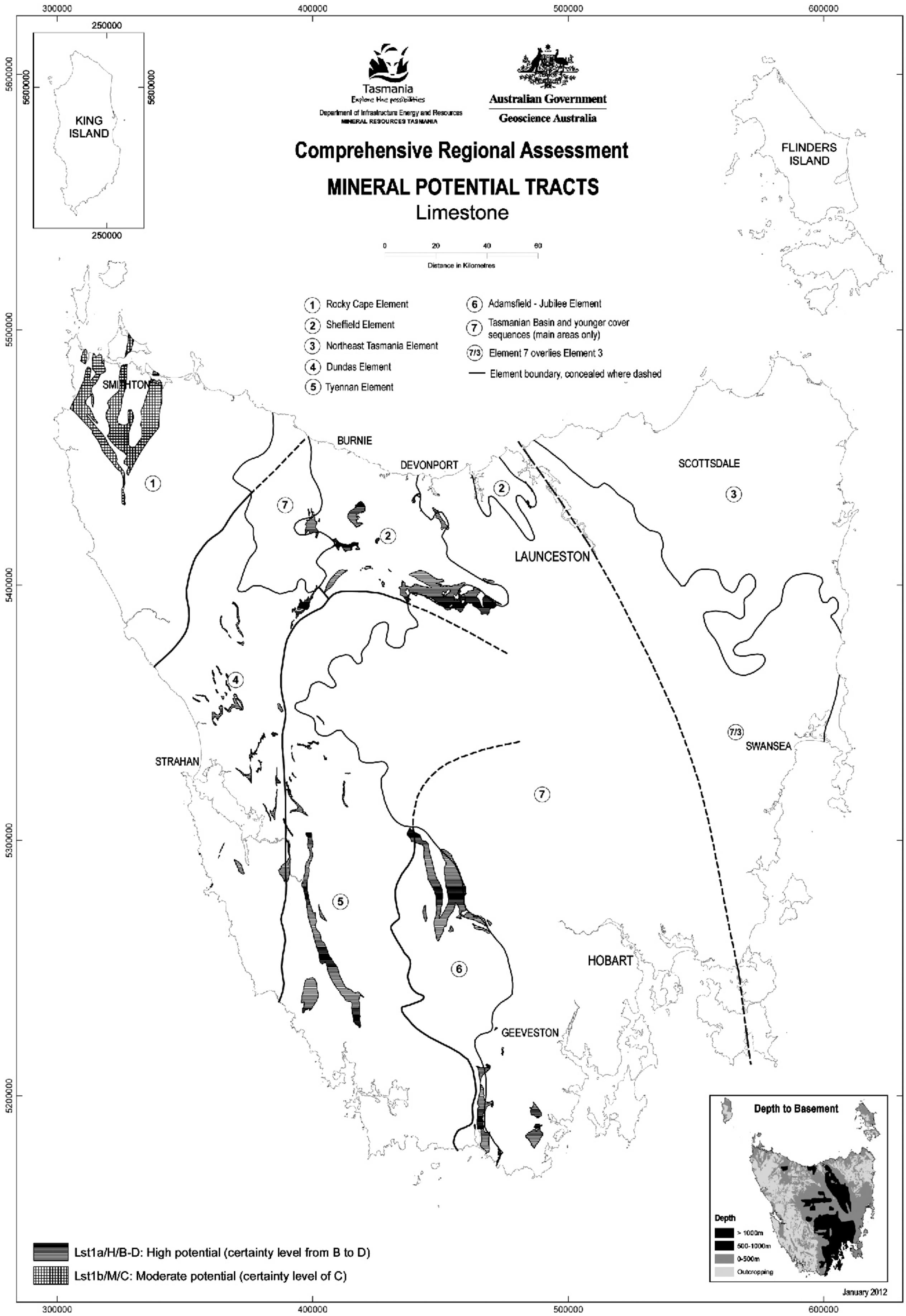
Cement: MgO in final product <6%, alkalies (Na_2O + K_2O) <0.6%.

Distance limitations to transportation, processing, end use:

As limestone deposits are unevenly distributed throughout the continent, the transportation cost depends on availability of the local resource and is frequently a major cost of the finished product.

Just over one million tonnes of limestone are annually extracted in Tasmania, the great majority for the manufacture of cement, most of which is exported interstate. Medium-grade (80–90% $CaCO_3$) limestone, but with <3% $MgCO_3$, is required. Other industrial uses are diverse and most require high-grade (c. 95% $CaCO_3$) limestone. These include usage in paper and glass manufacture, as a flux in ferromanganese manufacture, a neutralising agent for acid mine drainage and in zinc manufacture, a flocculating agent in water treatment, a stabiliser in road construction, and as an animal feed supplement. Agricultural limestone and crushed rock for road construction are also important uses.

Total resources are vast, but high-grade, easily extractable deposits without potential land use conflicts are not abundant.



Map 34 — Model I34

MODEL I35: Magnesite

Model description

Initial model by D. J. Perrkin.

Approximate synonym

Metasomatic magnesite.

Description

Massive concordant and discordant magnesite bodies in mafic volcanic rocks, tuff, intrusive or sedimentary rocks including dolomite with talc, tremolite-actinolite, antigorite, dolomite, and ?magnetite/hematite alteration. Impurities are quartz, dolomite, rhodochrosite and siderite, talc, pyrite and chlorite.

Geological environment

Rock types:

Stratabound dolomite and magnesite, thin quartzite and bedded chert. Associated tholeiitic mafic to andesitic flows and sub-volcanic intrusions, chlorite schists; diorite, monzonite and syenite porphyry may be present. Amphibolite and quartz-actinolite, quartz chlorite, and quartz-sericite schist, with minor pyrite-graphite schist. Intrusive dolerite and calcic-gabbro dykes and sills. Possible quartz diorite intrusive rocks at depth.

Age range:

Neoproterozoic in Tasmania.

Depositional environment:

Continental volcanic rocks and clastic sediments intruded by sub-volcanic mafic (-intermediate) plutons.

Tectonic setting(s):

Continental margin, epi-cratonic; intra-continental rift with marine to lacustrine graben. Subduction-related volcanic terrane. Associated with high-K volcanic rocks, possibly related to waning stages of volcanism.

Associated deposit types:

Sedimentary dolomite; sedimentary Fe oxides, sulphides, carbonates, or silicates in associated clastic rocks; apatite-magnetite deposits; hematite? in quartz-sericite alteration; possible disseminated Au.

Deposit description:

Mineralogy:

Major phase is magnesite. Some quartz, dolomite, siderite, rhodocrosite, pyrite as disseminations and occasional layers, magnetite blebs and layers. Trace apatite, rutile horizons. Talc chlorite tremolite gangue at margins of body.

Form:

Stratabound magnesite, massive to lensoid with anastomosing irregular and often sheared magnesite bodies on the boundary of the amphibolite/mafic volcanic host or on the margin of pre-existing dolomitic beds.

Texture/structure:

Massive, sometimes sheared, may be slightly banded; both fine grained (banded) and medium to coarse grained (non-banded) magnesite; can be disseminated in coarse (large) blebs or as magnesite aggregates; brecciated or metasomatised appearance in parts (especially at Long Plains where massive magnesite/magnetite 'spotted dog' rock occurs). May be equigranular, mottled, or show some rhythmic zoning.

Alteration:

Uralitisation, saussuritisation, and minor propylitisation (metasomatism) of mafic host rocks. Assemblages include tremolite-actinolite, chlorite, albite and epidote. Widespread but minor tourmaline and scapolite occur throughout the amphibolite and sheared amphibolite (schist), and may be related to late-stage meta-evaporite fluid activity. Some ore zones may have been altered by subsequent nickeliferous (and possibly cupriferous) solutions.

Ore controls:

Magnesite tends to be stratabound, with concordant to intrusive contacts; may be in cross-cutting bodies. Controls uncertain but solutions may have risen along competency contrasts between massive mafic volcanic rocks/ amphibolites and the adjacent incompetent quartz sericite schists. Deposits occur within an elongate narrow rift or graben bordered by major lineaments. Magnesite deposits may be associated with evaporitic sediments overlying mafic or other extrusive rocks. Deposits can include massive magnesite in replacement, breccia filling and stockwork veins; localisation of deposits may be related to large faults or to cupolas of deeper plutons.

Weathering:

Chemical weathering of magnesite/dolomite results in recessive topography with a mantling of fine-grained silica and other resistate minerals.

Geochemical signature:

Mg, Ca, Fe, Mn, P, V, Ti, Ni and minor Ba, F, Bi, Cu, Co.

Geophysical signature:

Magnetic lows associated with strong magnetic highs(?).

Examples

Savage River Central	(Frost, 1982; Matzat, 1986)
Main Creek	(Frost, 1982)
Long Plains	(Frost and Matzat, 1984)
Keith River	

Known deposits and mineral occurrences in Tasmania

Many magnesite (Fe oxide-sulphide-silicate) deposits are known in the Arthur Metamorphic Complex portion of the Rocky Cape Element, especially in the Bowry Creek member, some of the largest being the Savage River, Main Creek and Long Plains magnesite deposits; deposits are known at Keith River, Lyons River, Arthur River and at Cann and Syds creeks. Other smaller magnesite occurrences are distributed throughout the Arthur Lineament.

Associated deposit types:

Stratabound iron oxide/sulphide/gold (copper) deposits.

Assessment criteria

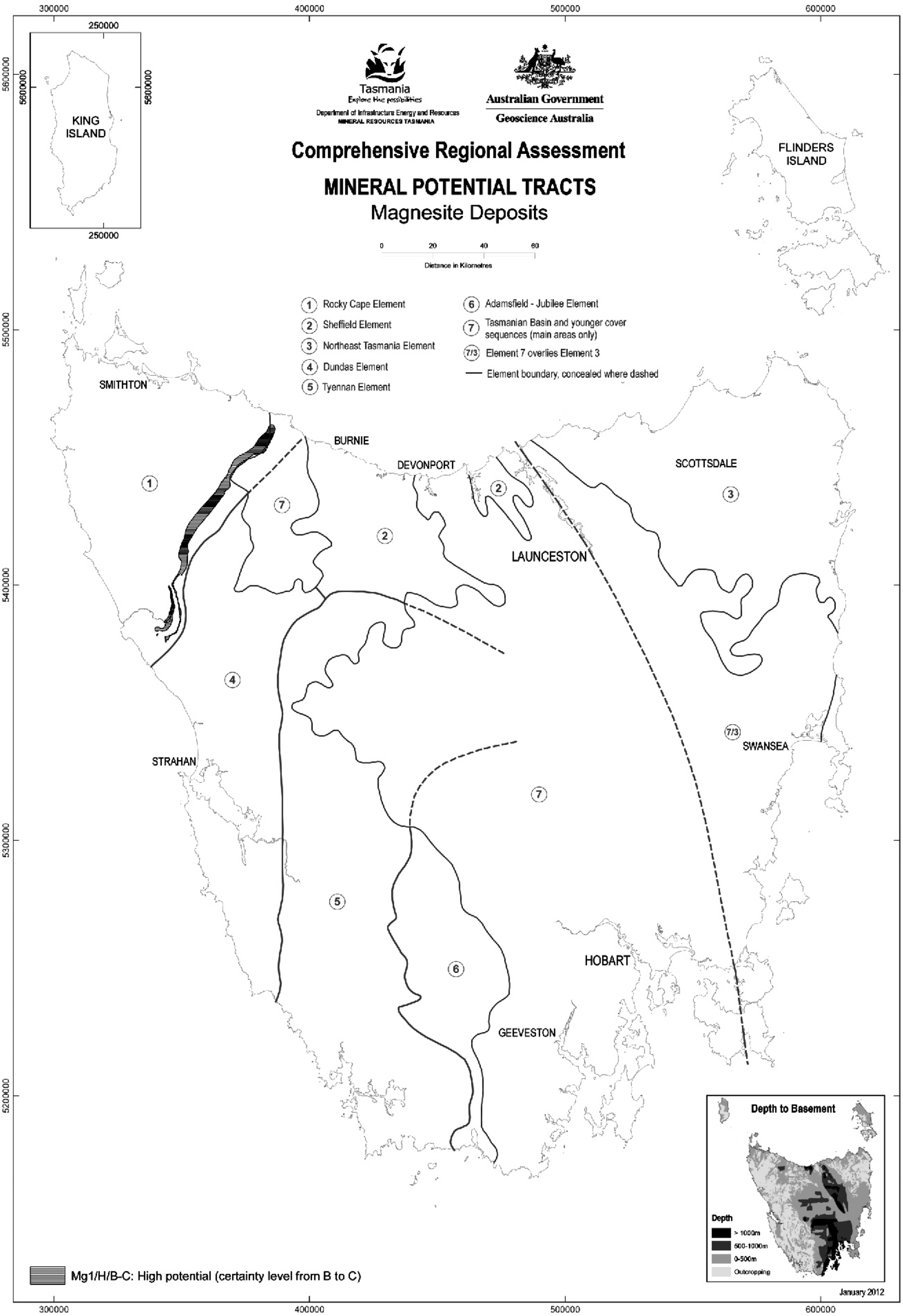
1. Presence of magnesite (sulphide-silicate] bearing host rocks or talc alteration.
2. Proximity to known magnesite (iron oxide-sulphide-silicate) deposits of this type.
3. Presence of Bowry Creek member or its equivalents.
4. Presence of magnetic anomalies (intense highs adjacent to intense lows).
5. Presence of massive to semi-massive magnetite/pyrite and or dolomite or mafic volcanic rocks/amphibolites.
6. Presence of chert and/or sedimentary exhalites.

Assessment: Tract Arthur Metamorphic Complex Mg1/H/B-C

The potential for magnesite in Tasmania is probably confined to the Arthur Metamorphic Complex, in the vicinity of known deposits, which occur in association with dolomite, metabasalt and amphibolite. The prospective units also have high potential for Savage River-type iron deposits, and the same tract is defined by the mapped distribution of chloritic schist, minor phyllite, dolomite and magnesite (Lac), and minor amphibolite (Lma), together with their interpolated and extrapolated extensions beneath thin Permo-Carboniferous sedimentary and Tertiary basalt cover. The potential is rated as high and the degree of uncertainty varies with the detail of geological mapping and amount of exploration done. The southern (Savage River mine–Corinna) and northern (Arthur River area) segments of the AMC south are fairly well known due to recent Geological Survey mapping and have a certainty level of C, whilst most of the central segment is one of the most poorly known areas in Tasmania and has a certainty level of B.

Economic significance

Magnesite, with low boron levels and low levels of other impurities, has the potential to be very important as a source of dead-burned magnesia or other forms of calcined MgO. Large tonnages of fairly pure magnesite could be the basis of an important magnesium industry where electricity is relatively cheap, as in Tasmania.



Map 35 — Model I35

MODEL I36: Ochre

Model description

Description of a model by D. J. Perkin.

Approximate synonyms

Red ochre, yellow ochre, brown ochre, red, yellow or brown earths, natural earth pigments.

Description

Ochre deposits consist mainly of iron oxides; red ochres tend to be dominantly hematitic while yellow ochres are made up mainly of hydrated oxides of iron-like goethite and limonite. The iron content in natural ochres ranges from 17 to 60% Fe_2O_3 with the remainder of the rock comprising clay and quartz. Ochre deposits of economic importance can be derived from weathering of basalt, dolerite and other mafic and ultramafic rocks, but may also be derived from hematitic and other iron oxide-bearing rocks including sediments and where redeposition of iron oxides has occurred in major fault or shear zones in topographically subdued areas. Ochre deposits may result from the re-deposition of iron oxides after leaching and oxidation of magnesite.

General references

Barrie, 1966*b*.

Geological environment

Rock types:

Generally soft and friable iron oxides and clays occurring at or near surface.

Age range:

The original iron-bearing source rock types can be of any age. In Tasmania, the protoliths include Proterozoic magnesite, Cambrian ultramafic rocks, Jurassic dolerite or Cainozoic/Recent basalt which have undergone intensive chemical weathering.

Depositional environment:

The formation of ochres depends on a wet oxidising environment during weathering of the source rocks.

Tectonic setting(s):

The present tectonic environment results in enhanced chemical weathering. This reflects a present day relatively stable craton or fold belt which was associated with major uplift in the Tertiary the extrusion of plateau basalts.

Associated deposit types:

Basaltic and dolerite-derived clays, magnesite, silica flour, gold, unconsolidated sandy sediments and silts.

Deposit description

Mineralogy:

Red ochres are dominantly hematitic while yellow ochres are made up mainly of hydrated oxides of iron like goethite and limonite. Natural ochres have from 17 to 60% Fe_2O_3 with the remainder of the rock comprising clays and quartz. Brown ochres may contain manganese oxides.

Texture/structure:

Clayey, massive, friable.

Alteration:

Older brownish limonite/goethite deposits may sometimes be altered to hematite in an oxidising environment.

Ore controls:

Presence of either iron-bearing magnesite or high-iron mafic to ultramafic intrusive or extrusive rocks exposed to prolonged periods of intensive weathering.

Weathering:

Weathering is an integral part of the formation of these types of deposits, intensifying with warmer climate. Tendency to form hematitic iron oxides from limonitic iron oxides in an oxidising environment.

Effect of metamorphism:

Recrystallisation of the iron oxide with an increase in grain size and colour intensity.

Geochemical signature:

Fe; occasionally Cr, Ti.

Geophysical signature:

Magnetic surveys may be useful.

Examples

Main Creek.

Known deposits and mineral prospects in Tasmania

There are large resources of ochre in the Arthur Metamorphic Complex near Savage River. A development proposal and environmental management plan for the production of 10 000 tonnes/annum of refined pigment/ochre was lodged, but the deposit remains undeveloped.

Red and yellow ochre is known at Mowbray and at many other places along the River Tamar near Launceston where it is derived from weathered dolerite.

At Spalford, near Ulverstone, red ochre is derived from the decomposition of basalt. Yellow ochre has been produced from deposits of limonite near Smithton. Red ochre has been obtained from Carlton, near Hobart. Brown, chocolate, green, red and yellow ochre has been won from the weathered iron chrome-bearing ultramafic rocks at Mount Vulcan/Andersons Creek near Beaconsfield.

Assessment criteria:

1. Presence of iron-bearing precursor rocks, particularly magnesite.
2. Enhanced weathering regime.
3. Known deposits of ochre.

Assessment: Tract Ochre/H/B-C

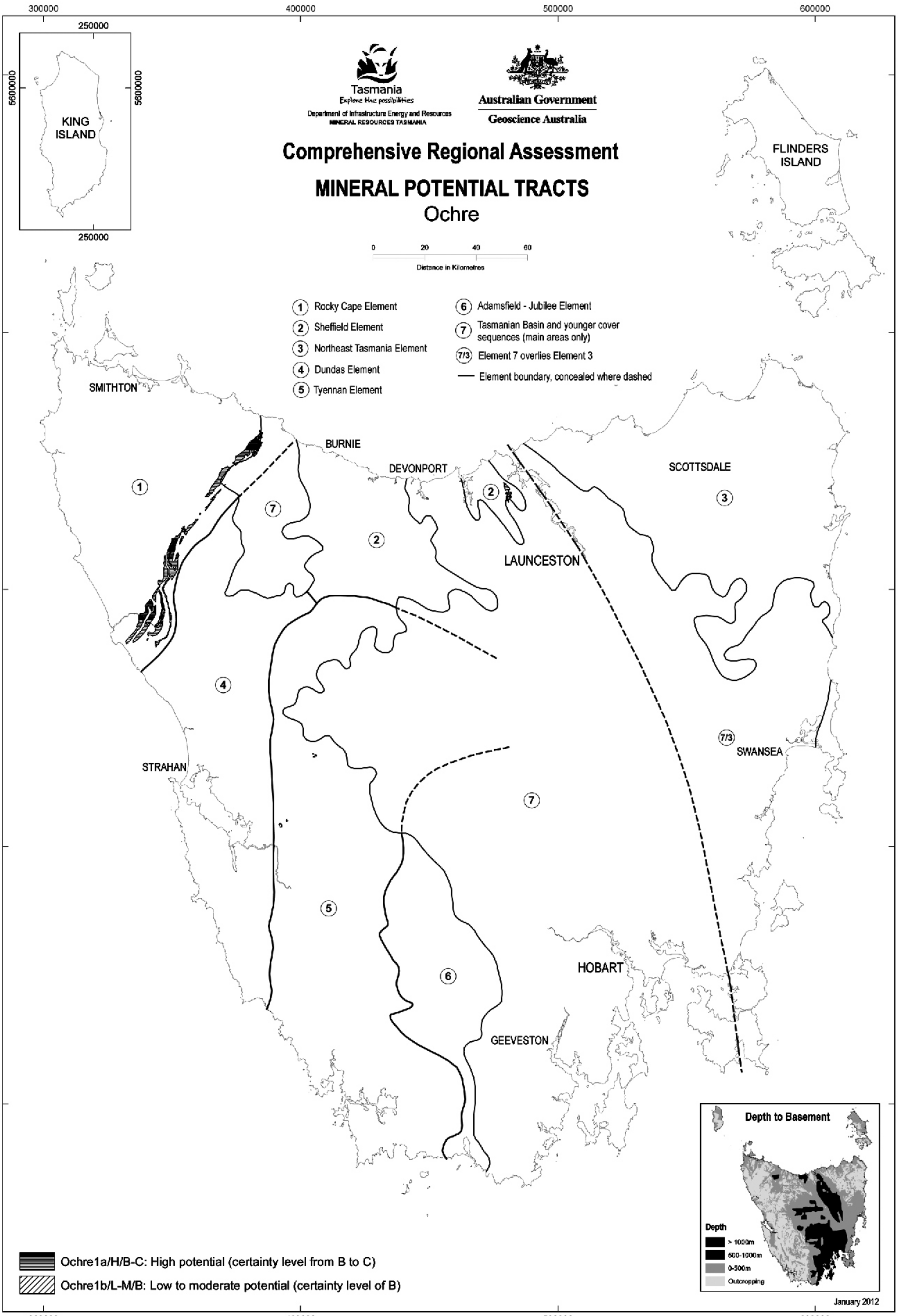
This tract is of high potential with a certainty level of B and C in the Arthur Metamorphic Complex. The Beaconsfield ultramafic complex is also considered of high potential with a certainty level of B.

Economic significance

This deposit type has accounted for much of the past ochre production in Australia. Thicknesses of mineable ochre deposits can vary widely depending on market requirements.

Physical/chemical properties affecting end use:

Specifications will vary depending on colours required. Washing and upgrading can be used. Calcination is also frequently used while fine grinding is required in paint manufacture.



Map 36 — Model I36

MODEL F37: Oil shale in the Tasmania Basin

Model description

Tasmanites oil shale, Tasmania Basin.

Approximate synonyms

Tasmanite, dysodile, yellow coal.

Description

A two-metre (maximum) thick horizon of oil shale of Late Carboniferous age, composed of bodies of *Tasmanites punctatus* (probably a green alga) in a matrix of very fine grained sand and silt. The oil shale was deposited in a close to shore, shallow marine environment. Oil can be extracted from the oil shale by heating the material.

The oil shale is part of the lower marine succession of the Lower Parmeener Supergroup.

General reference

Bacon, 1986.

Geological environment

Rock types:

Shale.

Age range:

Late Carboniferous.

Depositional environment:

Near-shore, shallow marine.

Tectonic Setting:

Continental shelf.

Deposit description

An interval of oil shale within a sandstone/mudstone/siltstone sequence composed of bodies of *Tasmanites*. In some places the concentration of algal bodies is greater than others. The unit is always quite thin, to a maximum of two metres, frequently less and sometimes occurring as discrete lenses over a two to three metre interval.

Examples

Outcrops and drill core intersections from Oonah, Mersey Valley, Poatina and Maydena.

Assessment criteria

1. Presence of lower marine succession, Lower Parmeener Supergroup.
2. Known occurrences of oil shale.

Assessment: Tract Mersey–Western Tiers: Oshl1a/M/B-C

This tract is drawn based on the presence of the lower marine succession, Lower Parmeener Supergroup, and known outcrops of oil shale, or intersections in diamond drill holes from exploration programs. Moderate potential has been assigned, with a certainty of B to C, based on low to moderate quality data.

Assessment: Tract Railton–Elizabeth Town: Oshl1b/L-M/B

This tract, covering various areas in northern Tasmania and Maydena, is drawn based on the presence of the lower marine succession, Lower Parmeener Supergroup, and known outcrops of oil shale, or intersections in a number of diamond drill holes from exploration programs. Low to moderate potential has been assigned, with a certainty of B, based on relative lack of occurrences and low quality data.

Assessment: Tract Oshl1c/L/B

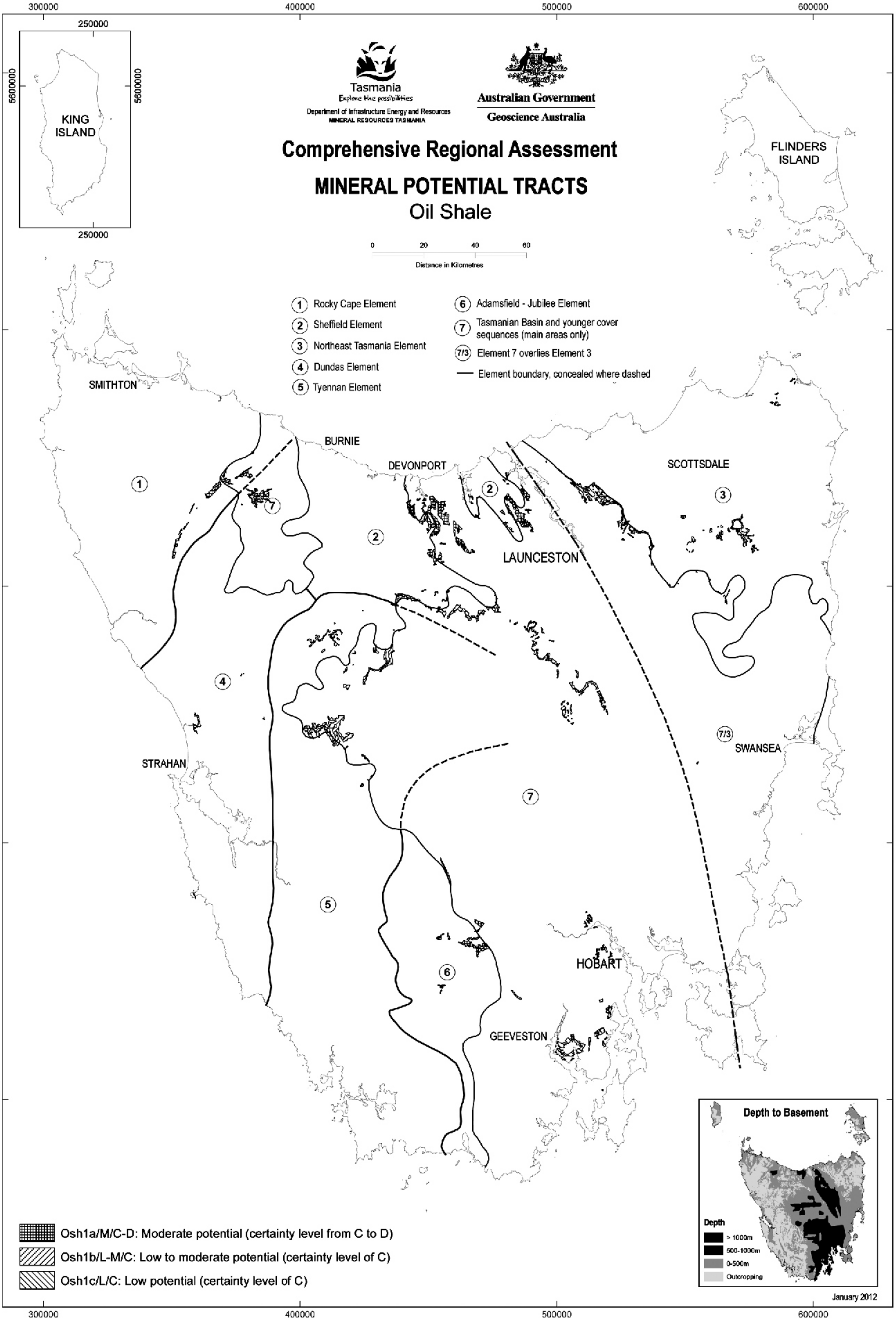
This tract, covering various areas in the northeast and southeast of Tasmania, is drawn based on the presence of the lower marine succession, Lower Parmeener Supergroup, with no known occurrences of oil shale. Low potential has been assigned, with a certainty of B, based on lack of occurrences and low quality data.

Assessment: Tract Oshl1d/Unk

This tract, covering various areas in the northeast and southeast of Tasmania, is drawn based on the inferred presence of the lower marine succession, Lower Parmeener Supergroup, with no known occurrences of oil shale. It has unknown potential.

Economic significance

A kerosene substitute was retorted from the oil shale earlier this century. A government retort operated (by subsidy) earlier this century. An in situ indicated deposit of 40 Mt has been found by exploration, but there is currently no market for this material.



Map 37 — Model F37

MODEL I38: Shoreline placer Ti (Model 39c of Cox and Singer, 1986)

Model description

Description of the model after Eric R. Force.

Approximate synonyms

Heavy mineral sands.

Description

Ilmenite, rutile, zircon, leucoxene, magnetite, monazite and other heavy minerals (chromite, garnet, xenotime, cassiterite, platinum group elements and gold) concentrated by beach processes.

Geological environment

Rock types:

Well-sorted medium to fine-grained sand in dune, beach and inlet deposits commonly overlying shallow marine deposits.

Age range:

Commonly Late Miocene to Holocene but could be any age range.

Depositional environment:

Stable coastal region with efficient sorting and winnowing, receiving sediment from deeply weathered granitic terranes and metamorphic terranes of sillimanite or higher grade.

Tectonic setting:

Margin of craton. Crustal stability during deposition and preservation of deposits.

Deposit description

Structure:

Elongate 'shoestring' deposits parallel to coastal dunes and beaches.

Ore controls:

Ultimately a high-grade metamorphic or granitic source but may include sediments and metasediments as source rocks in which heavy minerals were trapped during an earlier depositional cycle and subsequently eroded; stable coastline with efficient sorting and winnowing. Heavy mineral concentrations are formed by wave and wind action and include beach placer, beach ridge, and sand dune deposits.

Weathering:

Leaching of iron from ilmenite and destruction of labile heavy minerals results in residual enrichment of deposits.

Geochemical and geophysical signatures:

High Ti, Zr, Th, U, rare earth elements; anomalously high concentrations of heavy minerals; gamma radiometric anomalies due to monazite content; induced polarisation anomalies due to ilmenite.

Examples

Numerous heavy mineral concentrations of rutile and ilmenite along the current and ancient inland shorelines in northern New South Wales and southern Queensland (Wallis and Oakes, 1990).

Heavy mineral concentrations of ilmenite and rutile along ancient shorelines inland from the present coastline in southwest of Western Australia at Yoganup (Masters, 1990) and Eneabba (Shepherd, 1990).

At Naracoopa, on King Island, shoreline placers have been worked in the past, principally for ilmenite. There are proposals to rework this deposit for rutile, ilmenite, zircon and other commodities.

Known deposits and mineral prospects in Tasmania

There are several known occurrences of heavy mineral sands in the CRA, rich in either titanium (ilmenite) and/or zirconium (zircon). On the west coast a number of ilmenite and zircon sands have been reported (e.g. Ocean Beach; 1.5 Mt @ 10% heavy minerals; Wreck Bay, Trial Harbour). In the Payne Bay area ilmenite-bearing sand is known to occur. The northwestern coast has been targeted by exploration companies for mineral sands (e.g. Marrawah; 0.1 Mt @ 4–5% heavy minerals). At Nelson Bay the sands also contain chromite. The northern coast has a number of ilmenite-rich sands (e.g. Bakers Beach). Several deposits are known on the east coast, including Seven Mile Beach (near Hobart; 40 Mt @ 1.1% heavy minerals), Bruny Island, Friendly Beaches (near Coles Bay; 0.06 Mt @ 3% heavy minerals), Seymour, and others further north. No deposits are presently being worked.

The source rocks for the mineral sands are granitoids, plus various metamorphic, sedimentary and igneous rocks.

Assessment criteria

1. Appropriate coastal deposits of sand along current or ancient inland beach and dune sands.
2. Known occurrences of heavy minerals.
3. The presence of alluvial heavy mineral, alluvial gold and primary gold occurrences cropping out through the sediments on the coastal plain, or present upstream.
4. Presence of lineaments on radiometric images from airborne radiometric surveys.

Assessment: Tract MS1a/M/B

This tract covers three areas:

- Ocean Beach–Henty Dunes, southwest Tasmania;
- Nelson Bay–Nettley Bay, northwest Tasmania;
- Friendly Beaches–Moulting Lagoon–Chain of Lagoons, northeast Tasmania.

These areas include present day beach and dune sands and also older dune and swamp deposits on the coastal plain. These sediments have not been mapped in detail but may extend up to a few kilometres inland. Heavy mineral occurrences are present along the coast and heavy minerals may also be present in the older dune sand and possibly beach deposits inland.

These areas have all been explored by mining companies for heavy minerals, although most have only small and/or low grade reserves. Such deposits contain some gold, tin and platinum group elements and may occur largely within the older dune and possible shoreline sediments. On available information there is a moderate potential, with a certainty of B, for heavy mineral concentrations of sufficient size to be of economic interest.

Assessment: Tract MS1b/L-M/B

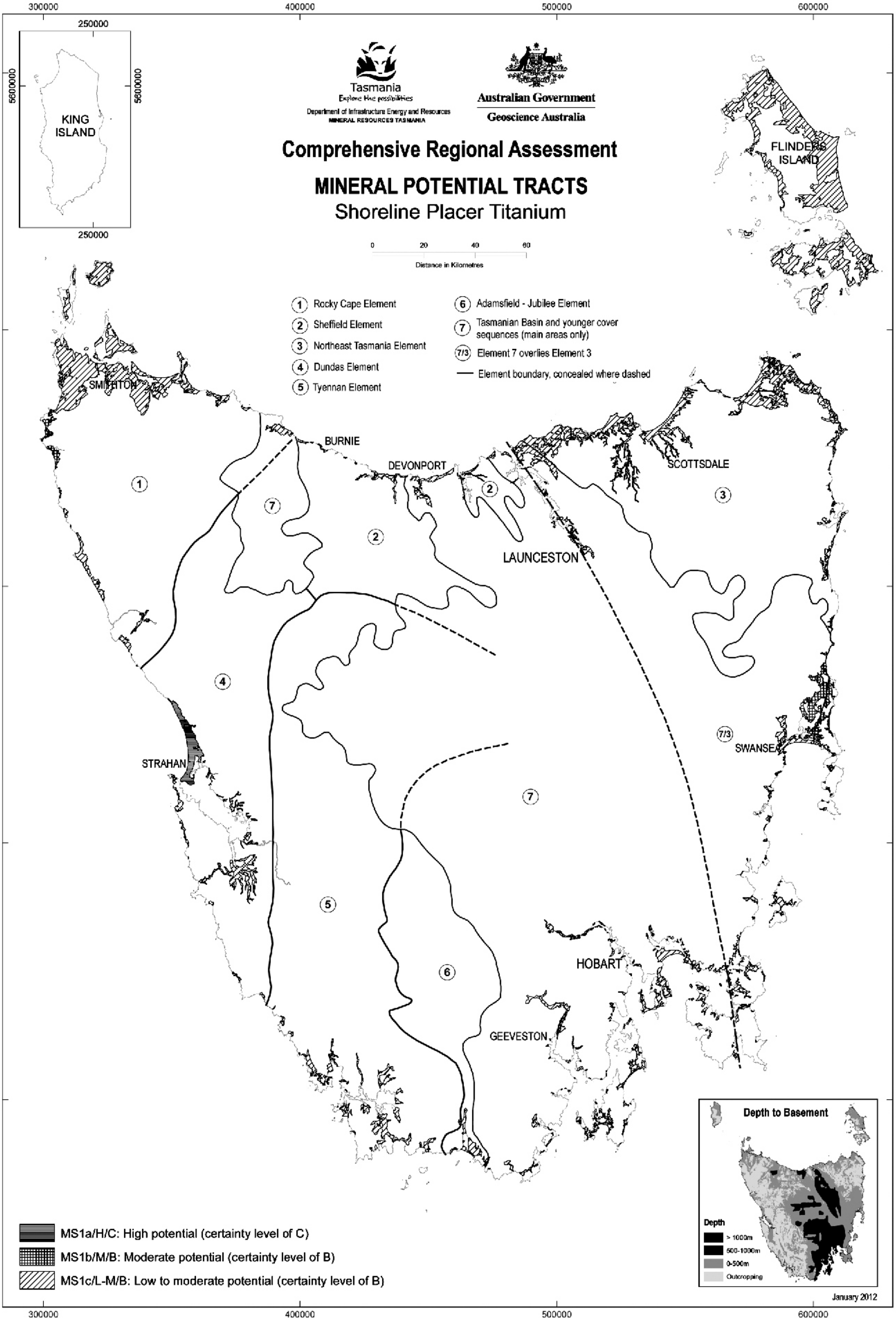
This tract includes the remainder of the present day beach and dune sands, including older dune and swamp deposits on the coastal plain. These sediments have not been mapped in detail but may extend up to a few kilometres inland. Heavy mineral occurrences are present along the coast and heavy minerals may also be present in the older dune sand and possibly beach deposits inland. Such deposits locally contain some chromite, gold, tin and platinum group elements.

On available information there is a low to moderate potential, with a certainty of B, for heavy mineral concentrations of sufficient size to be of economic interest.

Economic significance

Based on data on 61 deposits worldwide, shoreline placer deposits have a median ore tonnage of 11 million tonnes (Cox and Singer, 1986). Both beach and dune sand deposits are included in this sample. About 90% of these deposits contain at least 11 million tonnes of ore and 10% contain at least 690 million tonnes. The median grades for these deposits are 1.3% TiO_2 for ilmenite and 0.15% TiO_2 for rutile.

The economic viability of shoreline deposits is determined by the constituent mineralogy and size of the deposit. The limited extent of the beach and dune sand deposits in Tasmania suggests that the size of heavy mineral deposits, if present, is likely to be restricted to the lower range of tonnages for these deposits.



Map 38 — Model I38

MODEL I39: Silica Flour

Model description

Description of a model by D. J. Perkin.

Approximate synonyms

Derived residual sand, residual silica flour, lag detrital silica, detrital silica.

Description

Unconsolidated quartz silt and fine-grained silica sand ('flour') which forms thick incoherent beds above partly silicified dolomite and below poorly consolidated Tertiary gravel or above Precambrian quartzite.

General references

Bacon and Pemberton, 1995; Zaw *et al.*, 1992.

Geological environment

Rock types:

Paleogene to Recent unconsolidated/semi-consolidated silica sand, associated with a basement of dolomite (silicified in part) and dolomitic siltstone or quartzite. May be capped by Tertiary gravel.

Age range:

Tertiary to Recent. Original source rocks generally Neoproterozoic but may be of any age.

Depositional environment:

Where derived from dolomite the original dolomites were deposited in sedimentary basins or graben in a probable hypersaline environment associated with nodular and cherty fine silica. Weathering of the siliceous dolomite during and since the Tertiary allowed for the formation and preservation of fine-grained silica sand overlying the dolomite and protected in part by the gravels.

Tectonic setting(s):

Original (protolith) rock types like dolomite were deposited in lagoons and hypersaline environments.

The present tectonic environment results in enhanced chemical weathering and recent dissolution of the dolomite. This reflects a present day relatively stable craton or fold belt which was associated with major uplift in the Tertiary the extrusion of plateau basalts.

Associated deposit types:

Unconsolidated sandy sediments, alluvial gold and silt associated with lag gravels, and (?)chert.

Deposit description

Mineralogy:

About 99.9% SiO_2 normally. The most common elemental impurities when derived from dolomite are Ca and Mg because of preservation of tiny cores of dolomite at the centre of grains.

Texture/structure:

Massive, crudely bedded, unconsolidated fine-grained siliceous sand and quartz silt.

Alteration:

Groundwater results in the minor dissolution of quartz and reprecipitation in other parts of the deposit resulting in agate-like banded and multi-coloured siliceous fragments. This can also result in karst cavities at the base of the unconsolidated sands within the top of the dolomite; the karst may be filled with quartz silt and ?clay. In quartzite there is leaching which produces upgrading and silicification.

Ore controls:

The source of the initial silica in the dolomite is uncertain but could comprise either a diagenetic, hydrothermal or epithermal addition. Dissolution and disaggregation of the fine-grained silica originally disseminated throughout the Neoproterozoic Ahrberg dolomitic sequence by acidic solutions (humic/carbonic acid) derived from rotting vegetation and the atmosphere.

Weathering:

A balanced weathering regime is apparently very important for this deposit type. Chemical weathering of the protolith siliceous dolomite should be dominant while physical weathering must be subdued to non-existent and as a result of effective protection from overlying Tertiary gravel.

Geochemical signature:

None known apart from silica sand itself.

Geophysical signature:

Resistivity can be used to identify karst features in dolomite where the terrain is covered.

Examples

Corinna, Preolenna, Cann Creek, Arthur River–Roger River, Maydena.

Known deposits and mineral prospects in Tasmania

Corinna, Preolenna, Cann Creek, Blackwater, Hawkes Creek.

Assessment criteria

Presence of dolomite containing fine disseminated silica throughout or of suitably leached quartzite.

Elevated and/or peneplained area with very high annual rainfall.

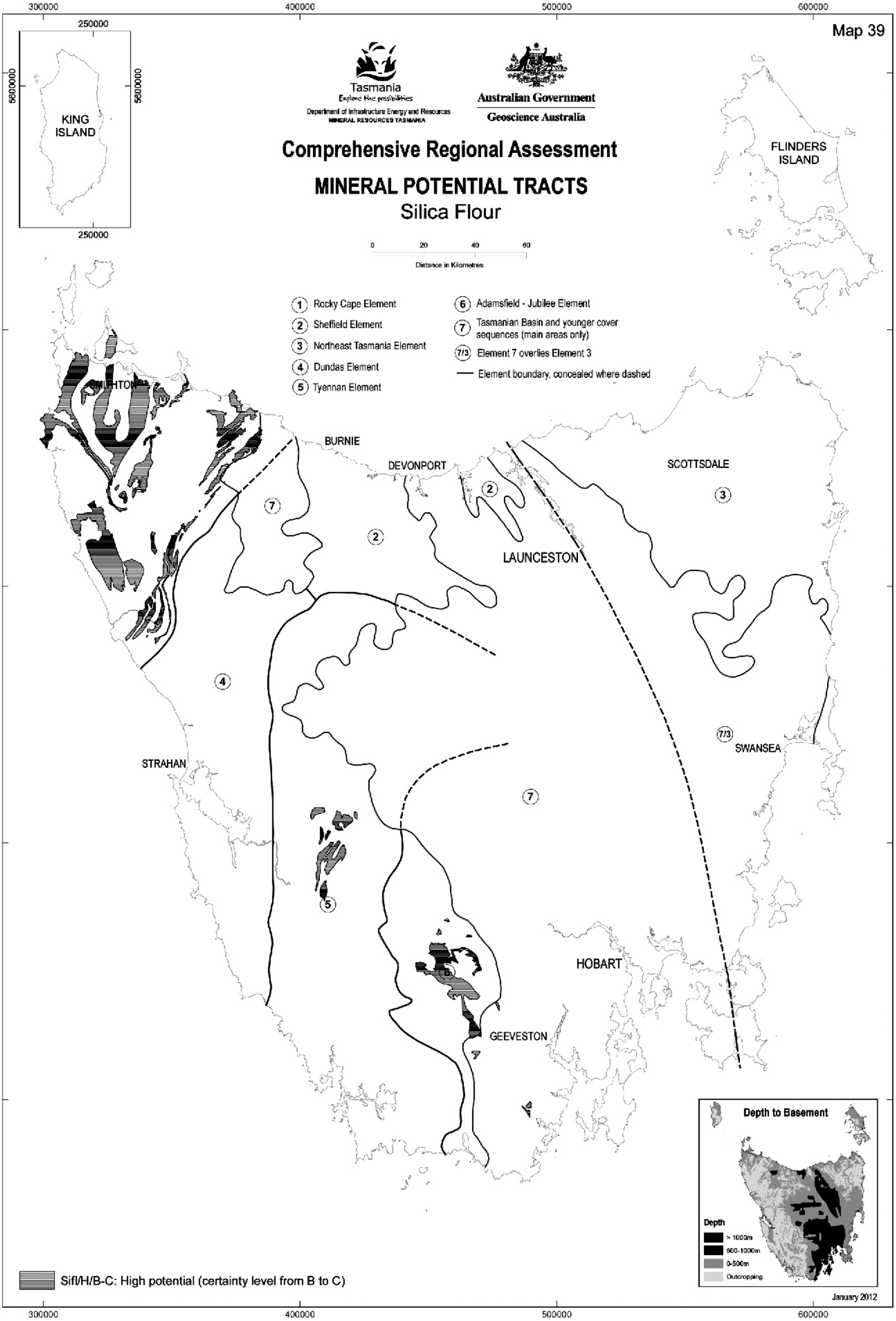
Assessment: Sifl/H/B-C

Small areas near Corinna, Blackwater Road, Hawkes Creek and Maydena where significant deposits are known, overlying Neoproterozoic dolomite, have high potential with a certainty level of C. In all other other areas of Neoproterozoic dolomite and in Proterozoic quartzite in northwest Tasmania the potential is also high with a certainty level of B.

Economic significance

This deposit type is important in the production of the very high quality end of silica for use in optical fibre, high quality lens glass, silicon chips and lead crystal throughout the world. The Corinna, Blackwater and Hawkes Creek deposits are currently being mined.

Thickness of the mineable unconsolidated silica sands ranges up to 45 metres. Impurities in the bulk deposit are mainly made up of minor fine-grained heavy minerals like ilmenite and also by contamination by pebbles and cobbles on the slopes from the overlying Tertiary gravel. A washing plant employing spirals is generally used to eliminate the heavy minerals.



Map 39 — Model I39

MODEL I40: Zeolites

Model description

Description of a model after R. A. Sheppard and G. J. Simandl by D. J. Perkin based on additional information supplied by R. S. Bottrill and J. L. Everard (Bottrill and Everard, 1997).

Approximate synonyms

Zeolites in tuff of open hydrological systems, open-system zeolites.

Description

Fine-grained to microcrystalline zeolites (including clinoptilolite, chabazite, mordenite, phillipsite, laumontite, stilbite, heulandite, analcite, natrolite) in non-marine accumulations of vitric tephra. The zeolites have characteristics, including capacity for ion-exchange, which make many varieties of considerable economic significance, especially if the beds are several metres thick and relatively massive (i.e. >70% zeolites).

Main reference

Original model from a draft by R. A. Sheppard and G. J. Simandl (1993).

General references

Broxton *et al*., 1987; Gottardi and Obradovic, 1978; Hay, 1963; Hay and Sheppard, 1977; Sersale, 1978; Sheppard, 1985; Harben and Bates, 1990.

Geological environment

Microcrystalline zeolites (clinoptilolite, chabazite, mordenite, phillipsite, laumontite, stilbite, heulandite, analcite, natrolite) crystallise in relatively thick, generally non-marine tephra sequences that commonly show a more or less vertical zonation of zeolites and associated silicate minerals that reflects the chemical modification of meteoric water as it flowed through the vitric sequence. The zeolites crystallised in a post-depositional environment over periods ranging from thousands to millions of years.

Rock types:

Varies from monomineralic, wholly zeolite-bearing lithologies to rocks with occasional zeolitic geodes or inclusions. Original rocks were volcanic ashes and tuffs having a broad compositional range, including rhyolite, dacite, trachyte, phonolite, and basalt to basanite. The silicic tuffs were commonly deposited as non-welded ash flows. Rhyolite to basalt occurs as flows. Other rock types include fluviatile mudstone, sandstone, conglomerate and diatomite. Zeolites form stratabound, stratiform or lens-shaped mineral zonation and may be cross-cutting to the bedding.

Age range:

Mesozoic to Holocene, but most in USA are Cenozoic. Zeolite deposits in British Colombia are Tertiary or Cretaceous. Deposits in Niger are Mesozoic.

Depositional environment:

Belts of shallow water sediments. Most deposits are non-marine (fluviatile and lacustrine), but some are shallow marine. Some thick tuffaceous deposits were air-laid onto the land. Typical regional depositional environments contain thick sequences of vitric tuff affected by very low grade metamorphism. The local attribute is vertical zonation of authigenic silicate minerals.

Tectonic setting(s):

Intra-continental rift, non-marine and rarer shallow marine basins in volcanic terranes. Depositional basins were often fault bounded, with zeolite concentrations in second or third-order basins.

Associated deposit types:

The zonation of the open-system type of zeolite deposit is similar to the upper zones of burial diagenesis (burial metamorphism) that affected thick sequences of silicic, vitric tuffs. Associated deposits include pumicite, bentonite, diatomaceous earth, oil shale and coal.

Deposit description

Mineralogy:

Clinoptilolite, chabazite, mordenite, phillipsite. In British Colombia, clinoptilolite is a major constituent. Authigenic smectite, mixed layer illite-smectite, opal-(cristobalite/ tridymite), quartz, plagioclase, microcline, biotite, muscovite, calcite; a variety of pyrogenic crystal fragments, a variety of volcanic rock and fragments, unreacted vitric material.

Texture/structure:

Massive, bedded. Finely crystalline, commonly bedded, similar to bedded diatomite or bentonite.

Alteration:

In silicic tuff sequences, the alkali-rich siliceous zeolites (clinoptilolite and mordenite) in the upper part of the deposit are commonly replaced at depth by analcime, potassium feldspar and/or albite.

Ore controls:

Grain size and permeability of host tuff, flow of meteoric water downward in an open hydrological system; hydrolysis and solution of vitric material by the subsurface water in the upper part of the system raised the pH, activity of SiO_2 and content of dissolved solids to values where zeolites crystallised. These result in a vertical or near-vertical zonation of zeolites and other authigenic minerals. Composition of the vitric material may have dictated which zeolite species precipitated; clinoptilolite and mordenite are common in silicic tuffs, but chabazite and phillipsite are common in mafic or trachytic tuffs. Conversion of zeolitic tuff to an assemblage of alkali feldspar + quartz can occur. (Sheppard and Gude, 1968).

Weathering:

Pastel pink and orange shades of more resistant monomineralic zeolitic beds to several metres thick can characterise the typical weathering pattern in some cases.

Effect of metamorphism:

Analcime and erionite alter to albite and K-feldspar respectively. Zeolites are thought to be largely metastable minerals which can form more stable internal structures as a result of heat or the passage of time (kinetic effect).

Geochemical signature:

None recognised. XRD analysis usually required.

Geophysical signature:

Possible use of colour-composite imagery from airborne multi-spectral scanner data to distinguish zeolitic tuffs.

Other exploration guides include very low grade or unmetamorphosed volcanic sequences. Vertical zonation of zeolites and associated authigenic silicate minerals in thick (100s to 1000s of metres) tuffaceous sequences. The vertical zonation commonly includes (from top to bottom) unaltered vitric material, smectite-clinoptilolite, ?mordenite ?opal-(cristobalite-tridymite) to analcime, ?potassium feldspar, ?quartz and then to albite, ?quartz. This zonation may cut across bedding. In British Colombia the vertical zonation is not observed, possibly because the favourable strata are too thin.

Examples

Clinoptilolite, Princeton Basin, British Colombia (Read, 1987; Marcille, 1989).

Clinoptilolite, Oligocene–Miocene John Day Formation, USOR.

Clinoptilolite and mordenite, Miocene Paintbrush Tuff, Tuffaceous beds of Calico Hills, and Crater Flat tuff at Yucca Mountain, Nye County, USNV.

Phillipsite and chabazite, Quaternary Campainian and Neapolitan yellow tuffs near Naples, Italy.

Clinoptilolite, USCA (Sheppard, 1985).

Known deposits and mineral prospects in Tasmania

Chabazite, phillipsite and analcite in Tertiary aquagene basaltic pyroclastic rocks at Gads Hill near Lorinna, Sheffield Element (Andersen, 1984; Askins, 1980).

Chabazite, phillipsite, heulandite, thompsonite, gonnardite, herschelite and analcite occur in Tertiary basaltic sequences, including basalt, tuff and pyroclastic rocks in the Guildford area (Everard, 1989).

Natrolite and analcite in Tertiary basaltic pyroclastic rocks at Weldborough, northeast Tasmania.

Natrolite and analcite in Tertiary basaltic tuff and agglomerate in the Redpa–Marrawah area, far northwest Tasmania (Heron, 1980; Poltock, 1980).

Assessment criteria

1. Presence of significant zeolite occurrences.
2. Presence of Tertiary pyroclastic rocks.

Assessment: Tract Zeol/M/B-C

A tract has not been drawn based on the distribution of the Tertiary basalt in Tasmania. The potential may be significant in some areas, but no economic deposits are known and so overall the potential is moderate with a certainty level B to C, depending on the detail of the geological mapping in the area.

Economic significance

The thickness of mineable zeolite deposits can range up to several tens of metres. Thickness of the section containing the zeolitic tuffs commonly ranges from 100s to 1000s of metres. Areal extent is commonly 100s to 1000s of square kilometres. Areal extent of some deposits covers hundreds of square kilometres (Green River Basin, USA).

Physical/chemical properties affecting end use:

The maximum limit of overburden is unknown, but probably tens of metres. Distance limits to transportation and processing is unknown. Hardness and attrition resistance of zeolitic tuff (commonly affected by abundance of opal-cristobalite-tridymite or quartz) are important in processing and end use. Crystal size of the zeolite is extremely fine grained and can affect the adsorption of gases and the extent and rapidity of cation exchange. Zeolites are used in ion-exchange and adsorption applications, clinoptilolite to remove NH^{4+} in tertiary sewage treatment; phillipsite to remove Cs and Sr from radioactive materials. The Si/Al ratio and exchangeable cation ratios of the zeolites affect certain uses. Cation exchange capacity and adsorption capacity for various gases are important. Colour (due to iron staining) and the abundance of non-zeolitic minerals may limit use. The immediate market for zeolites includes effluent treatment, mine waste management, pet-litter, soil conditioner, aquaculture, and construction. Higher-priced synthetic zeolites dominate in manufacturing, oil industry and chemical applications and the detergent industry.

Related deposit styles

Zeolite deposits may also occur in:

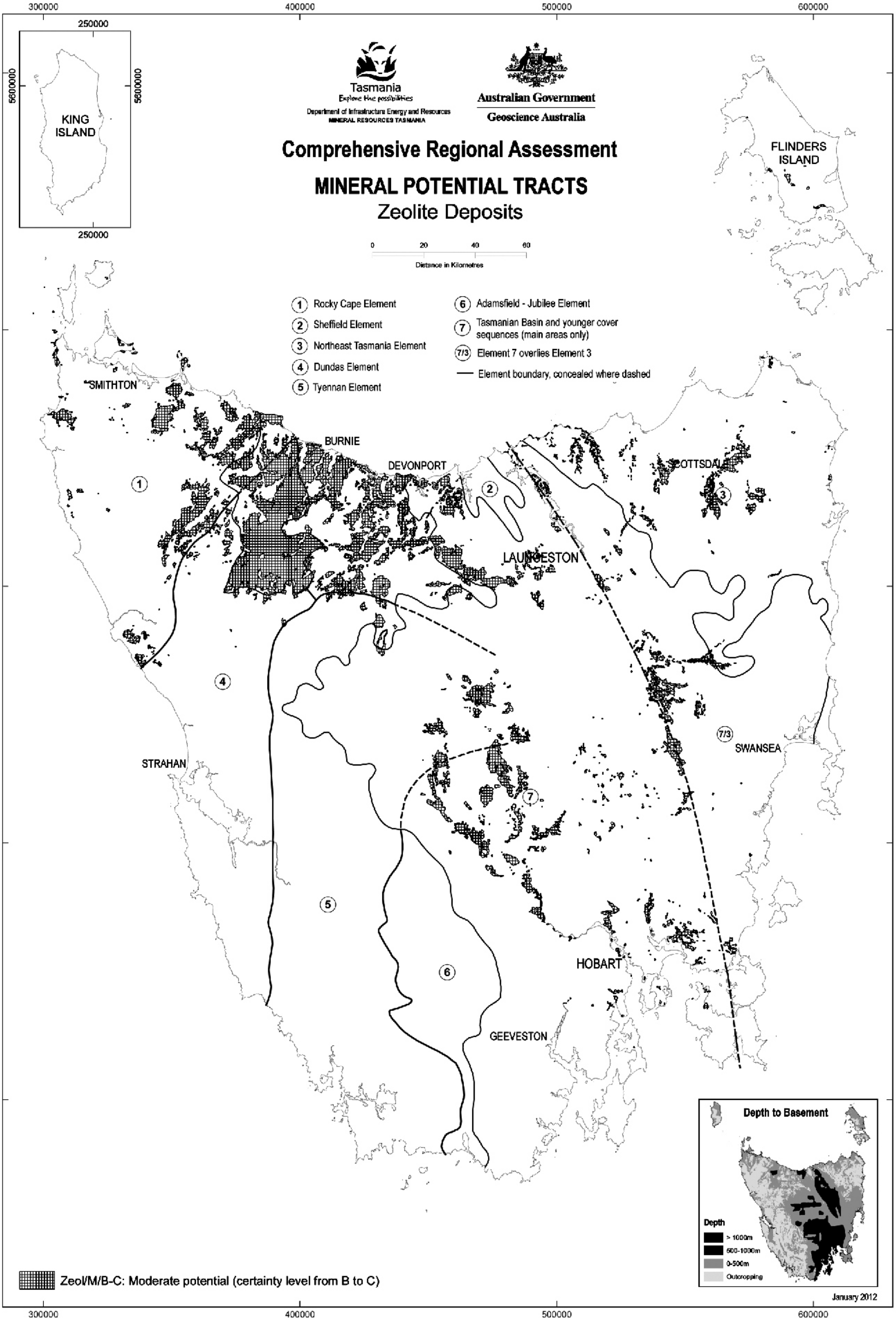
1. saline, alkaline lakes;
2. saline, alkaline soils;
3. tuffaceous sea-floor sediments;
4. hydrothermal veins and zones;
5. burial diagenesis deposits;
6. magmatic deposits.

The major known economic deposits in the USA, besides the open-system style, are of types 1 and 2. The alkaline environments necessary for the formation of these two mineralisation styles are not known to be present in Mesozoic and Cenozoic rocks in Tasmania.

It is interesting to note the occurrence of potentially economic zeolite deposits in Late Carboniferous lacustrine to fluvioglacial rocks at Werris Creek, New South Wales (Flood, 1991). There are obvious comparisons with the geological setting for Parmeener Supergroup (Late Carboniferous–Triassic) sequences in Tasmania, especially as felsic tuffs are known in some areas (Bacon and Everard, 1981). The Werris Creek deposit is considered to be of style 1 (alkaline lake setting). The potential for this style in Tasmania is unknown.

There is disseminated laumontite in Permo-Triassic volcaniclastic lithic sandstone near Wayatinah and York Plains, but this may be due to low-grade metamorphism, as in zeolitised volcanic-rich Triassic sandstone in Antarctica (Lavra *et al.*, 1980).

Deposits of types 4, 5 and 6 are locally zeolite-rich and abundant in Tasmania, but are small and not known to be economically significant. Their potential is low to unknown.



Map 40 — Model I40

MODEL I41: Silica: Metallurgical silica

Model description

Description of geological materials suitable for use as metallurgical silica.

Approximate synonym

Crushed quartzite.

Description

Proterozoic and Furongian to Ordovician quartzite has potential for use as metallurgical silica. The usual constraint on utilisation is the purity of the product, as even small quantities of metals such as titanium or iron render the deposit unusable.

General reference

Bacon and Pemberton, 1995.

Geological environment

Rock types:

All Proterozoic quartzite sequences in Tasmania have potential for metallurgical silica.

Age range:

Proterozoic and Furongian to Ordovician and derived surficial deposits.

Depositional environment and tectonic setting:

The Proterozoic quartzites were deposited in a range of depositional environments and tectonic settings which are discussed in the element descriptions.

Associated deposit types:

Residual and transported deposits derived from Precambrian quartzites.

Deposit description

Quartzite with relatively high SiO_2 content.

Examples

Metallurgical grade silica has been produced from Ordovician quartzite sequences near Beaconsfield, Deloraine and Railton; Proterozoic quartzite near Dip Range, Glovers Bluff, Hogs Back, Smithton and Forth; and Paleogene to Neogene gravels from Frankford and Calder.

Assessment criteria

All tracts are defined by prospecting and detailed geological mapping and based on mapped outcrop data. There has been no drilling to define resources.

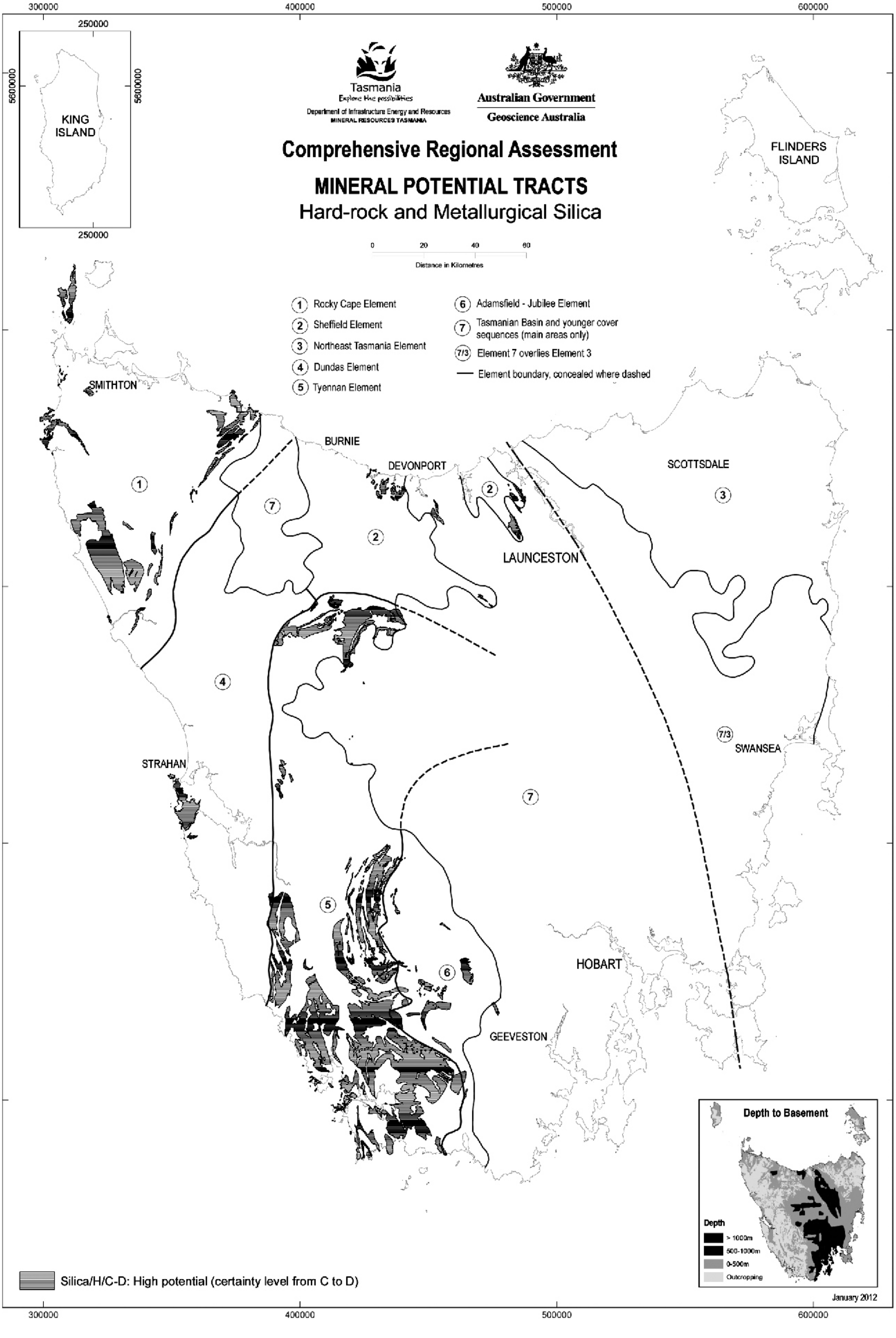
Assessment: Tract silica/H/B-C

All quartzites in Tasmania are regarded as having high potential for metallurgical silica. In addition there are small areas of Paleogene–Neogene and Quaternary deposits that have recorded production, and therefore high potential, for metallurgical silica.

Metallurgical silica: Paleogene to Neogene gravel sequences
Recent beach deposits (Leith)
Ordovician quartzite sequences
Proterozoic quartzite sequences

Economic significance

For metallurgical purposes high purity silica is essential. Despite the apparent abundance of quartzite in Tasmania, grades suitable for metallurgical use are not common. The end use of these materials is in the production of silicon metal, glass, ceramics, refractory items, ferrosilicon and related alloys of manganese and iron.



Map 41 — Model I41

MODEL C42: Dimension stone

Model description

Description of geological materials suitable for dimension stone uses.

Approximate synonyms

Freestone, building stone.

Description

Triassic sandstone and granitoids (both Cambrian and Devonian) are used as sources of dimension stone. There is some minor use made of Jurassic dolerite and Tertiary basalt.

General references

Bacon, 1987; Bacon, 1989; Sharples, 1990.

Geological environment

Many areas in Tasmania would have potential for the production of building stone (dimension stone) blocks if a suitable market existed.

Age range:

Cambrian to Tertiary.

Depositional environment and tectonic setting:

The variety of geological material used for dimension stone purposes encompasses a huge range of depositional environments and tectonic settings which is discussed in the element descriptions. The materials include granite, dolerite, basalt and sandstone.

Examples

Sandstone ('freestone') blocks have been quarried from numerous sites throughout Tasmania. Sandstone is currently mined at Nunamara, Buckland and Mike Howes Marsh. Slate has been mined from Mathinna Supergroup rocks in the North East Element at Bangor and Turquoise Bluff, and from the Cowrie Siltstone near Forest and at Tayatea. Granite building stone has been mined intermittently at Coles Bay and various other localities in northeast Tasmania and from two localities near Zeehan. Large quantities of granite have been mined for monumental purposes. Dolerite is infrequently mined for dimension stone blocks.

Assessment criteria

All tracts are defined by prospecting and detailed geological mapping and based on mapped outcrop data. There has been no drilling to define resources.

Assessment: Tract Dim1a:/H/B-C

Dimension stone sources are found throughout Tasmania. The types of material, with the geological sequences in which they are found, are tabulated below. All tested granitoids and known Triassic sandstones are rated as having high potential, with the certainty level varying from B to C depending on the detail of the geological mapping.

Dimension stone:	Parmeener Supergroup
	Dolerite
	Basalt
	Granite — Northeast Element
	Granite — Dundas Element
	Magnesite
	Slate — Mathinna Supergroup sequences (northeast Tasmania)

Assessment: Tract Dim1b:/M-H/C

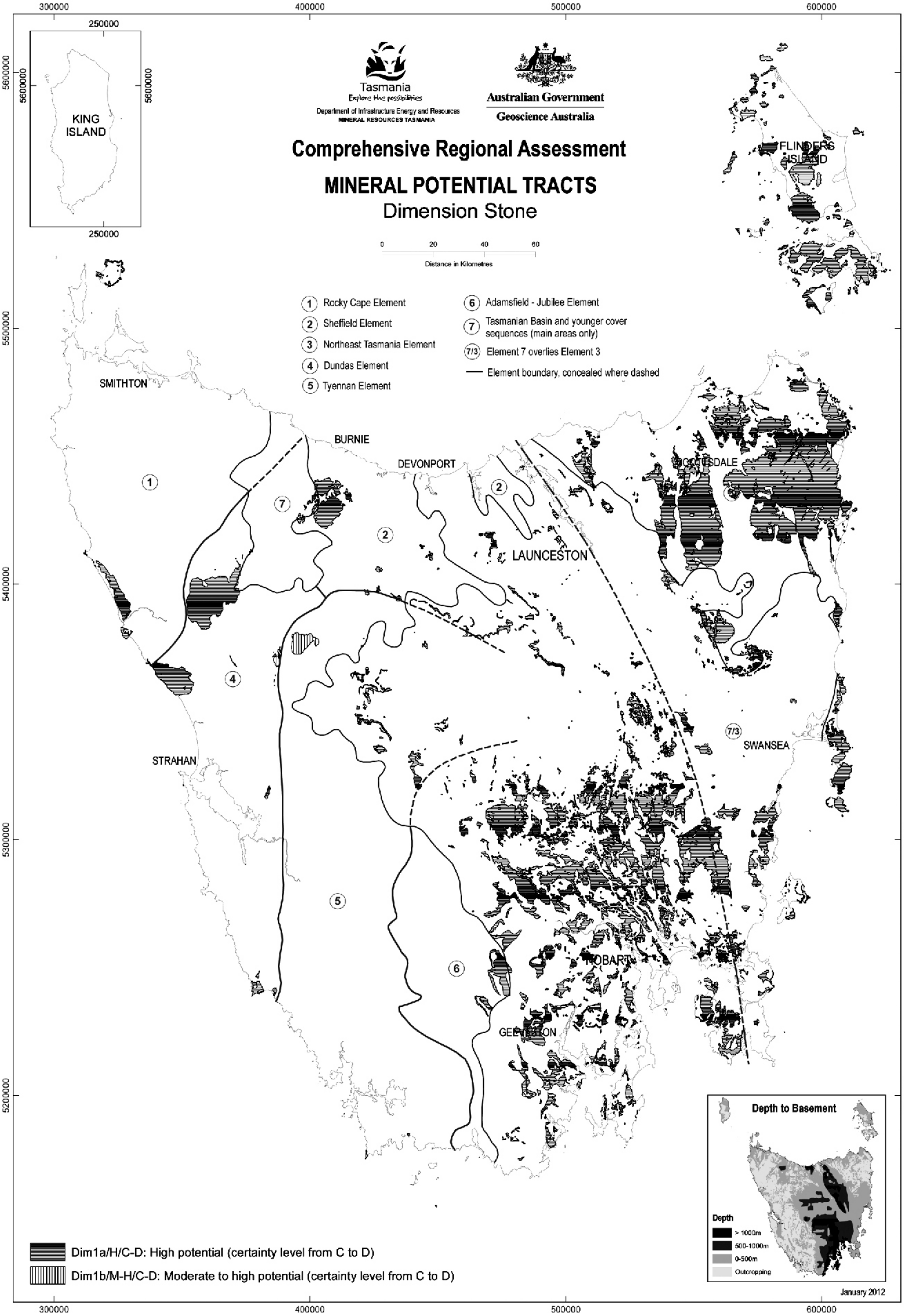
Dimension stone sources are found throughout Tasmania. The types of material with the geological sequences in which they are found are tabulated below. Granitoids that have not been tested are rated as having medium to high potential and the certainty level varies from B to C depending on the detail of the geological mapping.

Dimension stone:	Granite — Dundas Element

Economic significance

Relatively modest amounts of dimension stone are quarried, mostly for local use.

The rock must not be fractured. Blocks of large dimensions (3 m^3), and of uniform texture, must be able to be produced. The colour of the stone is an important determinant in saleability. 'Black' granite (i.e. dolerite and basalt) must be fine grained and of a uniform black colour. Grey tones are less acceptable. Weathering and fractures are also important. The Coles Bay granite is well suited for internal use, but as the feldspars quickly weather to unsightly pits, the stone is less useful as an outdoor facing stone. Total dimension stone production in 2010/2011 was 14 418 tonnes.



Map 42 — Model C42

MODEL C43: Construction materials (hard rock)

Model description

Description of the model by Clive R. Calver.

Approximate synonyms

Crushed aggregate, road base.

Description

Many rock types from Precambrian to Tertiary age have some potential application as a hard-rock construction material. The usual constraint on utilisation is the distance to a suitable market, as the transport cost forms a significant portion of the cost of the product.

General references

Bacon and Pemberton, 1995; Bacon *et al.*, 2008.

Geological environment

Rock types:

Most of Tasmania has varying degrees of potential for hard-rock construction materials, although in reality the potential is limited by conflict with current land use (usually urban) or distance from markets.

Many areas in Tasmania would have potential for the production of building stone (dimension stone) blocks if a suitable market existed.

Age range:

Precambrian to Tertiary.

Depositional environment and tectonic setting:

The variety of geological material used for construction purposes encompasses a huge range of depositional environments and tectonic settings which are discussed in the element descriptions for granite, dolerite, quartzite, basalt and sandstone.

Examples

Crushed rock, for a large variety of industrial and commercial applications, has been produced from hundreds of locations throughout Tasmania. Forestry Tasmania and municipal councils operate dozens of quarries throughout Tasmania to serve local needs. The principal rock types used are Jurassic dolerite, quartzite (Proterozoic and Paleozoic), and Tertiary basalt.

Large quantities of dolerite and basalt are produced from quarries at Bridgewater, Kingston, Cradoc, Flagstaff Gully, Ridgley, Deloraine, Perth, Western Junction and Mowbray.

Quarries producing crushed rock almost exclusively for road surfacing operate near Forth (quartzite), North Motton (chert?), No Where Else (conglomerate) and Deloraine (conglomerate). Road surfacing material is frequently produced in pits producing metallurgical materials. One example is quartzite from Corinna, most of which is of metallurgical grade but some lower quality material is used in local road surfacing. Crushed rock is frequently produced as a by-product of other quarrying operations.

Assessment criteria

All tracts are defined by prospecting and detailed geological mapping and based on mapped outcrop data. There has been no drilling to define resources.

Assessment: Tract Conmat1/H/C-D

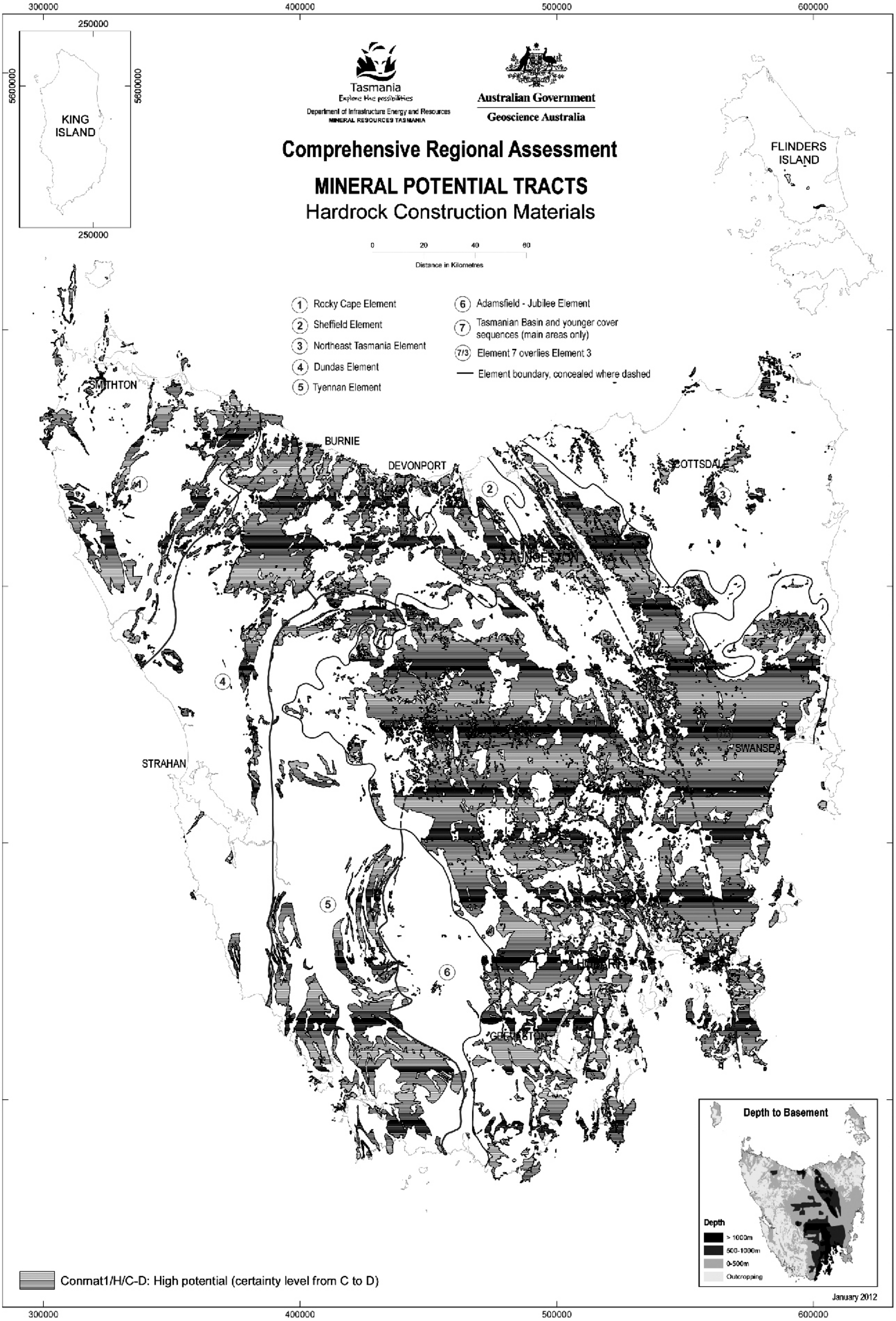
Hard-rock construction materials are found throughout Tasmania. The types of material, with the geological sequences in which they are found, are tabulated below. The potential is generally high and the certainty level varies from C to D depending on the detail of the geological mapping.

Crushed rock:	Dolerite
	Tertiary basalt
	Parmeener Supergroup: sandstone, mudstone
	Cambro-Ordovician sequences: chert, conglomerate
	Proterozoic sequences: quartzite, dolomite

Economic significance

Construction materials are essential for all building and construction activities. Because of their low cost in comparison to the transport costs it is critically important that local sources are available.

Many materials are used for road base, road surfacing, concrete aggregate, rock fill and associated applications. The specifications vary greatly depending on the particular project. The overwhelming economic factor is one of proximity to the market/location of use, as transport costs are a significant factor in the viability of any deposit. In 2010/2011, about three million tonnes of hard-rock construction materials were produced in Tasmania.



Map 43 — Model C43

MODEL C44: Construction materials: Gravel, sand, clay

Model description

Description of the model by Clive R. Calver.

Approximate synonyms

Sand, gravel, natural aggregate, building sand, bedding sand, concrete sand, quartz glass sand, clay.

Description

Most of the unconsolidated Tertiary–Quaternary deposits have some potential application as natural aggregates or other construction material. Residual or weathered older basement rock types are utilised in many places. The usual constraint on utilisation is the distance to a suitable market, as the transport cost forms a significant portion of the cost of the product.

General references

Bacon, 1992; Bacon and Pemberton, 1995; Bacon *et al*., 2008, Bottrill, 1995*c*.

Geological environment

Rock types:

Widespread Cenozoic unconsolidated deposits have potential for gravel/sand/clay. Residual sand is locally found on Triassic and Ordovician quartz sandstone. Residual gravel derived from in situ weathering of dolerite or granite is locally important. Clay deposits have formed as weathering profiles on basalt, dolerite and granite. The potential for these commodities is limited by conflict with current land use (usually urban), other environmental considerations or distance from markets.

Age range:

Paleogene to Recent.

Depositional environment and tectonic setting

The gravel, sand and clay encompass a range of depositional environments and tectonic settings which are discussed in the element descriptions. These include Tertiary basin fill, Tertiary basalt, Quaternary deposits and residual deposits.

Examples

Sand:

Pleistocene to Recent (dune) sand is mined on South Arm for use in glass manufacture and various construction purposes. Tertiary-aged sand from Scottsdale is coarser than the dune sand and is primarily used in concrete/paver/concrete block construction. Beach shingle and grit are mined near Port Sorell to provide a gritty material for use in sandblasting.

Paleogene to Neogene sand is mined with coarser gravel fractions in the Flowerdale area. Small deposits of sand derived from the weathering of quartz-rich rocks (such as Precambrian quartzite) and Triassic sandstone are known from a number of localities throughout Tasmania.

Clay:

Brick clay occurs in considerable quantities in the Derwent Valley and the Longford Basin. Clay is mined from weathered surficial deposits for use in cement manufacture and has been mined from Precambrian and Tertiary sources for use in paper manufacture.

Gravel:

Paleogene to Neogene gravel is mined at many locations throughout Tasmania. Weathered dolerite and laterite or pisolitic horizons and weathered granite are all commonly referred to as 'gravel'. The largest currently working pits are in the Flowerdale and Frankford areas.

Rounded quartz cobbles from estuarine deposits near Leith have been harvested to provide 'balls' for ball mill operation.

Assessment criteria

All tracts are defined by prospecting and detailed geological mapping and based on mapped outcrop data. There has been no drilling to define resources.

Assessment: Tract Conmat2/H/C-D: High potential

Gravel, sand and clay are found widely throughout Tasmania. The types of material, with the geological sequences in which they are found, are tabulated below. The potential is generally high and the certainty level varies from C to D depending on the detail of the geological mapping.

Sand	Quaternary sequences Tertiary sequences Residual deposits on older basement
Gravel:	Tertiary sequences Residual deposits on older basement
Clay:	Tertiary sequences Residual deposits on older basement

Economic significance

Gravel, sand and clay are essential for all building and construction activities. Because of their low cost in comparison to the transport costs it is critically important that local sources are available.

Sand:

The chemical composition and grain size distribution determine the use of sand deposits. A variety of products are produced at most pits. Dune sand tends to be too fine for most applications and is sometimes mixed with fines from crushing operations. Different size fractions of sand are used for concrete/bedding/paving/foundry and moulding purposes. Production in 2010/2011 was 675 000 tonnes.

Gravel:

Many materials are used for road base, road surfacing, concrete aggregate and associated applications. The specifications vary greatly depending on the particular project. The overwhelming economic factor is one of proximity to the market/location of use, as transport costs are a significant factor in the viability of any deposit. Gravel (natural aggregate) can be produced at lower cost than the crushed (hard rock) equivalent. Such sources generally have a cost advantage away from the major population centres where the large hard-rock operations supply most of the demand. Production of gravel in 2010/2011 was about 50 000 tonnes.

Clay:

To be economically useful, clay deposits must be chemically suited to the relevant purpose (bricks, pipes and tiles, terra cotta pottery, stoneware, paper manufacture, paper coating, cement manufacture etc.) and must be of an appropriate colour. The total production of clay in 2010/2011 was about 28 000 tonnes.

Map 44 — Model C44

MODEL M45: Cobar-style copper   gold, zinc, lead

Model description

Description of the model by Geoffrey R Green.

Approximate synonyms

N/A

Description

Syn-deformational, steeply plunging, disseminated, massive and vein-hosted ore bodies in predominantly turbidite sequences in high strain zones near intra-cratonic basin margins.

General references

Solomon and Groves, 1994; Glen, 1987; David, 2006; Lawrie and Hinman, 1998.

Geological environment

Rock types:

Host rocks include thinly bedded turbidites, with minor volcanic rocks and carbonates.

Age range:

Host rocks Early Devonian; mineralisation probably Late Devonian.

Depositional environment:

Marginal zone of deep marine sedimentary basin with adjacent coeval shallow water clastic sedimentary sequences.

Tectonic setting(s):

High strain inversion zone near reactivated basin margin.

Associated deposit types:

Volcanic-hosted massive sulphide deposits, intrusion-related gold deposits, Mississippi Valley lead-zinc deposits, slate belt gold deposits.

Deposit description

Mineralogy:

Pyrrhotite, pyrite, chalcopyrite, sphalerite, galena, arsenopyrite, gold, electrum.

Texture/structure:

Sulphide ore is dominated by deformation/annealing textures.

Alteration:

Proximal silicification, particularly below deposits. Ore bodies enveloped by chlorite-bearing low-grade sulphide stringer zones. An outer zone of porphyroblastic siderite in the host sediment is characteristic of Endeavor. Outer envelopes characterised by detrital chlorite destruction and growth of ankerite   siderite + quartz + chlorite   pyrrhotite. Proximal (<50 m) silicification + chlorite and quartz-carbonate veining + albite + sericite   stilpnomelane   barite. Visible alteration haloes up to 150 m above and 1.5 km (generally <200 m) lateral to deposits.

Ore control:

Ore deposits are pipe like and steeply plunging, controlled by the intersections of NNW basin margin parallel faults and NW or NNE-trending transfer faults and vein sets.

Geochemical signature:

Narrow ranges of S isotope compositions indicative of basinal source. Narrow Pb isotope range indicative of mixing of basinal and basement components. Lateral depletion haloes in Li, Na, Rb, Sr and Ba at CSA and Na at Endeavor.

Geophysical signature:

Strong magnetic signature, related to pyrrhotite in deposits and haloes, but can be displaced from ore body in up-dip direction. Local gravity, EM and IP anomalies.

Examples

CSA NSW	Shi and Reed, 1998
Endeavor (Elura) NSW	Webster and Lutherburrow, 1998 Nicholson and Mares, 2006
Peak, NSW	Cook *et al.*, 2006
Hera, NSW	Collins *et al.*, 2006

Known deposits and mineral prospects in Tasmania

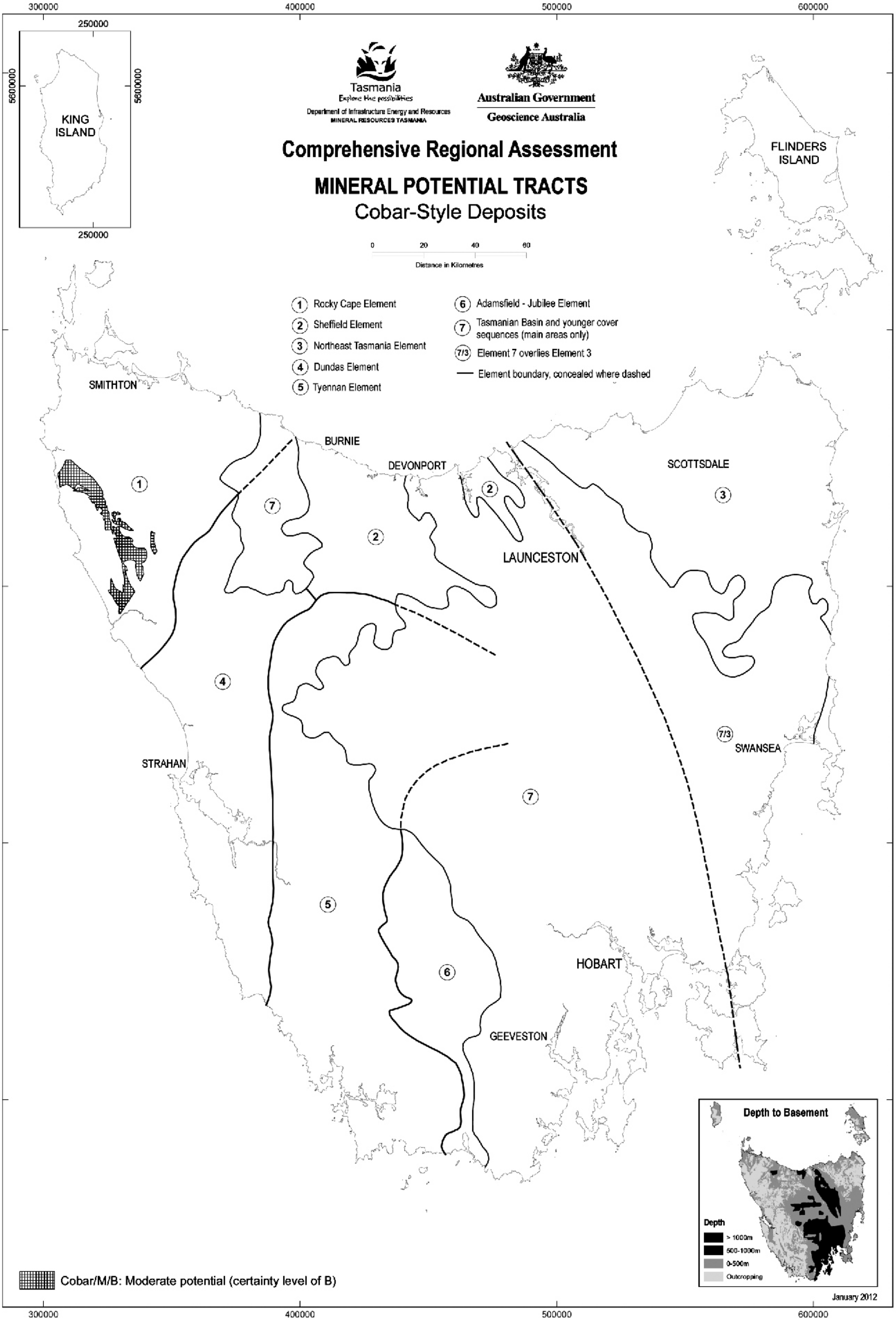
None, but Murrays Reward and other deposits along the Balfour copper trend show some features of the deposit style. These have a narrow range of S isotope compositions consistent with a homogenised country rock source (Taheri and Bottrill, 2004).

Assessment criteria

1. Presence of major syn-sedimentary fault zones reactivated during basin inversion.
2. Presence of localised magnetic or IP anomalies.

Assessment: Tract M45/M/B

The copper and magnetite deposits in far northwestern Tasmania are essentially restricted to the Balfour Subgroup of the Rocky Cape Group, a unit with distinctive magnetic properties. Most are concentrated in a major NNW trending linear zone.



Map 45 — Model M45

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Note: References in italics in the text are papers cited by Cox and Singer (1986) and are not included in the following list of references — the reader should refer to Cox and Singer (1986).

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