Tract HMS1b/M-H/C
The tract covers Quaternary (Pleistocene and Recent) sandy sediments in areas where heavy mineral sands are known to have been mined out, but where extensions or lower grade halos could be possible or become mineable by improved technology.

This tract is assessed on available information as having moderate to high potential, with a certainty of C, for heavy mineral concentrations of sufficient size to be of economic interest.

Tract HMS1c/M/B
The tract covers Quaternary sediments close to the present or palaeoshore lines. There is a moderate potential, with a certainty of B, for heavy mineral concentrations of sufficient size to be of economic interest.

If heavy mineral concentrations are present in the above tracts, they may also contain trace amounts of gold.

Economic Significance

Based on data on 61 deposits worldwide, shoreline placer deposits have a median ore tonnage of 11 Mt (Cox and Singer 1986). Both beach and dune sand deposits are included in this sample. About 90% of these deposits contain at least 11 Mt of ore and 10% contain at least 690 Mt. The median grades for these deposits are 1.3% TiO2 for ilmenite and 0.15 percent TiO2 for rutile.

The economic viability of shoreline deposits is determined by the constituent mineralogy, grades and size of the deposit. The successful working of these east coast deposits over the last 50 years suggests that the beach and dune sand deposits in the UNER are of significant economic importance, where there are no pre-existing State or National Parks covering the tract. It should be noted that environmental factors could affect the economic viability of the mineral sands tract.

Coal1: Open Cut Coal deposits in the Clarence-Moreton basin

Model Description

Approximate Synonyms: Coal Measures

Description
Coal-bearing and carbonaceous sequences within the Jurassic Walloon Coal Measures and Koukandowie Formation, and the Triassic Ipswich and Nymboida Coal Measures that are likely to occur at shallow depths.

General References

Geological Environment

Rock Types: Sandstone, siltstone, claystone, carbonaceous claystone and coal. Igneous rocks comprising Tertiary basalts and syenitic rocks are variably intruded within the formation.

Age Range: Middle Triassic to Middle Jurassic

Depositional Environment: Paludal, lacustrine and fluvial sediments. Peat swamps within structural depressions; peat swamps associated with fluvial flood plains and marginal to alluvial fans; lacustrine environment.

Tectonic Setting: Intracontinental, extensional sedimentary basin. Later folding and faulting in the Late Triassic and Late Cretaceous - Early Tertiary tectonism has produced strike-slip, reverse thrust and normal faulting and broad, open folds.

Associated deposit types: Coal Seam Methane and Oil shale.
Deposit Description

Mineralogy/Composition: Coal within the Walloon Coal Measures is high volatile bituminous, and high in vitrinite with minor exinite. Inherent ash is noted to be higher than Sydney Basin coals.

Coal within the Nymboida Coal Measures is low to medium volatile bituminous, tending to anthracite in places.

Sulphur content in both coals is low, ranging from 0.5% - 0.8%.

Known deposits and prospects in the CRA region

In the south western portion of the basin the Nymboida Coal Measures have been mined at Nymboida Colliery. The Walloon Coal Measures have been mined at Bonalbo, Ramornie, Nimbin and Tyalgum. Numerous shallow prospects within the Walloon Coal Measures are located throughout the outcrop extent.

Assessment Criteria

1. Presence of the Walloon Coal Measures.
2. Presence of the Nymboida Coal Measures.
3. Proximity to known coal deposits.
4. Maximum depth of cover to top of coal measures less than 100 metres.
5. Low to moderate seam dip.
6. Absence of vertical to sub-vertical intrusive igneous bodies.

Assessment

Tract Coal1a/M-H/B-C
The tract has moderate to high potential and is defined by the presence of Walloon Coal Measures at outcrop and at depths with opencut potential where geological structure indicates shallow dip and the anticipated thickness of the main coal sequence may be of mineable thickness. The tract covers an area on the western side of the basin, north of Urbenville and extending northerly into Queensland. Areas covered by Tertiary volcanic flows and sills are not downgraded with only the outcrop extent of intrusions such as plugs, dykes and volcanic complexes excluded. A certainty of B for this tract is due to poor quality data with no subsurface data.

A further tract with moderate to high potential is located in the central northern part of the basin extending from Nimbin north to Tyalgum. This tract is defined by the presence of Walloon Coal Measures at outcrop and at depths with opencut potential where geological structure indicates shallow dip and the anticipated thickness of the main coal sequence may be of mineable thickness. Areas covered by Tertiary volcanic flows and sills are not downgraded with only the outcrop extent of intrusions such as plugs, dykes and volcanic complexes excluded. A certainty of C is based on moderate quality data including previous mining.

Tract Coal1b/M/C
The tract is defined by the presence of Walloon Coal Measures at outcrop with opencut potential and the thickness of the main coal sequence is likely to be less than 15 metres. The tract extends around the majority of the basin edge from Urbenville in the north west, to Glenreagh in the south and along the eastern side of the basin as far north as the Coraki-Lismore area. Areas covered by Tertiary volcanic flows and sills are not downgraded with only the outcrop extent of intrusions such as plugs, dykes and volcanic complexes excluded. Areas overlain by Quaternary sediments are not excluded. A certainty of C is based on moderate quality data.

Another tract with moderate potential for locating open cut coal is defined by the presence of Nymboida Coal Measures at outcrop and at possible depths no greater than 100 metres. The tract is located at the south western margin of the basin. It is bounded by the Martin Fault in the north and extends south east into the Towallum area. A certainty of C is based on a moderate level of borehole data and previous mining at Nymboida Colliery.
Economic Significance

Currently no coal is produced from the Clarence-Moreton Basin within New South Wales. The strategic importance of viable coal deposits within this region would be considerable. A cheap energy source for both local power generation through either conventional coal-fired or fluidised-bed combustion technology. Combined with local industry and secondary processing of minerals from the New England Block this would be of considerable economic significance.

The division of coal deposits into opencut and underground potential reflects not only the expected mineable depth of coal seams, it is a recognition that the viability of underground coal resources of the quality known to occur in the Clarence-Moreton Basin would be significantly less than shallow resources amenable to opencut. The interbedded nature of typical Walloon Coal Measure seams renders them suitable only for selective mining which is currently only achieved in open cut extraction. However, the possibility remains that seams with better quality, in geologically more favourable environments, occur in the untested majority of these tracts.

BM1: Volcanic associated massive sulphide deposits

Model Description
Description of the model after Donald A. Singer.

Approximate Synonyms: Cupreous pyrite.

Description: Massive pyrite, chalcopyrite, and sphalerite in pillow basalts.


Geological Environment

Rock types: Ophiolite assemblage: tectonised dunite and harzburgite, gabbro, sheeted diabase dykes, pillow basalts, and fine-grained metasedimentary rocks such as chert and phyllite.

Textures: Diabase dykes, pillow basalts, and in some cases brecciated basalt.

Age range: Archaean(?) to Tertiary—majority are Ordovician or Cretaceous.

Depositional environment: Submarine hot spring along axial grabens in oceanic or back-arc spreading ridges. Hot springs related to submarine volcanoes producing seamounts.

Tectonic setting(s): Ophiolites. May be adjacent to steep normal faults.

Associated deposit types: Mn and Fe-rich cherts regionally.

Deposit Description


Texture/Structure: Massive sulphides (>60 percent sulphides) with underlying sulphide stockwork or stringer zone. Sulphides brecciated and recemented. Rarely preserved fossil worm tubes.

Alteration: Stringer zone: feldspar destruction, abundant quartz and chalcedony, abundant chlorite, some illite and calcite. Some deposits overlain by ochre (Mn-poor, Fe-rich bedded sediment containing goethite, maghemite, and quartz).

Ore controls: Pillow basalt or mafic volcanic breccia, diabase dykes below; ores rarely localised in sediments above pillows. May be local faulting.

**Geochemical signature:** General loss of Ca and Na and introduction and redistribution of Mn and Fe in the stringer zone.

**Examples**
- Cyprus deposits, CYPS: Constantinou and Govett 1973
- Opec, GUAT: Peterson and Zantop 1980
- York Harbour, CNFF: Duke and Hutchinson 1974
- Turner-Albright, USOR: Koski and Derkey 1981

**Known Deposits and Mineral Prospects in the CRA Region**

Stratiform and stratabound massive sulphide deposits occur as copper-rich sulphide lenses interlayered with deep water marine sediments. They are known to occur in the Late Devonian-Early Carboniferous Woolomin Group (and equivalents), Sandon Beds and in Silurian and Late Carboniferous sediments of the offs Harbour Block (Barnes et al. 1988). Most deposits in the Woolomin Group and Sandon Beds occur as stratiform lenses resting on altered metabasalts and as disseminations within altered metabasalts. Manganiferous cherts and jaspers overlie sulphide lenses (Herbert 1981 cited in Barnes et al. 1988). Mineralisation in the offs Harbour Block is generally associated with fine grained, siliceous metasediments (slates, phyllites) or quartz magnetite or jasper (Barnes et al. 1988). In the Cangai Copper mine, mineralisation is associated with ?Silurian-Devonian andesitic, fine grained cherty tuff, mudstone, siltstones, lithic wackes and conglomerates of the Willowie Creek beds (Henley 1993).

Mineralisation in all deposits except in the Cangai mine is interpreted to be associated with tholeiitic volcanism in submarine environment and belongs to the Oceanic Crustal Metallogenic Unit (Markham 1975b). For the Cangai mine a similar environment is also suggested although lead isotope studies indicate that the mineralising fluid might be related to the Towgon Grange Granodiorite (Brauhart 1991, cited in Henley 1993).

**Assessment Criteria**

1. Presence of rocks belonging to the ophiolitic assemblage consisting of mafic volcanic, volcanioclastic and volcanogenic sedimentary rocks formed in submarine environment. (Coffs Harbour Association, Sandon Association, Silverwood Association or Brooklana Beds, Coffs Harbour Beds, Coramba Beds, Cungleburg Creek Beds, Girakool Beds and Agnes Greywacke, Sandon Beds, Willowie Creek Beds).

2. Presence of known mineral occurrences.

**Assessment**

**Tract BM1a/M/C**

The tract includes the accretionary-prism rocks of the ophiolitic assemblage consisting of mafic and felsic volcanics and volcanioclastics and their metamorphic equivalents. It also includes sedimentary and metasedimentary rocks formed in proximity to submarine volcanic environment. The best markers of these environments are cherts, jaspers, manganese-rich sedimentary facies and magnetite rich rocks. The tract also includes all the known occurrences of volcanic associated massive sulphide mineralisation. Mineral potential of the tract is assessed to be moderate with a certainty level of C.

**Tract BM1b/L-M/C**

The tract includes the rest of the accretionary-prism rocks which are not reported to have chert or jasper horizons but are indicative of a general ophiolitic-related geological environment. The tract does not host any known mineral occurrences of volcanic associated massive sulphides. However these rocks have features which are indicative of broad ophiolitic assemblages. It is also possible that these rocks host some distal volcanic-massive sulphide mineralisation. Hence the potential of the tract is assessed to low to moderate with a certainty level of C.

**Economic significance**

The tract can host Cyprus and/or Besshi style volcanic massive sulphide deposits. Grade and tonnage data (Cox and Singer 1986) of these deposits indicates that 10% of these deposits can contain at least 17 Mt (Cyprus style) or 3.8 Mt of ore (Besshi style); 50% of the deposits contain at least 1.6 (Cyprus style) or
0.22 (Besshi style) Mt of ore; 90% of these deposits contain at least 0.1 (Cyprus style) and 0.12 (Besshi style) Mt of ore. The largest 10% of these deposits have at least 3.9% (Cyprus style) and 3.8% (Besshi style) copper in the ore. The two types of deposits also contain commercially important concentrations of gold, silver and zinc.

Au3: Metahydrothermal Gold - antimony veins (Models 27d, 36a of Cox and Singer 1986)

**Model Description**
Description of the model after James D. Bliss and Greta J. Orris; Byron R. Berger.

**Approximate Synonyms**
Mesothermal quartz veins, Mother Lode veins, turbidite-hosted gold veins, slate belt gold veins, low sulphide gold-quartz veins, deposits of quartz-stibnite ore (Smirnov and others, 1983).

**Description**
Gold in quartz veins and silicified lode structures, mainly in regionally metamorphosed rocks; stibnite-gold veins, pods, and disseminations in or adjacent to brecciated or sheared fault zones.

**General References**

**Geological Environment**

*Rock types:* Regionally metamorphosed volcanic rocks, greywacke, chert, shale, and quartzite, especially turbidite-deposited sequences, greenstone belts and oceanic metasediments. Alpine gabbro and serpentinite. Late granitic batholiths.

One or more of the following lithologies is found associated with over half of the antimony-gold vein deposits: limestone, shale (commonly calcareous), sandstone, and quartzite. Deposits are also found with a wide variety of other lithologies including slate, rhyolitic flows and tuffs, argillite, granodiorite, granite, phyllite, siltstone, quartz mica and chloritic schists, gneiss, quartz porphyry, chert, diabase, conglomerate, andesite, gabbro, diorite, and basalt.

*Age range:* Precambrian to Tertiary.

*Depositional environment:* Continental margin mobile belts, accreted margins. Veins age pre to post-metamorphic and locally cut granitic rocks.

*Tectonic setting(s):* Fault and joint systems produced by regional compression.

*Associated deposit types:* Stibnite-bearing veins, pods, and disseminations containing base metal sulphides + cinnabar + silver + gold + scheelite that are mined primarily for lead, gold, silver, zinc, or tungsten; low-sulphide Au-quartz veins; epithermal gold and gold-silver deposits; hot-springs gold; carbonate-hosted gold; tin-tungsten veins; hot-springs and disseminated mercury, gold-silver placers; infrequently with polymetallic veins and tungsten skarns. Placer Au-PGE.

**Deposit Description**

*Mineralogy:* Gold-low sulphide quartz vein deposits contain 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 instances because of fine-grained sulphides. Carbonates of Ca, Mg, and Fe abundant. Antimony-gold vein deposits contain stibnite + quartz + pyrite ± calcite; minor other sulphides frequently less than 1 percent of deposit and included ± arsenopyrite ± sphalerite ± tetrahedrite ± chalcopyrite ± scheelite ± free gold; minor minerals only occasionally found include native antimony, marcasite, calaverite, berthierite, argentite, pyrargyrite, chalcocite, wolframite, richardite, galena, jamesonite; at least
a third (and possibly more) of the deposits contain gold or silver. Uncommon gangue minerals include chalcedony, opal (usually identified to be cristobalite by X-ray), siderite, fluorite, barite, and graphite.

**Texture/structure:** Gold-low sulphide quartz vein deposits - saddle reefs, ribbon quartz, breccias, open-space filling textures commonly destroyed by vein deformation. Antimony-gold vein deposits contain stibnite in pods, lenses, kidney forms, pockets (locally); may be massive or occur as streaks, grains, and bladed aggregates in sheared or brecciated zones with quartz and calcite. Disseminated deposits contain streaks or grains of stibnite in host rock with or without stibnite vein deposits.

**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. Antimony-gold vein deposits exhibit silicification, sericitisation, and argillisation; minor chloritisation; serpentinisation when deposit is in mafic, ultramafic 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, eg shale/sandstone contacts and intrusive contacts may be important. Fissures and shear zones with breccia usually associated with faults; some replacement in surrounding lithologies; infrequent open-space filling in porous sediments and replacement in limestone. Deposition occurs at shallow to intermediate depth.

**Weathering:** Abundant quartz chips in soil. Red limonitic soil zones. Gold may be recovered from soil by panning. Yellow to reddish kermesite and white cerrantite or stibiconite (Sb oxides) may be useful in exploration for antimony-gold vein deposits; residual soils directly above deposits are enriched in antimony.

**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**

**Gold-low sulphide quartz vein:**
- 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

**Antimony-gold:**
- Amphoe Phra Saeng, Thailand: Gardner 1967
- Coimadai, Victoria, Australia: Fisher 1952
- Costerfield, Victoria, Australia: Stillwell 1953
- Hillgrove, NSW, Australia: Boyle 1990
- Last Chance, USA: Lawrence 1963

**Known deposits and mineral prospects in the CRA Region**

The gold-antimony-quartz vein mineralisation in the UNER can be divided into two sub-types, antimony-gold-quartz veins and gold-low sulphide-quartz veins. Both types are structurally controlled, are hosted mainly by metasediments or S-type granitoids and appear to have some spatial association with I-type granitoids.

Clusters of antimony-gold-quartz vein deposits and occurrences are located in the Lunatic and Lionsville goldfields in the central north of the CRA region. Other clusters occur in the Magword area straddling the southern boundary of the CRA a region and the Wild Cattle Creek area (also known as Lower Bielsdown) on the south eastern boundary of the CRA region. To the south of the region, major clusters occur in the Hillgrove field (hosted by the S-type Hillgrove Adamelite and Girrakool Beds metasediments) and the Taylors Arm field (hosted by Permo-Carboniferous metasediments). All these fields have been historic producers of antimony and gold but only Hillgrove continues to be a significant producer of antimony-gold concentrates.
Gold-low sulphide-quartz vein deposits and occurrences are mainly confined to the Coffs Harbour Block in the CRA region. The major goldfields from south to north are Coramba-Orara, Dalmorton, Lionsville and Lunatic. The Coramba-Orara field, in the south east corner of the CRA region, is the most important in terms of number of occurrences, followed by the Dalmorton field. The Lunatic, Lionsville and Dalmorton fields lie along a north-south zone about midway between the Demon Fault and the western margin of the Clarence Moreton Basin and may be structurally related to either of these features (Markham 1975b). However, the Coramba-Orara field is located well east of the Demon Fault and extends around the southern tip of the Clarence Moreton Basin, so that when considered together the four fields seem to parallel the margin of the Basin.

Gold-pyrite-arsenopyrite-quartz veins in the Coramba-Orara field occupy tension gashes and fissures in siliceous claystone of the Coramba Beds and have no obvious association with intrusive igneous rocks. Over 45 reef deposits have been recorded (Markham 1975b). To the north west in the Dalmorton field, there is also no spatial relationship between intrusives and numerous gold-quartz vein reefs in slates, greywacke and sandstones of the Brooklana and Coramba Beds.

Further north in the Lionsville goldfield, north-north-east and east-west trending gold-arsenopyrite-stibnite-low sulphide-quartz veins are hosted by metasediments and andesitic metavolcanics of the Willowie Creek Beds and the intruding Dumbudgery Creek Granodiorite (I-type). Near Tyringham gold-arsenopyrite-low sulphide quartz veins occur in the Dundurrabin Granodiorite (S-type) and adjacent Moombil Beds metasediments (Markham 1975b).

Significant gold production came from the Glen Elgin reef mine, central part of the CRA region, where gold occurs in pyrite-quartz veins in the Kingsgate Granite (I-type). The veins occur just west of the Demon Fault, which may have played a role in their genesis. A little west of the Demon Fault in the north west of the CRA region, near Boonoo Boonoo, gold-silver quartz veins occur in the I-type Stanthorpe Adamellite (Weber 1975).

Antimony deposits in, and near, the Dalmorton (central UNER) and Lionsville goldfields are hosted by granitic rocks. The Lunatic field comprises a western belt of antimony and eastern belt of gold deposits with mineralised veins hosted by Emu Creek Formation sediments and at Ottos lode (Pretty Gully) by Jenny Lind Granite. At Tooloom, gold-quartz veins occur in Emu Creek Formation sediments and acid volcanics.

Antimony-gold-quartz vein deposits are distributed adjacent to major geological structures, such as regional faults and geological block margins. Such structures may have provided pathways for rising metahydrothermal mineralising fluids generated by heat sources associated with the mantle or deep seated magmas. As the fluids cooled, gold/antimony/minor sulphide mineralisation was precipitated in veins, shears, stockworks and breccias higher in the earth’s crust (Minfo 1997). This depositional environment appears best developed around the Nambucca-Central Block margin, but also occurs adjacent to the western margin of the Coffs Harbour Block.

The fluids for both antimony-gold and gold-low sulphide-quartz veins may have been derived from circulation of large volumes of heated water generated by dewatering of wet ocean derived sediments, metamorphic dehydration of sediments and/or infiltration of meteoric (rain) water through the New England Orogen sedimentary rocks. The heat sources required to drive this circulation may have been provided, at least in part, by the I-type granitoid intrusives of the New England Batholith (Resource and Conservation Assessment Council 1996).

Both gold-low sulphide-quartz vein and antimony-gold-quartz mineralisation appear to overlap with emplacement of the I-type granitoids of the Permo-Triassic age New England Batholith and the granitoids were likely major sources of the mineralising fluids. This mesothermal mineralisation cross-cuts the older Permo-Carboniferous S-type granitoids, metasediments and (rarely) metavolcanics. Geochronology also indicates that the mineralisation may have formed in Late Permian to early Triassic times (Ashley et al. 1996). In addition, lamprophyre dykes of similar age to the New England Batholith commonly follow the strongly developed north and north west trending mineralised shears and veins of the Hillgrove antimony-gold field (Boyle 1990) and have geochemical affinities with the I-type granitoids (Ashley et al. 1996).
Markham (1975b) states that antimony-gold deposits, except the Wild Cattle Creek deposit, appear to be genetically linked to the Dundurrabin Granodiorite (S-type), Mount Mitchell Adamellite (I-type), Towgon Grange Granodiorite (I-type), Jenny Lind Granite (I-type) and Bruxner Adamellite (I-type).

Spatial analysis of known occurrences in the UNER and its buffer shows that 91% of metahydrothermal antimony-gold and gold-low sulphide-quartz vein occurrences are hosted by Permian and pre-Permian Accretionary Complex metasediments. Less than 1% of occurrences are in Lower Permian Volcanics.

Thirty seven percent (37%) of occurrences are in, or within five kilometres, of an I-type granitoid, while 8% lie in, or within five kilometres, of an S-type granitoid. Eight percent actually occur in I-type granitoids and 3% in S-type granitoids.

Seventy four percent (74%) of metahydrothermal antimony-gold and gold-low sulphide-quartz vein occurrences lie within five kilometres of a fault, 46% within two kilometres and 28% within one kilometre of a fault. Faults appear to have a north west to north-north-east preferred orientation (42% of faults), including a stronger northerly orientation (14% of faults). Fifty nine percent (59%) of metahydrothermal antimony-gold and gold-low sulphide-quartz vein occurrences lie within five kilometres of a north west to north-north-east trending fault, while 34% lie within 2 kilometres of them and 19% within one kilometre.

Ninety percent of metahydrothermal antimony-gold and gold-low sulphide-quartz vein occurrences have very small (<10kg gold) or unknown past production. Ten percent of occurrences in the CRA region and its buffer are considered small (<100kg gold production). Wild Cattle Creek (or Lower Bielsdown), with a resource of 327,000 tonnes at 4.95% antimony, is the only relatively large unmined deposit in the CRA region and its buffer.

Arsenic stream sediment geochemistry shows a group (of about 9 kilometres diameter) of assays greater than 30 ppm As just inside the CRA boundary about 30 kilometres north-north-west of Tenterfield. This group lies adjacent to the western contact of the Stanthorpe Adamellite in Accretionary Complex metasediments. No gold or other mineral occurrences are shown here. Similar arsenic geochemistry coincides with the Lunatic goldfield and to a lesser extent with the Lionsville goldfield. However no such geochemistry has been recorded for the Dalmorton or Coramba-Orara fields. Scattered arsenic assays greater than 30 ppm As are spread over a 30 by 15 kilometre zone extending to the south east of Glen Innes in the south west of the CRA region.

Assessment Criteria:

1. Presence of host rock metasediments and S-type granitoids of Late Permian to early Triassic age or older.
2. Presence of I-type granitoids as part of mineralisation genesis.
3. Presence of faults spatially controlling mineralisation within deposit clusters.
4. Presence of geological block margins, especially for antimony-gold vein-quartz deposits.
5. Presence of the above rock types and structures beneath relatively thin Mesozoic age Clarence-Moreton Basin or Tertiary basalt lava cover rocks.
6. Enhanced potential where New England Batholith intrusions are concealed beneath older rocks, as indicated by geophysical data, contact metamorphism (hornfelsing), alteration zones and/or relatively intense rock fracturing (Resource and Conservation Assessment Council 1996).
7. Presence of gold-low sulphide-quartz vein or antimony-gold vein-quartz deposits.

Assessment:

**Tract Au3a/H/B**

This tract consists of metasediments of early Triassic or older age and Permo-Carboniferous S-type granitoids within two kilometres of a known fault. Over 95% of known gold-antimony-quartz vein occurrences lie within the tract. Potential for the discovery of economic gold-antimony-quartz vein deposits in this tract is thought to be high with a certainty level of B.

**Tract Au3b/M-H/B**
This tract includes metasediments of early Triassic or older age and S-type granitoids not within two kilometres of a known fault, where unmapped faults with undiscovered surface or concealed gold-antimony-quartz vein deposits may occur. Potential for such deposits is considered moderate to high with a certainty level of B.

**Tract Au3c/L-M/B**

This tract delineates areas where the above Tract Au3a extends beneath Tertiary basaltic lavas and the relatively shallow Mesozoic age cover rocks along the western, southern and north eastern margins of the Clarence-Moreton Basin.

Limited geological cross section data indicate that a 20 kilometre zone along the inside of the above Clarence-Moreton Basin margins includes areas of less than 1000 metres thickness of cover rocks, beneath which detection of gold-antimony-quartz vein deposits by geophysics and drilling is possible. A similar zone is defined around a “window” of the older metasediments of the Mt Barney Beds on the central northern edge of the CRA region. Tertiary basaltic lavas across the Region are thought to be relatively thin, possibly 200-300 metres thick (pers. comm. R.G. Barnes, NSWGS 1998), and may also conceal accessible gold-antimony-quartz vein deposits.

Potential for such concealed economic gold-antimony-quartz vein deposits under Mesozoic and Tertiary rocks is considered low to moderate with a certainty level of B.

Where metasediments of early Triassic or older age and S-type granitoids occur outside Tract Au3a and appear to extend under Mesozoic and Tertiary rocks potential for economic gold-antimony-quartz vein deposits is unknown, with a certainty level of A.

**Economic Significance:**

Gold-low sulphide quartz vein deposits are one of the largest types 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 Mt of ore; 50% contain at least 0.03 Mt and 10% contain at least 0.91 Mt. 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.

The grade/tonnage model for simple antimony-gold vein deposits (Cox and Singer, 1986) indicates that 50% of deposits contain more than 180 tonnes of ore and 10% contain more that 4,900 tonnes. Ninety percent of these deposits contain at least 18% antimony, 50% of them contain at least 35% antimony, while 10% of them contain at least 66% antimony, 1.3 grams/tonne gold and 16 grams/tonne silver.

**Assessment of associated deposit types**

Disseminated gold deposits often occur as lower grade halos around higher grade metahydrothermal gold-low sulphide or antimony-gold vein-quartz deposits. Significant mineralisation of this type occurs in Bendigo-Ballarat and Melbourne Zones in Victoria. Conditions suitable for formation of such halo deposits may have existed in the CRA region but a lack of relevant detailed data prevents a reliable assessment of their mineral potential.

**Coal2: Underground Coal deposits in the Clarence-Moreton Basin**

**Model Description**

**Approximate Synonyms**: Coal Measures

**Description**

Coal-bearing and carbonaceous sequences within the Jurassic Walloon Coal Measures and Koukadowie Formation, and the Triassic Ipswich and Nymboida Coal Measures that are likely to occur at depths greater than open cut limits.

**Geological Environment**

**Rock Types:** Sandstone, siltstone, claystone, carbonaceous claystone and coal. Igneous rocks comprising Tertiary basalts and syenitic rocks are variably intruded within the formation.

**Age Range:** Middle Triassic to Middle Jurassic

**Depositional Environment:** Paludal, lacustrine and fluvial sediments. Peat swamps within structural depressions; peat swamps associated with fluvial flood plains and marginal to alluvial fans; lacustrine environment.

**Tectonic Setting:** Intracontinental, extensional sedimentary basin. Later folding and faulting in the Late Triassic and Late Cretaceous - Early Tertiary tectonism has produced strike-slip, reverse thrust and normal faulting and broad, open folds.

**Associated deposit types:** Coal Seam Methane and Oil shale.

**Deposit Description**

**Mineralogy/Composition:** Coal within the Walloon Coal Measures is high volatile bituminous, and high in vitrinite with minor exinite. Inherent ash is noted to be higher than Sydney Basin coals.

Coal within the Nymboida Coal Measures is low to medium volatile bituminous, tending to anthracite in places.

Sulphur content in both coals is low, ranging from 0.5% - 0.8%.

**Known deposits and prospects in the Clarence-Moreton Basin**

Within the south western portion of the basin the Nymboida Coal Measures have been mined at Nymboida Colliery. The Walloon Coal Measures have been mined at Bonalbo, Ramornie, Nimbin and Tyalgum. Numerous shallow prospects within the Walloon Coal Measures are located throughout the outcrop extent.

**Assessment Criteria**

1. Presence of the Walloon Coal Measures.
2. Presence of the Nymboida Coal Measures.
3. Proximity to known coal deposits.
4. Depth of cover to the top of the Walloon Coal Measures is greater than 100 metres and less than 300 metres.
5. Low to moderate seam dip.
6. Absence of vertical to sub-vertical intrusive igneous bodies.

**Assessment**

**Tract Coal2a/M/B**

The tract is defined by the presence of Walloon Coal Measures at depths no greater than 300 metres to the top of the formation. The tract has moderate potential for underground coal only. This tract is generalised to the outcrop extent of the Kangaroo Creek Sandstone which overlies the coal measures and has a thickness of between 200 and 500 metres. Areas covered by Tertiary volcanic flows and sills are not downgraded with only the outcrop extent of intrusions such as plugs, dykes and volcanic complexes excluded. Areas overlain by Quaternary sediments are not excluded. Certainty of B is based on poor quality data with borehole spacing between 20 and 30 kilometres.

A second tract with moderate potential is defined by the probable presence of Walloon Coal Measures with similar quality to shallower coal seams within the same region. Within this tract the Walloon Coal Measures are overlain by extensive Tertiary volcanic flows with a depth of cover no greater than 300 metres to the top of the formation. This tract occurs mainly in the north western part of the basin from Mummulgum north to the Woodenbong area where extensive Tertiary volcanic flows overlie the Walloon
Coal Measures. A certainty of B is based on the probable presence of Walloon Coal Measures but with a lack of knowledge due to lack of subsurface data.

A third tract delineates areas with moderate potential for underground coal and is defined by the possible presence of Nymboida Coal Measures at mineable depth beneath the lower Bundamba Group, downdip from the mapped outcrop extent to an approximated depth of 300 metres. The tract is terminated to the north east by the Martin Fault. A certainty of B is based on the lack of any subsurface data.

Tract Coal2b/L/B
The tract is defined by the probable presence of Walloon Coal Measures at depths greater than 300 metres to the top of the formation. This tract is generalised to the outcrop extent of the Grafton Formation. Areas of thick Tertiary volcanic flows where depth of cover to the Walloon Coal Measures is expected to exceed 300 metres are included. The outcrop extent of intrusions such as plugs, dykes and volcanic complexes are excluded. Areas overlain by Quaternary sediments are not excluded. The tract delineates areas of low potential for underground coal based on the expected depth to coal being greater than 300 metres. A certainty of B is based on the expected presence of Walloon Coal Measures throughout the area with no coal quality information and only limited data from petroleum well chip logs. The possibility remains that unknown structures such as faults or anticlines may position the Walloon Coal Measures at shallower depths than expected.

Economic Significance
Currently no coal is produced from the Clarence-Moreton Basin within New South Wales. The strategic importance of viable coal deposits within this region would be considerable. A cheap energy source for both local power generation through either conventional coal-fired or fluidised-bed combustion technology. Power generation through in situ gasification is also a possibility. Combined with local industry and secondary processing of minerals from the New England Block this would be of considerable economic significance.

The division of coal deposits into opencut and underground potential reflects not only the expected mineable depth of coal seams, it is a recognition that the viability of underground coal resources of the poor quality known to occur in the Clarence-Moreton Basin would be significantly less than shallow resources amenable to opencut extraction. The interbedded nature of typical Walloon Coal Measure seams renders them suitable only for selective mining which is currently, only achieved in open cut extraction. The possibility remains that seams with better quality, in geologically more favourable environments, occur in the untested majority of these tracts.

BM2: Silver-Bearing Polymetallic Vein deposits (Model 22c of Cox and Singer 1986)

Model Description

Approximate Synonyms: Felsic intrusion-associated Ag-Pb-Zn veins.

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


Geological Environment

Rock Types: Veins related to calc-alkaline to alkaline, diorite to granodiorite, monzonite to monzogranite in small intrusions and dyke swarms in sedimentary, igneous and metamorphic rocks. Subvolcanic intrusions, necks, dykes, plugs of andesite to rhyolite composition.

Textures: Granitic texture, fine- to medium-grained equigranular and porphyroclanitic.

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, polynmetallic replacement, skarns, epithermal deposits, greisens, etc.

Deposit Description

Mineralogy: galena + sphalerite + pyrite ± tetrahedrite-tennantite ± chalcopyrite ± arsenopyrite ± Ag ± Au 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 mineralised 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 ultrabasics.

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, Au, 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, AUTS Cox 1975

Known deposits and mineral prospects in the CRA region

There are numerous occurrences of this deposit type within the area, the most significant being the Conrad Ag lodes near Howell, the Webbs silver mine (Collisons) north west of Emmaville, and the Tulloch silver mine, near Rockvale. They are spatially and genetically associated with Middle Permian to Late Triassic, post-orogenic, I-type fractionated, and reduced granites the most important of which are the Mole Granite and the Gilgai and Tingha Granites. Mineralisation is in the form of silver-rich and base metal bearing veins, pipes and disseminations. Some silver-rich vein mineralisation is also associated with the Late Carboniferous-Early Permian S-type fractionated granites such as the Bundarra Plutonic Suite.

Assessment Criteria

1. Distribution of S-type or I-type fractionated and reduced granites.
2. Distribution of granitic intrusions at shallow depth inferred from geophysical information, and silver-rich and base metal bearing vein occurrences and tin veins closer to the intrusive.
3. Presence of silver-rich vein occurrences.

Assessment

Tract BM2a/H/B-C
This tract includes the (I-type) Mole, Gilgai and Ruby Creek Leucogranites plus a five kilometre buffer around these bodies. These are extremely fractionated and reduced granite bodies, although there appears to be some degree of variability in their relative oxidation (particularly within the Ruby Creek Granite). A large number of silver-bearing veins are associated with each of these bodies and each intrusive hosts, or is closely related to important silver-bearing polymetallic veins deposits (Mole -Taronga, Ruby Creek - Sundown, Gilgai - Conrad). This tract also includes the Tingha granite, which although part of the Uralla suite, has been intruded by the upper parts of the Gilgai granite and has provided a highly suitable host for many silver-bearing vein deposits whose source is very probably fluids from the Gilgai Granite.

The tract also includes a sub-surface south west extension of the Mole Granite, interpreted from a magnetic low and from the presence of numerous polymetallic vein and tin occurrences.

Mineral potential of the tract is assessed to be high with a certainty level of B in areas of subsurface extension of granites interpreted from magnetic lows. For the rest of the tract the certainty level is C.

Tract BM2b/M-H/B-C
This tract has been defined by drawing a corridor running between the high potential areas mentioned in the above BM2a/H/B-C. Numerous silver-rich base metal veins (distal varieties of the Sn vein-type deposits) occur within this tract hosted by country rocks other than granite. The tract also generally has a low magnetic response, similar to that of the high potential granites.

The tract also contains, fractionated, I-type and reduced (ilmenite is the only opaque mineral) Round Mountain Leucoadamellite of the Gundle Suite plus a 5 kilometre buffer around it. The potential is assessed to be Moderate to High with a certainty level of B for the area defined by the corridor and with a certainty level of C for the area occupied by the Round Mountain adamellite.

Tract BM2c/L-M/B
This tract includes the leucogranites and a 5 kilometre buffer, excluding those granites which are included in the Tract BM2a/H/B-C. These granites not as fractionated as those in the Tract BM2a/H/B-C and are locally more oxidised, and show variable levels of oxidation state. Numerous small occurrences are hosted by these leucogranites, especially the Dandahra Leucogranite and parts of the Red Range Microleucogranite. The potential of the tract is assessed to be low – moderate with a certainty level of B.

Tract BM2d/L/B
This tract is defined by the presence of relatively reduced, not very fractionated granitoids of the Uralla, Bundarra and Hillgrove suites. It also contains granites of the Moonbi Suite which are slightly more oxidised. The Uralla (I-type) and Bundarra (S-type) suites both contain silver-bearing base metal occurrences. Granites of the (I-type) Moonbi suite are characterised as relatively oxidised and vary in relative oxidation states. Moonbi Suite Granites are not as fractionated as the leucogranites but contain a few occurrences of silver-bearing base metal veins. Thus low degree of fractionation as well as relatively oxidised nature of these granitoids means that the potential of the tract is low with a certainty level of B.

Economic Significance

The 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 shows 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.

Sn1: Tin Vein deposits (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.


Geological Environment

Rock Types: Close spatial relation to multiphase granitoids; specialised biotite and(or) muscovite leucogranite common; pelitic sediments generally present.

Textures: Common plutonic textures.

Age Range: Palaeozoic 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 postorogenic 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

Known Deposits and mineral occurrences in the CRA region

The region has numerous tin vein deposits and occurrences. They are spatially and genetically associated with Middle Permian to ?Late Triassic, post-orogenic, I-type fractionated, and reduced granites the most important of which are the Mole Granite and the Gilgai and Tingha Granites. Mineralisation is in the form of cassiterite bearing veins, pipes and disseminations. Some tin vein mineralisation is also associated with the Late Carboniferous-Early Permian S-type fractionated granites such as the Bundarra Plutonic Suite.

Assessment Criteria

1. Distribution of S-type or I-type fractionated and reduced granites.
2. Distribution of granitic intrusions at shallow depth inferred from geophysical information, Sn- and base metal vein occurrences.

3. Presence of Sn-vein occurrences.

Assessment

Tract Sn1a/H/B-C
This tract includes the (I-type) Mole, Gilgai and Ruby Creek Leucogranites plus a five kilometre buffer around these bodies. These are extremely fractionated and reduced granite bodies, although there appears to be some degree of variability in their relative oxidation (particularly within the Ruby Creek Granite). A large number of Sn deposits are associated with each of these bodies and each host or are closely related to large Sn deposits (Mole - Taronga, Ruby Creek - Sundown, Gilgai - Conrad). This tract also includes the Tingha granite, which although part of the Uralla suite, has been intruded by the upper parts of the Gilgai granite and has provided a highly suitable host for many Sn deposits whose source is very probably fluids from the Gilgai granite.

The tract also includes a sub-surface south west extension of the Mole Granite, interpreted from a magnetic low and from the presence of numerous tin and polymetallic vein occurrences.

Mineral potential of the tract is assessed to be high with a certainty level of B in areas of subsurface extension of granites interpreted from magnetic lows. For the rest of the tract the certainty level is C.

Tract Sn1b/M-H/B-C
This tract has been defined by drawing a corridor running between the high potential areas mentioned in Tract Sn1a. Numerous Sn and base metal veins (distal varieties of the Sn vein-type deposits) occur within this tract hosted by country rocks other than granite. The tract also generally has a low magnetic response, similar to that of the high potential granites.

The tract also contains, fractionated, I-type and reduced (ilmenite is the only opaque mineral) Round Mountain leucoadamellite of the Gundle Suite plus a 5 kilometre buffer around it. The tract contains a few significant tin deposits.

The potential is assessed to be moderate to high with a certainty level of B for the area defined by the corridor and with a certainty level of C for the area occupied by the Round Mountain adamellite.

Tract Sn1c/L-M/B
This tract includes leucogranites and a 5 kilometre buffer, excluding those granites which are included in the Tract Sn1a/H/B-C. These granites not as fractionated as those in the Tract Sn1a/H/B-C and are locally more oxidised, and show variable levels of oxidation state. Numerous small occurrences are hosted by these leucogranites, especially the Dandahra Leucogranite and parts of the Red Range Microleucogranite.

The potential of the tract is assessed to be low – moderate with a certainty level of B.

Tract Sn1d/L/B
This tract is defined by the presence of relatively reduced, not very fractionated granitoids of the Uralla, Bundarra and Hillgrove suites. It also contains granites of the Moombi Suite which are slightly more oxidised. The Uralla (I-type) and Bundarra (S-type) suites both contain rare, small Sn occurrences. Granites of the (I-type) Moombi suite are characterised as relatively oxidised and vary in relative oxidation states. Moombi Suite Granites are not as fractionated as the leucogranites but contain a few occurrences of tin veins. Thus low degree of fractionation as well as relatively oxidised nature of these granitoids means that the potential of the tract is low with a certainty level of B.

Economic Significance

According to grade/tonnage models for tin vein deposits, 90% of deposits contain at least 0.012 Mt of ore, 50% at least 0.24 Mt and 10% at least 4.5 Mt. 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).

Sn2: 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 & Groves (1994)

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, miorolitic cavities may be common; generally nonfoliated; equigranular textures may be more evolved (Hudson and Arth 1983); aplitic and porphyritic textures common.

Age Range: May be any age; tin mineralisation temporally related to later stages of granitoid emplacement.

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 postdate 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 wallrocks); 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 wallrock 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 greisens may have high contents of SiO2 (>73 percent) and K2O (>4 percent), and are depleted in CaO, TiO2, 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 1984
Known Deposits and prospects in the CRA region

The region contains numerous occurrences and deposits of tin-bearing greisens. The most important of these are associated with S or I-type, fractionated and reduced granites (the Mole Granite, the Gilgai Granite, the Ruby Creek Granite, the Daisy Plains Leucogranite, and the Gundle Granite). The Elsmore (granite) also hosts a number of greisen style deposits. All tin-greisen deposits are located within granite hosts.

Assessment Criteria

1. Distribution of S-type or I-type, fractionated, felsic and reduced granites.
3. Presence of mineral occurrences of tin greisens.
4. Presence of mineral occurrences and/or deposits of tin veins
5. Proximity of known occurrences of alluvial tin.

Assessment

Tract Sn2a/H/B-C
The tract is the same as the tract Sn1a/H/B-C for tin veins except that the 5 kilometre buffer is not used for tin greisens. This tract includes the (I-type) Mole, Gilgai and Ruby Creek Leucogranites. These are extremely fractionated and reduced granite bodies, although there appears to be some degree of variability in their relative oxidation (particularly within the Ruby Creek Granite). A large number of Sn deposits are associated with each of these bodies and each host or are closely related to large Sn deposits (Mole - Taronga, Ruby Creek - Sundown, Gilgai - Conrad). This tract also includes the Tingha granite, which although part of the Uralla suite, has been intruded by the upper parts of the Gilgai granite and has provided a highly suitable host for many Sn deposits whose source is very probably fluids form the Gilgai granite.

The tract also includes a sub-surface south west extension of the Mole Granite, interpreted from a magnetic low and from the presence of numerous tin and polymetallic vein occurrences.

Mineral potential of the tract for tin greisen deposits is assessed to be high with a certainty level of B in areas of subsurface extension of granites interpreted from magnetic lows. For the rest of the tract the certainty level is C.

Tract Sn2b/M-H/B
The tract is the same as the tract Sn1b/M-H/B for tin veins except that a 5 kilometre buffer around the Gundle Suite, is not used for tin greisen deposits. This tract has been defined by drawing a corridor running between the high potential areas mentioned in Sn1b/M-H/B. Numerous Sn and base metal veins (distal varieties of the Sn vein-type deposits) occur within this tract hosted by country rocks other than granite. The tract also generally has a low magnetic response, similar to that of the high potential granites.

The tract also contains, fractionated, I-type and reduced (ilmenite is the only opaque mineral) Round Mountain Leucogranite of the Gundle Suite. The tract contains a few significant tin deposits.

The potential is assessed to be moderate to high with a certainty level of B for the area defined by the corridor and with a certainty level of C for the area occupied by the Round Mountain adamellite.

Tract Sn2c/L-M/B
The tract is the same as the tract Sn1c/L-M/B for tin veins except that a 5 kilometre buffer around granite is not applied. The tract includes leucogranites, excluding those granites which are included in the tract Sn2a/H/B-C. These granites not as fractionated as those in the Tract Sn2a/H/B-C and are locally more oxidised, and show variable levels of oxidation state. Numerous small occurrences are hosted by these leucogranites, especially the Dandahra Leucogranite and parts of the Red Range Microleucogranite. The potential of the tract is assessed to be low – moderate with a certainty level of B.

Tract Sn2d/L/B
The tract is the same as the tract Sn1d/L/B for tin veins except for the 5 kilometre buffer around granite. The tract is defined by the presence of relatively reduced, not very fractionated granitoids of the Uralla, Bundarra and Hillgrove suites. It also contains granitoids of the Moonbi Suite which are slightly more oxidised. The Uralla (I-type) and Bundarra (S-type) suites both contain rare, small Sn occurrences. Granitoids of the (I-type) Moonbi suite are characterised as relatively oxidised and vary in relative oxidation states. Moonbi Suite Granitoids are not as fractionated as the leucogranites and but contain a few occurrences of tin veins. Thus low degree of fractionation as well as relatively oxidised nature of these granitoids means that the potential of the tract is low with a certainty level of B.

**Economic Significance**

According to grade/tonnage models for tin greisen deposits, 90% of deposits contain at least 0.8 Mt of ore, 50% at least 7.2 Mt and 10% at least 65 Mt. 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).

**Dimnd: Alluvial Diamond deposits (Model 39d of Cox and Singer 1986)**

**Model Description**

After Dennis P. Cox.

**Description:** Diamonds in alluvial, beach sediments, sandstone and conglomerate.


**Geological Environment**

**Rock types:** Sand and gravel in alluvial and beach deposits. Conglomerate beds may contain palaeoplacers.

**Textures:** Coarse clastic.

**Age Range:** Tertiary and Quaternary.

**Depositional Environment:** Streams draining areas of kimberlite pipes or other mantle derived igneous intrusives or diamond concentrations in sedimentary or metamorphic rocks. Alluvial diamond deposits may be 1,000 km from source. It is possible that some diamonds may have been derived from Archaean greenstone belts and Palaeozoic fold belts associated with subduction.

**Tectonic Setting(s):** Stable craton, accreted fold belts.

**Associated Deposit Types:** Primary diamond pipe deposits.

**Deposit Description**

**Mineralogy:** Diamond, bort or carbonado (polycrystalline, generally dark coloured), ballas (spherulitic, polycrystalline and amorphous carbonado).

**Texture/Structure:** Diamonds derived from ancient placers in sedimentary rock commonly retain sand grains cemented to grooves or indentations in the crystal.

**Ore Controls:** Diamonds are concentrated in low-energy parts of stream systems with other heavy minerals. Diamonds decrease in size and increase in quality (fewer polycrystalline types) with distance from their source.

**Geochemical Signature:** Diamond: Cr, Ti, Mn, Ni, Co, PGE, Ba. Anomalous Ni and Nb together with the heavy minerals pyrope, Mg-ilmenite, and phlogopite indicate nearby kimberlite pipes.

**Examples**
Known deposits and mineral prospects in the UNER

The Copeton diamond field lies in the far west of the UNER where rich (3.3 to 12 carats/cubic metre of gravel, Brown and Stroud 1997) diamond deposits were discovered in 1872 and mined in association with tin from between 1884 and 1922. Recorded diamond production was over 200,000 carats but mining was not very profitable (MacNevin 1975b). A high proportion (90% approx) of the diamonds is of gem quality (Cluff Resources Pacific NL 1991 p.3, 1996a) but they are relatively small. They are found in Tertiary boulder beds, gravels and sands, and Quaternary river/creek gravels within and bordering the Copeton Dam (Brown and Stroud 1997).

Small scale open cut mining of remaining resources at old mine sites such as Streak of Luck, Doctors Workings and Round Mount on the east side of the Copeton Dam commenced in 1996 (Cluff Resources Pacific NL 1997). Diamond grades are estimated at 0.5 carats/tonne underground at Mount Ross and 0.05 to 0.07 carats/tonne in open cut resources at Streak of Luck and Round Mount (Cluff Resources Pacific NL 1996b). Numerous old workings on the northern side of the Copeton Dam offer significant potential for mineable resources, such as at Wonderland, Staggy Creek, Oaky Creek and others.

Cluff Resources Pacific NL (1996b) infer a gaseous volcanic vent/crater (diatreme) concealed beneath basalt lava at Mount Ross as the primary source of diamond in the Mt Ross area. The 1km x 2km crater encompasses Streak of Luck, Doctors Workings and possibly Round Mount. Diamondiferous sands and boulder beds fill the crater and are thought to be a mixture of initial explosive volcanic material and sediment washed back into the crater. Local erosion of this material may give rise to alluvial diamond deposits outside the crater. More than ten similar volcanic centres have been interpreted in the Copeton diamond field where past diamond production has occurred, such as at Staggy Creek and Collas Hill. Airborne electromagnetic geophysical anomalies in the Oaky Creek area suggest the presence of volcanic centres hidden beneath basalt lavas.

Brown and Stroud (1997) concur with historical opinion that the Mount Ross diamond/tin deposits are of alluvial deep lead origin and observed no evidence of volcanoclastic rocks in the granite basement rock derived diamondiferous gravels. Ryders, Kenzie and Collas Hill deposits to the south of Mount Ross are also described as deep lead deposits. The deep lead deposits are often protected from erosion by basalt lava capping but the basalt may be wholly or partially eroded to expose residual diamondiferous Tertiary sediments (MacNevin 1977). MacNevin (1975b) suggests these deep leads form part of a once continuous Tertiary stream system with primary diamond sourced from concealed or eroded “kimberlitic” or basic volcanic breccia pipes originating from deep seated magma sources. Brown and Stroud (1997) and MacNevin (1977) refer to dolerite dykes and “plugs” in the deep leads of the Copeton field as possible primary diamond sources.

The very high gem quality component (90%) and relatively small average size (0.25 carats approx) of the Copeton diamonds indicates they may have travelled a significant distance prior to deposition unless a nearby primary source has an unusually high proportion of gem diamond. Copeton diamonds show little or no abrasion (Brown and Stroud 1997) in contrast to abraded and rounded stones from other localities (Kleeman 1988)

Quaternary alluvial flats along Copes Creek were mined for diamond and tin between Copeton township and the Gwydir River and along Bobs Creek, which drains Mount Ross and flows into Copes Creek. Alluvial diamond and tin is also known from Quart Pot gully to the south of Copeton township (Brown and Stroud 1997).

Assessment Criteria
1. Presence of Tertiary sediments.
2. Presence of Tertiary lavas that may conceal deep lead deposits.
3. Presence of known diamond deposits.

Assessment

Tract Dimnd/H/C
This tract consists of Tertiary basalt lavas or sediments within a five kilometre radius of known mineral occurrences that have diamond recorded as a major commodity or have recorded diamond production. These five kilometre buffers are designed to coalesce into a north west to south east trending zone that includes the above Copeton alluvial diamond occurrences and associated known Tertiary basalts and sediments, possibly controlled by Tertiary palaeo-drainage.

The potential for economic alluvial diamond deposits associated with old workings of these diamond occurrences is considered high with a certainty level of C.

This tract does not include placer diamond deposits associated with concealed Tertiary sediments within the above five kilometre buffers, as existing data is insufficient to assess their potential.

Diamonds have been reported from Quaternary tin placers but no significant alluvial diamond deposits have been recorded. Dilution by the sediment load in the Quaternary streams may have hindered the formation of such deposits (MacNevin 1977 pp.39-40).

Concealed Quaternary alluvial sediment horizons could host placer diamond deposits but existing information does not allow assessment of their potential. Hence the potential for diamond deposits formed by the erosion of diamonds from the Tertiary sediments into Quaternary streams is unknown.

Sapp: Alluvial Sapphire deposits (Model 39 of Cox and Singer 1986)

Model Description
After Dennis P. Cox

Description: Sapphires in alluvial sediments.

General References:

Geological Environment

Rock types: Sand and gravel alluvial deposits. Conglomerate beds may contain palaeoplacers.

Textures: Coarse clastic.

Age Range: Tertiary and Quaternary.

Depositional Environment: Streams draining areas of mantle derived igneous intrusives with associated sapphire bearing pyroclastic rocks.

Tectonic Setting(s): Accreted fold belts.

Associated Deposit Types: Alluvial diamond, minor cassiterite (tin).

Deposit Description

Mineralogy: Sapphire of inky blue to green and yellow parti-coloured associated with zircon and other heavy minerals.
Texture/Structure: Sapphire and zircon as subhedral to euhedral crystals with glossy crystal faces in Tertiary alluvial sediments but more abraded in Quaternary sediments.

Ore Controls: Sapphire is concentrated in low-energy parts of stream systems with other heavy minerals. Sapphires decrease in size and increase in quality with distance from their source.

Examples

Kings Plains, AUNSW Brown and Pecover 1986b
Braemar, AUNSW Brown & Pecover 1986a, Pecover & Coenraads 1989

Known deposits and mineral prospects in the CRA region

The Tertiary age Mount Maybole basalt shield volcano, 25 kilometres south west of Glen Innes on the south western edge of the CRA, has played an important role in the genesis of sapphire in the sapphire bearing eastern portion of the Central Volcanic Province of the New England region. Pyroclastic rocks erupted early in the volcanic sequence were subsequently overlain by significant thicknesses of basalt lava flows. The pyroclastic rocks, and to a lesser extent basal basalt lava flows, carry sufficient low grade sapphire (Brown and Stroud 1997) to act as source rocks for richer alluvial sapphire concentrations in nearby or overlying Tertiary deep lead river sediments covered by later basalt lava flows. As the basalt lavas were eroded around their margins, sapphire was shed into adjacent Quaternary river sediments by further erosion of exposed pyroclastics and Tertiary deep lead deposits. Streams also cut down through the basalt lavas for some distance within their margins and concentrated sapphire from the pyroclastics into associated river sediments.

The sapphire bearing pyroclastic source rocks are also associated with a number of smaller volcanic centres or vents related to the Mount Maybole volcano. The very rich Kings Plains sapphire deposit, one of the world’s largest and richest, was located close to the Swan – Kings Plains Vent Complex, about 35 kilometres north east of Inverell and was mined out in 1997. This deposit was in Tertiary river sediments probably derived from nearby sapphire bearing pyroclastic rocks, overlain by a thin basalt flow and concealed beneath up to five metres of Quaternary alluvium (Brown and Pecover 1986b, Pecover 1992). Sapphires are now being mined at lower grade from the base of the overlying Quaternary alluvium.

Sapphire has also been mined from Tertiary river sediments interbedded with basal basalt lava flows at Braemar, just outside the CRA region, near Elsmore.

Most of the historical sapphire production has come from Quaternary sediments. Quaternary deposits recently mined for sapphire include Wellingrove Creek and Reddestone Creek, just inside the south west boundary of the CRA region. The rich and extensive workings along Frazers Creek, Swan Brook (Pecover 1987) and Horse Gully (Brown and Stroud 1997) are other examples, just to the south west of the CRA region.

Virtually all the streams draining the Maybole Volcano are sapphire bearing (Pecover 1992) with sapphire occurring up to 60 kilometres away. As distance from the basalt lava/pyroclastic rock margins increases, sapphires are progressively broken down by abrasion and percussion during water transport and their frequency of occurrence is diluted by sediment influx. These factors appear to limit occurrence of sapphire bearing streams to within 20 kilometres from the edges of the basalt lava associated with Mt Maybole and related smaller volcanic vents (map in Dept of Mineral Resources 1983). Sapphire bearing creeks just outside the CRA region, between Armidale and Guyra, may be related to the Balbair Sugarloaf and Chandlers Peak volcanic vents while the Sara River alluvial sapphire may be associated with the Mount Mitchell vent.

Several minor occurrences of alluvial sapphire with tin are located along the eastern margin of the Tertiary age basaltic Ebor Volcanics on the south west boundary of the CRA region. The large Tweed shield volcano, in the north east of the CRA region, has no recorded sapphire despite considerable partial erosion of the basal volcanic rock units around its margins and the central volcanic plug that forms Mount Warning.

Assessment Criteria

1. Presence and proximity to sapphire related Tertiary volcanic centres.
2. Presence of sapphire bearing pyroclastic source rock units related to early stages of Tertiary volcanism.
3. Presence of Tertiary and Quaternary river sediments.
4. Presence of Tertiary lavas or Quaternary sediments that may conceal deep lead deposits.
5. Streams, rivers, lakes and swamps with unmapped Quaternary sediments.

Assessment

Tract Sapp1a/M-H/C
Significant sapphire concentrations and occurrences are restricted to Quaternary and Tertiary sediments within a 60 kilometre radius of the Mount Maybole shield volcano centre. These Quaternary and Tertiary sediments may contain economic sapphire deposits and the Quaternary sediments may conceal Tertiary sediments with economic sapphire deposits.

This tract includes the above Quaternary and Tertiary sediments within:
(c) a 20 kilometre buffer around Tertiary basalt lavas and basalt lava outcrop and
(d) basalt lava outcrop.

Outside the 20 kilometre buffer, sapphire is thought to have been largely destroyed or diluted by sediments during erosion and transport.

Also included in the tract are 100 metre buffers along creeks in area (a) to take account of unmapped Quaternary and Tertiary sediments.

Some known alluvial sapphire deposits that are marginally economic may become viable in the foreseeable future. Brown 1997 suggests that there are considerable resources remaining in known deposits and others await discovery, while paler blue sapphire in the eastern part of the tract is underexploited. Thus the potential for economic sapphire deposits in this tract is considered moderate to high with a certainty level of C.

Concealed deep lead deposits derived from previously removed Tertiary basalt lavas/pyroclastics may also exist beneath Quaternary sediments outside the above 20 kilometre buffer but there are insufficient data to assess their potential.

The minor occurrences of alluvial sapphire along the western margin of the Ebor Volcanics have not been included in the tract, as the potential for economic sapphire deposits is considered very low. The large Tweed shield volcano, in the north east of the CRA region, has also been excluded, as there are no recorded sapphire occurrences despite considerable partial erosion of its basal volcanic rock units.

Tract Sapp1b/L-M/B
This tract consists of the interfluves between stream buffers of in a 20 kilometre buffer around Tertiary basalt lavas that are within 60 kilometres of Mount Maybole. Economic sapphire deposits may occur in these interfluves within unmapped Quaternary and Tertiary sediments, and in Tertiary sediments concealed beneath unmapped Quaternary sediments.

Basalt lava outcrop within 60 kilometres of Mount Maybole is also included in the tract because it may hide economic Tertiary deep lead sapphire deposits.

Potential for economic sapphire deposits in the tract is considered to be low to moderate with a certainty of B.

W-Mo: Tungsten-Molybdenum pipes, veins and disseminated deposits (Model 15a of 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 porphyrophanitic dykes.

*Age range:* Palaeozoic to late Tertiary.

*Depositional environment:* Tensile fractures in epizonal granitic plutons and their wallrocks.

*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 vughs, 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, China: Hsu 1943; Giuliani 1985
- Isla de Pinos, Cuba: Fage and McAllister 1944
- Hamme District, USA: Foose et al. 1980
- Round Mountain, USA: Shawe and others 1984
- Chicote Grande, Bolivia

**Assessment Criteria**

1. Presence of I-type granitoids (leucocratic granitoids) which have undergone fractional crystallisation and are moderately oxidised.
2. Presence of granites with moderate or high levels of magnetic response on the aeromagnetics.
3. Presence of known occurrences of tungsten and molybdenum veins.

**Assessment**

*Tract W-Mo1a/H/B-C*

This tract has been delineated based on the distribution of granitoids of the Moonbi Suite and the group of Leucoadamellites which have not been assigned to any plutonic suite and are collectively referred to as Leucoadamellites (undetermined). A buffer zone of two kilometres around the Moonbi Suite and Leucoadamellites is also included.
The Moonbi Suite granitoids are I-type, moderately oxidised and fractionated (Blevin & Chappell 1993, Ashley et al. 1996). A number of tungsten - molybdenum veins and pipes occur along the margins of these granitoids, the largest being the Moonbi Mo-W deposit 20 km north east of Tamworth. Based on the above information, it is concluded that the Moonbi Suite has a high potential for tungsten - molybdenum veins with a certainty level of C.

The leucoadamellites (undetermined) are I-type, moderately oxidised, and fractionated. A number of W-Mo veins occur along the margins of these granitoids. Molybdenum-bismuth-tungsten occur as pipes, veins and dissemination at the outer contact of the Kingsgate granite and other leucograniites (Gilligan & Barnes 1990). The main deposits are those at Kingsgate where approximately 350 t of molybdenite and 200 t of bismuth have been won from over 50 pipes. The leucoadamellites have a high potential for tungsten - molybdenum veins with a certainty level of B.

Overall, this tract has a high potential for tungsten - molybdenum veins with a certainty level of B-C.

Tract W-Mo1b/M-H/B
This tract outlines a granite shelf or possible cupola at shallow depths below the Glen Eden deposits. The Glen Eden deposits comprise tungsten - molybdenum stockwork mineralisation and hydrothermal breccia pipes within Permian felsic volcanics (Barnes et al. 1988). Based on the presence of this style of mineralisation and from interpretations of the magnetics, it is postulated that a shallow granite shelf or cupola underlies the area of this tract. The mineralising granite has been identified during exploration drilling at a depth of 200 m (Amoco Minerals & Electrolytic Zinc Co. 1983).

Based on the above information, it is concluded that this tract has a moderate - high potential for tungsten - molybdenum veins with a certainty level of B.

Tract W-Mo1c/M/B
This tract is based on the distribution of the leucoadamellites, (including the Mole, Gilgai and Ruby Creek granitoids) and the Bolivia sub-type (Blevin and Chappell 1996). Over 150 lodes (including tin tungsten and molybdenum) occur in the Mole Granite and 60 occur in and around the Gilgai Granite/Tingha Adamellite. The tract also includes a 2 km buffer around these leucoadamellites. The leucoadamellites are I-type, reduced and highly fractionated (Blevin & Chappell 1993, Ashley et al. 1996). A large number of W-Mo veins occur along the margins of these granitoids, particularly the Bolivia sub-type. The roof pendant of the Mole Granite is excluded from the tract.

Based on the above information, it is concluded that this tract has a moderate potential for tungsten - molybdenum veins with a certainty level of B.

Tract W-Mo1d/L-M/B-C
This tract is based on the following:
- granitoids of the Clarence River Plutonic Suite,
- granitoids of the Uralla Plutonic Suite,
- Gundle Granite,
- a corridor connecting the Mole Creek, Gilgai and Ruby Creek granitoids.
- a buffer zone two kilometres wide is drawn around all the granitoids listed above.

Granitoids of the Clarence River Plutonic Suite are I-type, highly oxidised, and fractionated. These bodies have a number of molybdenum deposits. At Nundle, quartz - calcite - gold - tungsten - antimony veins are adjacent to granitoid contacts.

Granitoids of the Uralla Plutonic Suite are I-type, reduced and fractionated. A number of tungsten - molybdenum veins occur along the margins of these bodies.

The Gundle Granite is I-type (?), reduced and fractionated. There are a few tungsten - molybdenum veins associated this granite, the largest being the Guy Fawkes molybdenum deposit, 60 km east of Armidale.

The tracts enclosing the granitic suites listed above are considered to have low - moderate potential for tungsten - molybdenum mineralisation with certainty level C.
Evidence from geological data and magnetics suggest that the Gilgai, Mole and Ruby Creek granitic plutons are connected at shallow depth. The area of this shallow connection is considered to have low - moderate potential for tungsten - molybdenum mineralisation with certainty level B.

Overall, the tract has low - moderate potential with certainty level B-C.

**Summary W-Mo Veins tracts**

<table>
<thead>
<tr>
<th>Tract</th>
<th>Tract component</th>
<th>Potential</th>
<th>Certainty</th>
<th>Reasons</th>
</tr>
</thead>
<tbody>
<tr>
<td>WMo1a</td>
<td>Moonbi plutonic suite Also including the Bolivia subtype</td>
<td>High</td>
<td>C</td>
<td>I-type, moderately oxidised, fractionated, large number of W-Mo veins and occurrences. Bolivia subtype has a large number of W-Mo occurrences.</td>
</tr>
<tr>
<td>WMo1a</td>
<td>Leucoadamellites (undetermined)</td>
<td>High</td>
<td>B</td>
<td>I-type, moderately oxidised (?), fractionated, number of W-Mo veins and occurrences</td>
</tr>
<tr>
<td>WMo1b</td>
<td>Buried granite cupola beneath Glen Eden deposits</td>
<td>M-H</td>
<td>B</td>
<td>Buried granite cupola, has W-Mo stockwork mineralisation and hydrothermal breccia pipes in felsic volcanics. (Barnes et al, 1988)</td>
</tr>
<tr>
<td>WMo1c</td>
<td>Leucoadamellites (including Gilgai, Ruby Creek and Mole granites, but excluding the roof pendant of the Mole granite).</td>
<td>M</td>
<td>B</td>
<td>I-type, reduced, highly fractionated, has a number of W-Mo veins and occurrences</td>
</tr>
<tr>
<td>WMo1d</td>
<td>Clarence River plutonic suite</td>
<td>L-M</td>
<td>C</td>
<td>I-type, highly oxidised, fractionated, no recorded W mineralisation but has a number of Mo veins.</td>
</tr>
<tr>
<td>WMo1d</td>
<td>Uralla</td>
<td>L-M</td>
<td>C</td>
<td>I-type, reduced, fractionated, has a number of W-Mo veins and occurrences.</td>
</tr>
<tr>
<td>WMo1d</td>
<td>Gundle Granitoid belt</td>
<td>L-M</td>
<td>C</td>
<td>I-type (?), fractionated, reduced, has a few occurrences of W-Mo mineralisation.</td>
</tr>
<tr>
<td>WMo1d</td>
<td>Corridor around Mole/Gilgai/Ruby Creek granites</td>
<td>L-M</td>
<td>B</td>
<td>Geology suggests there is a shallow connection between these granites. Difficult to determine from magnetics because granites are non-magnetic</td>
</tr>
</tbody>
</table>

All granites have a 2km buffer zone.

**Economic Significance**

According to grade/tonnage models for tungsten deposits, 90% deposits contain at least 0.045 Mt of ore, 50% at least 0.56 Mt and 10% at least 7 Mt. In these types of deposits, 90% contain at least 0.6 wt% WO₃, 50% at least 0.9 wt% WO₃ and 10% at least 1.4 wt% WO₃ (Cox and Singer 1986).

**W: 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 & Groves 1994).


**Geological Environment**

**Rock Types**: Tonalite, granodiorite, quartz monzonite; limestone.

**Textures**: Granitic, granoblastic.

**Age Range**: Mainly Mesozoic, but may be any age.

**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.

**Examples**

- King Island, Australia, Tasmania  
  Solomon and Groves 1994
- Pine Creek, US, California  
  Newberry 1982
- MacTung, Canada, British Columbia.  
  Dick and Hodgson 1982
- Strawberry, US, California  
  Nokleberg 1981

**Known Deposits and Mineral Prospects in UNER**

W skarn deposits are not abundant in the New England region because of the paucity of suitably reactive host rocks (Ashley et al. 1996).

The Gilgurry Mudstone near the Drake Volcanics contains calcareous mudstone and fossiliferous units. The area where this unit is intruded by the Stanthorpe Adamellite has high potential for skarn deposits (pers. comm. R.G. Feb. 1998).

The scheelite-molybdenite bearing andradite skarns at Attunga are exoskarn replacement of marble and calc-silicate hornfels and minor endoskarn replacement of the quartz monzonite intrusive (Moonbi Supersuite).

**Assessment Criteria**

1. Presence of granitoids (I-type granites which are moderately oxidised) associated with tungsten-molybdenum mineral deposits or with a potential to host tungsten-molybdenum deposits.
2. Presence of suitable calc-magnesian rocks in proximity to granitoids with a potential to host tungsten-molybdenum deposits.
3. Presence of known occurrences of skarns, hornfels and skarn-related mineral occurrences.
Assessment:

Tract W/M/B
The tract is based on the following geological parameters:
- A 5 km wide zone adjacent to the margins of Triassic granitoids which are potential source rocks for tungsten mineralisation, i.e. I-type granitoids which are fractionated and moderately oxidised. A detailed analysis of the granitoids which are potential source rocks for tungsten mineralisation is given in the model for tungsten-molybdenum veins and pipes,
- Palaeozoic calcareous sediments and ultramafic rocks which were intruded by these granitoids.

The intersection of the above two geological parameters defines the tract for tungsten skarn deposits, which is assessed as moderate potential with certainty level B.

Economic significance
Grade and tonnage data (Cox and Singer 1986) suggests that 10% of this type of deposits contain at least 22 Mt of ore, 50% at least 1.1 Mt and 90% at least 0.05 Mt. In 10% of these deposits ores have at least 1.4% WO3, 50% at least 0.67% and 90% at least 0.05% WO3.

Silexite: Quartz topaz W-Mo-Bi deposits (Silexite)

Model Description
Description of the model by A.D. McKay

Description: Quartz - topaz rock with veins and disseminations of wolframite, molybdenite and bismuthinite and native bismuth. Occurs within altered microgranite, pegmatite and granite. Similar to greisenised granite.


Geological Environment

Rock Types: Silexite was developed as altered dykes, bosses and sills of microgranite in apical areas of granite roof, and in the sedimentary rocks of the roof pendant (Permian) overlying the Mole Granite. Silexite was developed after emplacement of the Mole Granite and is associated with later stages of fractionation of the melt. Associated rock types include muscovite-bearing greisens. Distinctive accessory minerals include lithium siderophyllite, fluorine-rich schorl, fluorine-rich muscovite, fluorite, beryl, dickite.

Textures: Textures and structures within the microgranite and seriate or porphyry granites, are pseudomorphed by silexite. Aplitic and porphyritic textures common, miarolitic cavities.

Age Range: In the case of the Mole Granite, the silexite is Triassic.

Depositional Environment: Plutonic, granitic bodies emplaced at high levels in the crust. Preservation of roof pendant due to partial unroofing by erosion. Silexite was developed as altered dykes, bosses and sills of microgranite in apical areas of granite roof, and in the sedimentary rocks of the roof pendant (Permian) overlying the Mole Granite.

Tectonic Setting(s): Fold belts of thick sediments ± volcanic rocks deposited on stable cratonic shield; accreted margins; granitoids generally postdate major folding.

Associated Deposit Types: Muscovite-quartz-chlorite-W-Sn-Bi rich greisens, sheeted vein quartz-cassiterite deposits, stockwork Mo-W-Bi mineralisation.

Deposit Description
Mineralogy: Topaz, wolframite, molybdenite, bismuth, bismuthinite, Cu-Pb-Zn sulphide. Gangue mineralogy includes quartz, Li-siderophyllite, F-schorl, F-muscovite, fluorite, beryl.

Texture/Structure: Various textures and structures, greisen textures are common. Textures and structures within silexite are pseudomorphs of the original microgranite and seriate granite. Quartz-wolframite-molybdenite-bismuthinite in silexite, greisens, veinlets and stockworks (in cupolas or in overlying roof pendant). Less common are pipes, lenses, and tectonic breccia.

Alteration: Hydrothermal alteration of microgranite and other host granite by hot, highly saline Si-rich and F-rich aqueous fluids. Fluid inclusion studies indicate fluid temperatures of 570-620° C. Incipient silexite (granite): quartz, topaz, muscovite ± chlorite, tourmaline, and fluorite (original texture of granites retained). Greisenised granite: quartz-muscovite-topaz-fluorite, ± tourmaline

Ore Controls: Silexite 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: Wolframite and cassiterite placer deposits form by weathering and erosion.

Geochemical Signature: Wolframite, cassiterite, topaz, and tourmaline in streams that drain exposed silexite deposits. Associated granites may have high contents of SiO2 (>73 percent), and are depleted in CaO, TiO2, MgO, and total FeO. They are enriched in W, Sn, F, Rb, Li, Be, Mo, Cs, U, and Th and impoverished in Ni, Cr, Co, V, Sc, Sr, La, and Ba (Cox & Singer 1986).

Examples
Torrington roof pendant, Mole Granite.

Known deposits and mineral prospects in the CRA region
Silexite is a quartz-topaz rock formed by alteration of granite by F-rich fluids (Kleeman 1985). It also contains various amounts of wolframite, Li-siderophyllite, F-schorl, F-muscovite, beryl, molybdenite, bismuth, bismuthinite and dickite (Plimer et al 1995). Silexite contains more than 5% topaz. Silexite is the product of hydrothermal alteration of solidified granite, most frequently microgranite but also of seriate and other varieties of the Mole Granite (Kleeman et al 1997). Most silexite is developed as altered dykes, bosses and sills of microgranite in the sedimentary rocks of the roof pendant (Permian) within the Mole Granite. Textures and structures within the microgranite and seriate or porphyry granites, are pseudomorphed by silexite. Fluid-inclusion studies topaz grains in silexite have homogenisation temperatures of 570-620° C.

The Mole Granite is interpreted as a sill-like mass only a few kilometres thick, emplaced at a high level in the crust (Kleeman et al. 1997). It was emplaced at 246±2 Ma. Crystallisation inwards produced a pressure quenched coarsely grained granite carapace. Microgranite was extensively emplaced as dykes in the fractured carapace and overlying country rock. An aqueous magmatic fluid utilising the same structures as the microgranite, at 246 Ma, reacted in places with the granite to form silexite.

At the Fielder’s Hill mine, which was one of the largest mines in the roof pendant, the first 20 000 t of silexite ore contained 1.6% WO3, but the bulk grade of all the quartzose rock mined was 0.5% WO3. At the The Bismuth mine, wolframite and native bismuth occurred in pegmatite and silexite. Overall production from the roof pendant deposits was 2000 tons wolframite (Kleeman 1990).

Assessment Criteria
1. Roof pendants in highly fractionated, felsic granites such as the Mole Granite.
2. Presence of known occurrences of topaz bearing greisen rocks.

Assessment
Tract Silexite/M-H/B
The tract includes the area corresponding to the roof pendant of Mole Granite plus a 200 m wide buffer zone surrounding it. It contains all the known occurrences of silexite in the region.
Economic Significance

During the late 1980s, a pilot scale topaz calcination plant operated at Parramatta. Topaz is converted to pure mullite (3Al2O3.2SiO2) when calcined at 1350° C. Mullite is an important industrial mineral for the refractory industries.

CuAu2: Copper-gold skarn deposits (Model 18b of Cox and Singer 1986)

Model Description
Description of the model after D.P. Cox and T.G. Theodore

Description: Chalcopyrite in calc-silicate contact metasomatic rocks.


Geological Environment

Rock Types: Tonalite to monzogranite intruding carbonate rocks or calcareous clastic rocks.

Textures: Granitic texture, porphyry, granoblastic to hornfelsic in sedimentary rocks.

Age Range: Mainly Mesozoic, but may be any age.

Depositional Environment: Miogeosynclinal sequences intruded by felsic plutons.

Tectonic Setting(s): Continental margin late orogenic magmatism.

Associated Deposit Types: Porphyry Cu, zinc-lead-silver skarn, gold skarn, polymetallic replacement, Fe skarn.

Deposit Description

Mineralogy: Chalcopyrite + pyrite ± hematite ± magnetite ± bornite ± pyrrhotite. Also molybdenite, bismuthinite, sphalerite, galena, cosalite, arsenopyrite, enargite, tennantite, loellingite, cobaltite, and tetrahedrite may be present. Au and Ag may be important products.

Texture/Structure: Coarse granoblastic with interstitial sulphides. Bladed pyroxenes are common.

Alteration: Diopside + andradite centre; wollastonite + tremolite outer zone; marble peripheral zone. Igneous rocks may be altered to epidote + pyroxene + garnet (endoskarn). Retrograde alteration to actinolite, chlorite, and clays may be present.

Ore Controls: Irregular or tabular ore bodies in carbonate rocks and calcareous rocks near igneous contacts or in enclaves in igneous stocks. Associated igneous rocks are commonly barren.

Weathering: Cu carbonates, silicates, Fe-rich gossan. Calc-silicate minerals in stream pebbles are a good guide to covered deposits.

Geochemical Signature: Rock analyses may show Cu-Au-Ag-rich inner zones grading outward to Au-Ag zones with high Au:Ag ratio and outer Pb-Zn-Ag zone. Co-As-Sb-Bi may form anomalies in some skarn deposits. Magnetic anomalies.

Examples
Mason Valley, Victoria, Copper Canyon, Carr Fork, Red Dome, AUQL
Known deposits and mineral prospects in the CRA region

There are quite a few known occurrences of this type in the area. Typical examples of these are the magnetite skarn-associated copper deposits at Fine Flower, Fine Flour, Busy Bee, Wiley’s, Potato Cud, West Potato Cu, and Pluck Cu deposits. Other skarn-related prospects in the UNER include Pulganbar-Flintoff-Glamorgan; (associated with siliceous tourmaline veins) and Lantana Downs, May Queen Cu, & Paddy Dougherty Cu, and the Tabulam magnetite skarn (east of Drake). Also, there are hornfelsed Cu and Au occurrences at Solferino.

Assessment Criteria

1. Presence of granitoids associated with Cu-Au mineralisation or with a potential to host Cu-Au deposits.
2. Presence of suitable calc-magnesian rocks in proximity to granitoids with a potential to host Cu-Au deposits.
3. Presence of known occurrences of skarns, hornfels and skarn-related mineral occurrences.

Assessment

Tract CuAu2a/L-M/B
The tract includes zones where reactive calc-magnesian rocks lie within 5 km of granitoids that have a potential for hosting Cu-Au deposits. The tract is assessed as low to moderate because there are no economic skarn deposits known in the area, and because the occurrence of calc-magnesian rocks is generally irregular and intermittent with the potential host sequence.

Economic Significance

According to grade/tonnage models for copper skarn deposits, 90% of deposits contain at least 0.034 Mt of ore, 50% at least 0.56 Mt and 10% at least 9.2 Mt. In these types of deposits, 90% contain at least 0.7% Cu, 50% at least 1.7% Cu and 10% at least 4.0% Cu (Cox and Singer 1986).

Au4: Alluvial (Placer) Gold deposits(Model 39a of Cox and Singer 1986)

Model Description
Description after Warren E. Yeend.

Approximate Synonym:

Description: Elemental gold as grains and (rarely) nuggets in gravel, sand, silt, and clay, and their consolidated equivalents, in alluvial, beach, aeolian, 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: Cainozoic. 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): Tertiary 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, eg. 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 equidimensional 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, dykes, 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, rutile. Au nuggets have decreasing Ag content with distance from source.

Geophysical signature: Seismic methods define buried channels or deep leads.

Examples

- Sierra Nevada, Californía, USA
- Bendigo-Ballarat region, Vic, Australia

Known deposits and prospects in the CRA region

Placer deposits account for a significant portion of the gold produced in the New England region. About two thirds of this alluvial gold came from the Rocky River, Uralla and Nundle-Hanging Rock area to the south east of the UNER. The gold was recovered from Quaternary sediments along the Rocky River and its tributaries draining the Uralla Granodiorite (I-type), and Tertiary deep lead deposits preserved by overlying basalt lava flows, such as at Sydney Flat, Mount Beef and Bourkes Knob. The Sydney Flat workings were up to 60 metres deep. Together these deposits constitute the Rocky River Gold Field and a number of them were relatively rich in gold (Weber 1975).

In the UNER, gold has been won from basal conglomerates along the western edge of the Mesozoic Clarence Moreton basin, Tertiary deep leads, Quaternary river gravels along river channels and beach placer deposits. Significant alluvial gold production by hand sluicing and dredging came from Oban in the central south of the CRA region, Mann River/Glen Elgin and Timbarra River in the central part of the CRA region, and Clarence River/Tooloom in the central north of the CRA region (Barnes & others 1988).

Alluvial gold is associated with gold-quartz vein reefs in the Dalmorton field in the central east of the CRA region and further north in the Lionsville goldfield and at Tyringham, where recent and deep lead alluvial deposits also occur (Markham 1975b). The Lunatic goldfield in the north of the CRA and Coramba-Orara goldfield in the south of the CRA region are also source areas for alluvial gold.

At Tooloom alluvial gold deposits appear to be derived from local gold-quartz veins in Emu Creek Formation sediments/acid volcanics and nearby outcrops of gold bearing Jurassic conglomerate (Markham 1975b). Near Boonoo Boonoo, in the north west of the CRA region, gold-silver quartz veins in Stanthorpe Adamellite (I-type) may be the source for nearby alluvial gold (Weber 1975). Disseminated gold in the Stanthorpe and Bungulla Adamellites may have contributed gold to alluvial deposits in the Timbarra area (Resource and Conservation Assessment Council 1996). Further south, gold-quartz veins and Jurassic conglomerate (Laytons Range Conglomerate Member) were also gold sources for the nearby alluvial gold at Pretty Gully Gold Field and Paddy's Gully (Weber 1975).
Minor gold in the Kingsgate Granite (I-type) molybdenum-bismuth pipes (Weber 1975) may have contributed to alluvial gold deposits in the central part of the CRA region. The Wards Mistake Adamellite (I-type), and Kookabookra Adamellite (S-type) and especially the Oban River Leucomadamellite (I-type) appear to be the source of alluvial gold probably from gold bearing bismuth minerals in molybdenum-bismuth pipes. The only significant alluvial production has come from streams draining the Oban River Leucomadamellite (Weber 1975).

**Assessment Criteria**

1. Distribution of rocks containing, or with potential for other types of gold deposits.
2. Distribution of gold-bearing vein and other deposits.
3. Distribution of alluvial gold prospects and deposits.
4. Distribution of possibly gold bearing Clarence-Moreton Basin basaltic Jurassic conglomerate.
5. Distribution of Tertiary sediments deposited by ancient streams, rivers, lakes and swamps.
6. Distribution of Tertiary basalts concealing deep leads.
7. Distribution of Quaternary sediments deposited by ancient streams, rivers, lakes and swamps.
8. Streams, rivers, lakes and swamps with unmapped Quaternary sediments.

**Assessment**

**Tract Au4a/M-H/C**
This tract includes 100 metre buffers along streams, rivers, swamps, lakes, Quaternary sediments, Tertiary sediments and Tertiary lavas within 10 kilometres of known gold deposit clusters. Potential for economic Quaternary/Tertiary alluvial gold and deep lead deposits concealed beneath Tertiary basalt is considered to be moderate to high. Even though most alluvial gold areas have been worked in the past, modern technology may make some of these areas viable in future and allow access to deep lead deposits not previously mined. The certainty level is assessed at C.

**Tract Au4b/M/B**
This tract includes 100 metre buffers along streams, rivers, swamps, lakes, Quaternary sediments, Tertiary sediments and Tertiary lavas that occur in areas of potential alluvial gold source rocks as delineated by the tracts in the following models of this report:
- gold-antimony quartz veins
- disseminated gold in leucogranite
- epithermal gold
- molybdenum-bismuth-minor gold veins/pipes
- skarn/ironstone gold
- volcanic massive sulphide gold
- porphyry copper-gold

Potential is considered moderate with a certainty of B.

**Economic significance**

According to global grade and tonnage data these deposits are usually small. 90% of them have at least 0.022 Mt or ore, 50% at least 1.1 Mt and 10% have more than 50 Mt of ore (Cox and Singer 1986). The ores in 90% deposits contain at least 0.084 g/t gold, in 50% deposits the ores have at least 0.2 g/t gold and 10% deposits contain more than 0.48 g/t gold.

**Au5: Gold associated with massive sulphide mineralisation including gold in chert and jaspers**

**Model Description**
Description of the model by S. Jaireth.

**Approximate Synonym**: Gold-rich Noranda type, volcanogenic massive sulphide, felsic to intermediate volcanic type. Gold in chert and jaspers.
Description: Gold, copper, lead and zinc-bearing massive sulphide deposits in marine volcanic rocks of intermediate to felsic composition.


Geological Environment


Textures: Flows, tuffs, pyroclastics, breccias, bedded sediment, and in some cases felsic domes.

Age range: Archaean through Cainozoic.

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 grabens 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


Texture/structure: Massive (>60 percent 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: Toward 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 palaeo depressions in the seafloor. In Japan, best deposits have mudstone in 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, Fe.

Geophysical signature:

Examples

<table>
<thead>
<tr>
<th>Location</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rosebery, AUTS</td>
<td>Huston and Large 1988</td>
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<tr>
<td>Mt. Lyell, AUTS</td>
<td>Hills 1990</td>
</tr>
<tr>
<td>Hellyer, AUTS</td>
<td>McArthur and Dronseika 1990</td>
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<td>Mt Morgan, AUQL</td>
<td>Taube 1990</td>
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<tr>
<td>Britania, CNBC</td>
<td>Payne et al. 1980</td>
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</table>
Known deposits and Prospects in the CRA Region

There are several occurrences of this type. They are confined to the Coffs Harbour Block. In most of them gold mineralisation is in the form of stratabound concentrations hosted by chert, pyritic chert and jaspers. In several prospects stratabound mineralisation co-exists with epigenetic gold veins. In the Cod Hole prospect mineralisation is confined to a fractured chert horizon and is associated with introduced silica, pyrite and arsenopyrite (Keevers and Jones 1984 cited in Gilligan et al. 1992). In the Illabo gold mine, several stacked horizons of chert and jaspers extending for several hundred metres occur within mafic tuffs (Keevers and Jones 1984 cited in Gilligan et al. 1992). Here chert and jaspers are extensively fractured and flooded with ankerite, pyrite and sericite.

Gold bearing chert and epigenetic veins are in close spatial association with stratabound copper deposits. Hence tracts delineated for Cyprus style massive sulphide deposits also define the mineral potential tracts for gold associated with massive sulphide deposits.

However, because not all volcanic associated massive sulphide deposits host economic grade gold mineralisation the level of potential needs to be lower than that for massive sulphide deposits (the notion of conditional probability).

Assessment Criteria

1. Presence of rocks belonging to the ophiolitic assemblage consisting of mafic volcanic, volcaniclastic and volcanogenic sedimentary rocks formed in submarine environment. (Coffs Harbour Association, Sandon Association, Silverwood Association or Brooklana Beds, Coffs Harbour Beds, Coramba Beds, Cungleburg Creek Beds, Girakool Beds and Agnes Greywacke, Sandon Beds, Willowie Creek Beds).
2. Presence of subvolcanic intrusives.
3. Presence of known deposits and occurrences of volcanic associated massive sulphide mineralisation.
4. Areas with a potential for volcanic associated massive sulphide deposits.
5. Distribution of known deposit type and occurrences gold in chert and jaspers.

Assessment

Tract Au5a/M/C

The tract is similar to the tract BM1a/M/C for volcanic associated massive sulphide deposits because gold mineralisation is spatially and temporally associated with massive sulphide mineralisation. Both styles result from submarine volcanic hydrothermal systems. The tract is marked by the presence of chert and jaspers which are known to host gold mineralisation in the area. The tract also hosts all the known occurrences of gold of this type in the CRA region. Mineral potential of the tract is thus assessed to moderate with a certainty level of C.

Tract Au5b/L-M/B

The tract is similar to the tract BM1b/L-M/B for volcanic associated massive sulphide deposits. Although the tract does not contain known occurrences of gold or volcanic associated massive sulphide mineralisation, it is marked by an environment which is favourable for distal type volcanic massive sulphide mineralisation. Hence mineral potential of the tract is assessed to be low to moderate with a certainty level of B.

Economic Significance

There is limited grade and tonnage data about gold deposits associated with chert and jasper but volcanic associated massive sulphide deposits are known to be important sources for gold and silver. Global grade/tonnage models for this type of deposits indicate that 90% of these deposits have more than 0.12 Mt of ore, 50% have more that 1.5 Mt and 10% have more than 18 Mt. Similarly 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.
Sn3: Alluvial Tin deposits (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 streambeds.

**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 instance, 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 Palaeozoic to Cainozoic 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 (<8) 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 relation 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 rilles, 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 prospects in the CRA region**

The region hosts several important prospects and deposits of alluvial and deep lead tin, the most notable of which are at Emmaville which produced more than 6500 tonnes of cassiterite and Tingha (70000 tonnes of tin concentrate, Gilligan and Barnes 1990). Most placer concentrations are associated with
active watercourses. Cassiterite recovered from active watercourses is largely black, waterworn and fine to coarse. The cassiterite-bearing alluvials range in thickness from several centimetres to approximately ten metres. Their lateral extent ranges from several metres wide and tens of metres long, to deposits hundreds of metres wide and kilometres long (Brown and Stroud 1997). Frequently redistributed Tertiary wash or eluvium and broad areas of shallow wash beyond watercourses also contain significant accumulation of cassiterite. The distribution of cassiterite in alluvium varies between localities. In some places cassiterite is richest or restricted to particular layers, especially towards or at the base of the sequence. In other places it is developed throughout the alluvium from ‘grass roots’ to the base (Brown and Stroud 1997). Scant historical data indicate that some watercourses returned from several kg/m3 to 100 kg/m3.

The deep lead cassiterite deposits are overlain by basalt. In the Copeton Group of deep leads, two main levels of intrabasaltic alluvials containing cassiterite and diamonds were worked. The economic layers were overlain by subeconomic, fine-grained sandy layer. In the Tingha-Gilgai area deep leads range in depth from several metres to fifty metres. Most deep leads are capped by thick strongly weathered to fresh basalt, shallow to deep basaltic soil and in many places by surficial concretionary laterite/bauxite (Brown and Stroud 1997).

**Assessment Criteria**

1. Presence of rocks containing, or with a potential for, tin
2. Distribution of tin vein and greisen deposits.
3. Distribution of alluvial tin prospects and deposits.
4. Distribution of possibly tin bearing Clarence-Moreton Basin basal Jurassic conglomerate.
5. Distribution of Tertiary sediments deposited by ancient streams, rivers, lakes and swamps.
6. Distribution of Tertiary basaltic lavas concealing deep leads.
7. Distribution of Quaternary sediments deposited by ancient streams, rivers, lakes and swamps.
8. Streams, rivers, lakes and swamps with unmapped Quaternary sediments.

**Assessment**

**Tract Sn3a/M-H/C**
This tract includes 100 metre buffers along streams, rivers, swamps, lakes, Quaternary sediments, Tertiary sediments and Tertiary lavas within 10 kilometres of known tin deposit clusters (fields). Potential for economic Quaternary/Tertiary alluvial tin and deep lead deposits concealed beneath Tertiary basalt is considered moderate to high. Even though most alluvial areas have been worked in the past, modern technology may make some of these areas viable in future and allow access to deep lead deposits not previously mined. The certainty level is assessed at C.

**Tract Sn3b/M/B**
This tract includes 100 metre buffers around streams, rivers, swamps, lakes, Quaternary sediments, Tertiary sediments and Tertiary lavas that occur in areas of potential alluvial tin source rocks as delineated by the tracts for tin veins and tin greisens. Potential is considered moderate with a certainty of B.

**Fe1: Volcanic-hosted Magnetite (Model 25i of Cox and Singer, 1986)**

**Model Description**
Description of the model by Dennis P. Cox.

**Approximate Synonym:** Porphyrite iron, Kiruna iron.

**Description:** Massive concordant and discordant magnetite ore bodies in intermediate to alkaline volcanic rocks with actinolite or diopside alteration.

**Geological Environment**

**Rock types:** Andesitic to trachytic flows and subvolcanic intrusions, also at Kiruna, quartz porphyry, syenite porphyry, monzonite, and diorite.
Textures: Porphyrophanitic to fine- to medium-grained equigranular. Flows may be amygdaloidal.

Age range: Mesozoic to Holocene in circum-Pacific area. In Sweden and Missouri, 1,300-1,500 m.y.

Depositional environment: Continental volcanic rocks and clastic sediments intruded by subvolcanic intermediate plutons.

Tectonic setting(s): Continental margin, subduction-related volcanic terrane. Especially with high-K volcanic rocks, possibly related to waning stages of volcanism.

Associated deposit types: Sedimentary Fe in associated clastic rocks, apatite-magnetite deposits, hematite in quartz-sericite alteration, possible disseminated Au.

Deposit Description

Mineralogy: Magnetite + apatite. Rarely pyrite, chalcopyrite, chalcocite, and covellite. Ti is in sphene.

Texture/structure: Fine, granoblastic, skarn type textures.

Alteration: Actinolite or diopside, andradite, biotite, quartz, albite, andesine, K-feldspar, sodic scapolite, epidote; carbonates, and locally, tourmaline, sphene, chlorite, barite, fluorite, kaolin, or sericite.

Ore Controls: Magnetite in massive replacement, breccia filling and stockwork veins. Orebodies may be stratabound, concordant to intrusive contacts or in cross-cutting veins. Possibly related to cupolas of deeper plutons.

Geochemical and geophysical signature: Fe, P, V, and minor Ba, F, Bi, Cu, Co; strong magnetic anomalies.

Examples:
- Kirunavaara, Sweden Frietsch 1982, 1978
- El Romeral, Chile Bookstrom 1977
- Middle-Lower Yangtze Valley Research Group of Porphyrite Iron Ore 1977

Known Deposits and Prospects in the CRA Region

There are no known occurrences of this type in the CRA region. In the Tamworth Belt stratabound magnetite mineralisation is reported to be present within andesitic volcanic rocks. In the Croydon magnetite deposit, massive coarse grained magnetite with chlorite joint fills, interstitial and vein epidote and minor quartz veins is associated with Late Devonian Mostyn Vale Formation (Dpmx). The Mostyn Vale Formation consists of deep water marine sedimentary and volcanic rocks such as lithic wackes, and rhyodacitic to basaltic lavas and tuffs.

Assessment

Tract Fe1a/M-H/C
The tract includes rocks of the accretionary complex that are known to contain magnetite-rich units (Texas Beds), ironstones (Coffs Harbour Beds), magnetite-bearing chert or quartz-magnetite accumulations (Brookland Beds). These rocks also host all the known occurrences of volcanogenic magnetite in the CRA region. Mineral potential of the tract is assessed to be moderate to high with a certainty level of C

Tract Fe1b/L-M/B
The tract includes the rest of the rocks of the accretionary complex. Locally some units are magnetite rich and are interpreted to be related to skarns. Most rocks in this tract have a potential for volcanic associated massive sulphide and volcanogenic manganese deposits. As the formation of volcanogenic magnetite is closely related to the formation of volcanic associated massive sulphide and volcanogenic manganese, mineral potential of this tract is assessed to be low to moderate with a certainty level of B.
Economic significance

Although volcanic-hosted magnetite deposits are smaller in size that the banded iron formation, they often contain significant quantities of iron ores. Grade and tonnage data (Cox and Singer 1986) suggest that 10% of the deposits contain at least 450 Mt of ore, 50% at least 40 Mt and 90% at least 3.5 Mt. In 10% of the deposits ores have at least 64% iron and 0.92% phosphorus, 50% have at least 58% iron and 0.38% phosphorus and 90% have at least 38% iron and 0.13% phosphorus.

Cr: Podiform Chromite (MODEL 8a/8b of Cox and Singer 1986)

Model Description
By John P. Albers

Approximate Synonym: Alpine type chromite (Thayer 1964).

Description: Podlike masses of chromitite in ultramafic parts of ophiolite complexes.


Geological Environment

Rock Types: Highly deformed dunite and harzburgite of ophiolite complexes; commonly serpentinised.

Textures: Nodular, orbicular, gneissic, cumulate, pull-apart; most relict textures are modified or destroyed by flowage at magmatic temperatures.

Age Range: Pre-Late Carboniferous – Permian (?).

Tectonic Setting(s): Magmatic cumulates in elongate magma pockets along spreading plate boundaries. Subsequently exposed in accreted terranes as part of ophiolite assemblage.

Depositional Environment: Deep oceanic crustal rocks. Obducted ophiolite terrane?

Associated Deposit Types: Ultramafic hosted talc, chrysotile asbestos, lateritic /saprolitic nickel.

Deposit Description

Mineralogy: Chromite ± ferrichromite ± magnetite ± Ru-Os-Ir alloys ± laurite.

Texture/Structure: Massive coarse-grained, granular to finely disseminated.

Alteration: None related to ore.

Ore Controls: Restricted to dunite bodies in tectonised harzburgite or lower portions of ultramafic cumulate. Restricted to serpentinised ultrabasics.

Weathering: Highly resistant to weathering and oxidation.

Geochemical Signature: None recognised.

Examples

- Oakey Creek (Gordonbrook) Deposits MacNevin 1975a
- Thetford Mines Ophiolite Complex, Canada Kacira 1982

Known Deposits and Mineral prospects in the CRA region

The Gordonbrook Serpentinite Belt in the central parts of the Upper North East Region of NSW hosts about 30 small to moderate sized chromite deposits. It is interpreted as an obducted ophiolite terrane.
During tectonic thrusting, faulting and hydration the original chromite layers were disaggregated and boudinaged resulting in discontinuous chromite pods scattered throughout the serpentinite. As a result the serpentinite contains numerous small but high grade chromite deposits.

Assessment Criteria

1. Existence and extent of highly deformed ultramafic bodies.
2. The occurrence of a major fault in proximity to the ultramafic mass appears to be an important feature. Tectonically re-emplaced to form deposits of the podiform type.
3. Known chromite mineral occurrences.
4. Known Ni-Cr-PGE geochemical anomalies.

Assessment

Tract Cr/H/C
This tract is characterised by the presence of an ultramafic body consisting of serpentinite known as the Gordonbrook Serpentinite belt. It contains at least 6 known chromite deposits and a further 25 other prospects. There are significant Ni-Cr-PGE geochemical anomalies. The potential for further deposits of chromite is considered to be high with a certainty level of C.

Lst: Limestone

Model Description
Description of the model after D. Hora (1992).

Approximate Synonyms: Limerock, 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).


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 limestones and dolomites.

Deposit Description:

Mineralogy: Limestone is a sedimentary rock consisting of 50% or more of calcite (CaCO3) and dolomite (CaMg(CO3)2). There is a complete gradation from impure limestone to high calcium limestone (>95% CaCO3). In dolomites, 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. Maximum limitations of overburden extremely varied depending on the end use. Limestones are known to be mined underground even for uses like cement production.

Weathering: Weathering results in a variety of karst landforms in most climatic areas, but intensifies with warmer climate.

Geochemical signature:

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 the CRA Region

The CRA region hosts only a few minor deposits of limestone. These are: Four Mile, Tabulam and Plumbago Creek (hosted in calcareous beds the ?Emu Creek Formations), Tenterfield (Texas Beds) and Inglebar Creek and Purgatory Creek (hosted in calcareous rocks of the Willowie Creek Beds).

Assessment Criteria:

1. Presence of marine sedimentary rocks.
2. Presence of known occurrences of limestone and/or marble.

Assessment

Tract Lst1a/H/B
The tract is defined by the presence of known limestone quarries (The Four Mile, Tabulam and Plumbago Creek). The tract is considered to have a high potential for additional limestone/dolomitic limestone deposits with a certainty level of B.

Tract Lst1b/M/B
The tract is defined by rocks of the Willowie Creek Beds. The beds host two known limestone quarries but because the distribution of calcareous units in these beds could be erratic and irregular, mineral potential of the tract is assessed to be moderate with a low certainty level of B.

Economic Significance

Limestone/dolomitic limestone, like many other industrial minerals, have a low value per unit of volume but it is essential that they are accessible in large quantities close to urban areas for use in construction. Thus competing land uses are a constant pressure on the availability of these resources. Other uses are in agriculture, roads and fillers for paper and plastic.

Limestone/dolomitic limestone deposits usually need to be either outcropping or near surface to be economic to extract. Distance from markets is also an important factor in the viability of a limestone/dolomitic limestone deposit as transport makes up a substantial proportion of product costs.

Mn1: Volcanogenic Manganese (Model 24c of Cox and Singer 1986)

Model Description
Description of the model after Randolph A. Koski.

Approximate Synonym: Volcanogenic-sedimentary.
Description: Lenses and stratiform bodies of manganese oxide, carbonate, and silicate in chert associated with sedimentary and mafic volcanic rocks. Genesis related to volcanic (volcanogenic) processes.


Geologic Environment

Rock types: Chert, shale, sandstone, greywacke, jasper, tuff, basalt; chert, jasper, basalt (ophiolite); basalt, andesite, rhyolite (island arc); basalt, limestone; conglomerate, sandstone, tuff, gypsum.

Textures: White, red, brown, and green chert in thin-bedded or massive lenses, commonly with shale partings. Some of chert contains radiolarians.

Age range: Cambrian to Pliocene.

Depositional environment: Sea-floor hot spring, generally deep water: some in shallow water marine; some may be enclosed basin.

Tectonic setting(s): Oceanic ridge, marginal basin, island arc, young rifted marginal basins; all can be considered eugeosynclinal.

Associated deposit types: Kuroko massive sulphide deposits, Cyprus-style massive sulphide deposits, Besshi-style massive sulphide deposits.

Deposit description

Mineralogy: Rhodochrosite, Mn-calcite, hausmannite, braunite, neotocite, alleghenyite, spessartite, rhodonite, Mn-opal, manganite, pyrolusite, coronadite, cryptomelane, hollandite, todorokite, amorphous MnO2.

Texture/structure: Fine-grained massive crystalline aggregates, botryoidal, colloform in bedded and lensoid masses.

Alteration: Spilitic or greenschist-facies alteration of associated mafic lavas, silicification, hematization.

Ore controls: Sufficient structure and porosity to permit sub-sea-floor hydrothermal circulation and sea-floor venting; redox boundary at sea floor/seawater interface around hot springs; supergene enrichment to upgrade Mn content.

Weathering: Strong development of secondary manganese oxides (todorokite, birnessite, pyrolusite, amorphous MnO2) at the surface and along fractures.

Geochemical signatures: Although Mn is only moderately mobile and relatively abundant in most rocks, Mn minerals may incorporate many other trace elements such as Zn, Pb, Cu, and Ba.

Examples

Olympic Peninsula, USWA Park 1942, 1946; Sorem and Gunn 1967
Franciscan type USCA, USOR Taliaferro and Hudson 1943, Snyder 1978, Kuypers and Denyer 1979

Known Deposits and Prospects in the CRA Region

Known manganese deposits and prospects are developed as stratiform and locally discordant manganese oxide (rhodonite lenses interlayered with deep water marine sediments and mafic lavas (Brown and Stroud, 1997). Most common host rocks are: Woolomin Group (SDwx), Whitlow Formation (Cws); Texas beds (Ctx), Sandon beds (Csx), Neronleigh-Fernvale beds (Cnx), Willowie Creek beds, and Permian sediments (Px).

The deposits are generally hosted by jasper beds in which they form lenses, beds, laminae and nodules. Many manganese oxide deposits pass into rhodonite at depth (Brown and Stroud, 1997)
Assessment Criteria

1. Presence of deep marine sedimentary and volcanogenic sedimentary rocks in particular cherts and jaspers, indicative of submarine volcanic hydrothermal systems. For delineating tracts the following units have been selected: DOR-Csx; DOR-Cwm; GOO-Ctl; GRA-Px; GRA-SDwx; INV-Csx; INV-Csx+Pwev; INV-Ctx; INV-Csx; INV-Cws; MAC-Cnx. Also included are the Willowie Creek beds and Permian sediments.

2. Proximity to granitoids.

3. Presence of known occurrences.

Assessment

Tract Mn1a/M/C

The tract is similar to the tract BM1a/M/C for volcanic associated massive sulphide deposits because volcanogenic manganese mineralisation is spatially and temporally associated with massive sulphide mineralisation. Both styles result from submarine volcanic hydrothermal systems. The tracts include rocks of the accretionary complex such as jaspers, cherts and other mafic rocks (altered and/or metamorphic equivalents), indicative of submarine volcanic-hydrothermal systems. It also hosts all the known occurrences of manganese mineralisation. Mineral potential of the tract is assessed to be moderate with a certainty level of C.

Tract Mn1b/L-M/B

The tract is similar to the tract BM1b/L-M/B for volcanic associated massive sulphide deposits. Although the tract does not contain known occurrences of manganese or volcanic associated massive sulphide mineralisation, it is marked by an environment which is favourable for distal type volcanic massive sulphide mineralisation. Hence mineral potential of the tract is assessed to be low to moderate with a certainty level of B.

Economic significance

Volcanogenic manganese deposits are generally smaller than sedimentary deposits of manganese such as the Groote Eyland deposit in the Northern Territory but still represent important accumulation of manganese. Grade and tonnage data (Cox and Singer 1986) indicates that 10% of these deposits contain at least 0.91 Mt of ore, 50% at least 0.047 Mt and 90% at least 0.0028 Mt. In 10% of the deposits the ores have at least 49% manganese, 50% at least 42% and 90% at least 24% manganese.

CONMATAG and CONMATPV Construction Materials - aggregate and pavement materials

Model Descriptions


Definitions

Construction materials are naturally occurring, low unit value commodities which are generally exploited in bulk and with limited processing for use in civil construction. Transport costs contribute significantly to the delivered cost of construction materials and, therefore, it is important to obtain such materials as close as possible to markets. Increased transport costs associated with the need to use more distant resources result in increased raw material costs which are inevitably passed on to the consumer.

Approximate Synonyms

The term extractive resources is used as a synonym for construction materials. However, that term commonly includes structural clay/shale, which is specifically excluded from the present discussion because of striking differences in the nature of required material properties, mode of occurrence, evaluation and usage.

Various terms are used to describe construction materials depending on particle sizes, mode of occurrence, and end use specifications. Such terms include hard rock aggregate, coarse aggregate, crushed
and broken stone, rip rap, decorative aggregate, prepared road base, fine aggregate, construction sand, sand and gravel, river stone, and shingle. Note that some of these terms describe products (e.g., coarse aggregate, fine aggregate, construction sand) whereas others describe geology (e.g. gravel and sand) or a combination of geology and materials (e.g. hard rock aggregate).

Two of several broad classes of construction materials are discussed herein, namely aggregates and road pavement materials. These terms are used generically to emphasise broad product similarities and the properties of most common product of the class (e.g. concrete aggregate among coarse aggregates). This usage does not differentiate the varied product range currently produced in the region (e.g. sealing aggregate and railway ballast is not differentiated from coarse aggregate for use in concrete production). Product classes excluded from the discussion are armour stone (specialised product produced on a limited scale for specialised usage) and fill (too widely produced and too easily substituted to model easily).

For the Upper North East region, two separate but overlapping tracts have been determined, reflecting two separate but overlapping construction material models for these two broad classes of materials:
- CONMATAG for higher value aggregates.
- CONMATPV for moderate value road pavement materials.

These two models are described together as they have many features in common.

General References


Deposit Description

Coarse aggregate: The main types of hard rock crushed to produce coarse aggregate in the study area are basalt, greywacke, argillite, rhyolite, granitoids, and hornfels. Unconsolidated fluvial gravels are also processed to produce coarse aggregate.

Fine aggregate: Currently, most fine aggregate in the region is produced from friable quartz sandstone deposits. Quaternary fluvial deposits are also important sources, and locally, some sand is derived from Quaternary estuarine and marine barrier sand deposits.

Crushed rock pavement materials. Coarse aggregate producers generally also produce graded products that satisfy specifications for road pavement materials (e.g DGB20, DGS20 as specified by the Roads and Traffic Authority). Specifications for pavement materials are slightly less stringent than for coarse aggregate in some properties (e.g. wet/dry strength variation among coarse particles), exclude certain tests (e.g. alkali reactivity), and generally require the presence of fines (sand and silt size particles). This allows incorporation of some weathered or weak rock that would be excluded from coarse aggregate production. Lesser strength requirements also permit the crushing of some rocks that are not strong enough to serve as coarse aggregate (e.g. quartz sandstone of the Kangaroo Creek Sandstone) or would be otherwise unacceptable (e.g some weathered cherty rocks of the Neranleigh-Fernvale beds). Some of these materials require stabilisation through addition of lime or blending with other materials to pass specifications.

Natural pavement materials. Certain materials have been used in road pavement following ripping, but without processing other than (in some instances) stabilisation through addition of lime or blending with other materials. These include: laterite (ironstone) developed on the Kangaroo Creek Sandstone, coarse granite sand developed in the eluviated (A1) zone of certain granites (especially along the New England and Mount Lindsay Highways), rippable, weathered cherty rocks, (especially in the Neranleigh-Fernvale beds), and Tertiary gravels.

Known Deposits and Mineral Prospects in the CRA region

There are more than 2000 active, historic or identified potential construction material sites in the Upper North East region. Assessment of these is ongoing, and information is only available for some (generally the more important). The great majority of these were probably used to supply road making materials for older unsealed or poorer quality sealed roads. These materials would probably only qualify as fill materials by contemporary standards and not discussed further. Discussion herein is restricted to
aggregates (higher value materials) and road pavement materials (moderate value materials). The North Coast of NSW is an area of very high population growth and there is a strong and continuing demand for construction materials. Reconstruction of the Pacific Highway is currently placing considerable demands on the productive capacity of North Coast operators.

A list of the more important construction material deposits is given in Appendix E.

**Assessment Criteria:**

Geology is an important assessment criterion, because it strongly influences material properties, and the size and nature of deposits. However, geological maps commonly depict rock units identified by a variety of criteria including age and genetic association, and not just lithological character. Moreover equivalent products can sometimes be produced from diverse rock units. Further, available geological maps are broad-scale, and site selection may ultimately be dominated by local geological variations or other site factors such as landforms (e.g. controlling site workability) or weathering (e.g. controlling the cost of stripping). Therefore, regional geology is important in predicting resource potential, but needs to be used judiciously, and in conjunction with other factors such as markets, transport distance, access and site factors.

Distance from existing roads is an important criterion in assessing the development potential of any particular site. Transport to markets is generally by truck and therefore requires road linkage from the quarry to markets. Building new access roads is expensive, and may not be economically justified. Generally, larger quarries producing higher value products are more likely to warrant the construction of longer, better quality new roads. These considerations have been incorporated into a land access rating based on distance from existing roads. Gaining legal transport access to a site and appropriate development consent for any needed road development/upgrading are preconditions to developing suitable access roads to quarries. Thus upgrading of an existing road might be far easier than developing a new one, and this reinforces the importance of proximity to existing roads.

**Distance constraints - roads**

Roads are important for construction materials in several main ways:

- They provide transport routes to population centres where most construction materials are consumed
- Road density in a given area reflects the population density
- They are themselves major consumers of materials.

The AUSLIG Geodata road data set has been used for modelling. This road data set is classified as follows:

<table>
<thead>
<tr>
<th>Class</th>
<th>Description</th>
<th>Freeway, tollway or other major road with lanes in different directions separated</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Dual carriageway</td>
<td>Principal road Highway, regional and through road</td>
</tr>
<tr>
<td>2</td>
<td>Principal road</td>
<td>Connector and distributor road</td>
</tr>
<tr>
<td>3</td>
<td>Secondary road</td>
<td>Access, residential, local road</td>
</tr>
<tr>
<td>4</td>
<td>Minor road</td>
<td>Public or private roadway of minimum or no construction, not necessarily maintained</td>
</tr>
<tr>
<td>5</td>
<td>Track</td>
<td></td>
</tr>
</tbody>
</table>

The AUSLIG data set is a 1:250,000 scale data set and is not particularly comprehensive especially in recording minor roads and tracks. Nevertheless, in the absence of a more detailed data set it has been used as follows:

For the purposes of tract creation, the Pacific Highway has been reclassified from a Class 2 road to a Class 1 road. This reflects the importance of this road within the UNER and the fact that major upgrades of this road to Class 1 are currently being undertaken.
From experience with known deposits and their locations, each of the road classes has been buffered as follows:

<table>
<thead>
<tr>
<th>Class</th>
<th>Description</th>
<th>Buffered distance each side of road (metres)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Pacific Highway</td>
<td>4800</td>
</tr>
<tr>
<td>2</td>
<td>Principal road</td>
<td>2400</td>
</tr>
<tr>
<td>3</td>
<td>Secondary road</td>
<td>1200</td>
</tr>
<tr>
<td>4</td>
<td>Minor road</td>
<td>600</td>
</tr>
<tr>
<td>5</td>
<td>Track</td>
<td>300</td>
</tr>
</tbody>
</table>

The cost of road construction, and the difficulties in gaining road access to deposits further away from existing roads that these distances, would greatly reduce the likelihood of their development. Therefore suitable rock types further afield have all been rated as of low potential regardless of rock type. Within these buffered roads, potential has been determined by the underlying geology. An exception has been applied in both cases where an existing operation is outside these buffers, to allow for inadequacies of the existing road network data coverage.

**Distance constraints - existing deposits**

Material potential is highest for rock sequences with given physical characteristics adjacent to known deposits. There is also a major overall increase in material usage as high value aggregate deposits are often also highly prospective for lower value pavement materials. The reverse does not apply, i.e. the presence of an existing pavement material deposit or deposit of unknown or other type does not enhance the potential for aggregate near that deposit.

Buffer distances indicating increased potential around existing deposits have been determined as in the following table. It must be noted that the assignment on this basis to some extent is a recognition that limitations in the existing geological and roads data sets have not allowed for adequate modelling for some deposits due to spatial errors in geological boundaries, road location or deposit grid references. The presence of a deposit also implies that the correct geological requirements exist even though this may not be reflected in the known mapped geology.

<table>
<thead>
<tr>
<th>Deposit type</th>
<th>Buffered distance (metres)</th>
<th>CONMATAG potential</th>
<th>CONMATPV potential</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aggregate - Hard Rock</td>
<td>400</td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>Aggregate - Unconsolidated</td>
<td>400</td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>Armour Stone</td>
<td>400</td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>Road Pavement - Hard Rock</td>
<td>200</td>
<td>As determined by geological features</td>
<td>H</td>
</tr>
<tr>
<td>Road Pavement - Residual</td>
<td>200</td>
<td>As determined by geological features</td>
<td>H</td>
</tr>
<tr>
<td>Other or Unknown</td>
<td>200</td>
<td>As determined by geological features</td>
<td>H</td>
</tr>
</tbody>
</table>

**Geological features**

Given the locational constraints above, the geological factors which have been applied within the roads buffered areas are summarised in the following table:

<table>
<thead>
<tr>
<th>Description of geological unit</th>
<th>Rating Aggregate</th>
<th>Tract name /Potential/ Certainty</th>
<th>Rating Road pavement</th>
<th>Tract name/ Potential/ Certainty</th>
<th>Selection criteria</th>
</tr>
</thead>
</table>

<p>| | | | | | |
| | | | | | |</p>
<table>
<thead>
<tr>
<th>Sand and gravel (unconsolidated)</th>
<th>H</th>
<th>Conmatag/H/C</th>
<th>H</th>
<th>Conmatapv/H/B</th>
<th>Quaternary units rich in sands and gravels, not including units rich in fine muds i.e. Qa, Qa1, Qa2, Qac, Qb, Qal, Qam, Qap, Qaw</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coarse quartz sandstone, thick and friable and containing a large operating quarry in Ripley Road sandstone at Suffolk Park</td>
<td>H</td>
<td>Conmatag/H/C</td>
<td>H</td>
<td>Conmatapv/H/B</td>
<td>Graphic selection of subset from Ripley Road Sandstone</td>
</tr>
<tr>
<td>Contact metamorphosed sedimentary rocks. Older sedimentary rocks within 500m of a granite body</td>
<td>H</td>
<td>Conmatag/H/C</td>
<td>H</td>
<td>Conmatapv/H/B</td>
<td>Separate coverage prepared, (hornfels) comprising all pre Late Permian sedimentary rock sequences within 500m of granitoids</td>
</tr>
<tr>
<td>Specific coastal granites. Granitoid body at Valla.</td>
<td>H</td>
<td>Conmatag/H/C</td>
<td>L-M</td>
<td>Conmatapv/L-M/B</td>
<td>Selected by name</td>
</tr>
<tr>
<td>Tertiary volcanics, especially basalts. Many aggregate quarries are present in Tertiary basalts especially in the Tweed and Lismore regions</td>
<td>M-H</td>
<td>Conmatag/M-H/C</td>
<td>H</td>
<td>Conmatapv/H/B</td>
<td>All Tertiary except Tertiary sediments</td>
</tr>
<tr>
<td>Wandsworth Volcanic Group except Drake Volcanics</td>
<td>M-H</td>
<td>Conmatag/M-H/B</td>
<td>H</td>
<td>Conmatapv/H/B</td>
<td>Geological System = “Late Permian volcanics” excluding Drake Volcanics units</td>
</tr>
<tr>
<td>Accretionary complex rocks east of the Demon Fault including the Beenleigh block and Coffs Harbour block but excluding the Emu Creek block and Nambucca block</td>
<td>M-H</td>
<td>Conmatag/M-H/B</td>
<td>H</td>
<td>Conmatapv/H/B</td>
<td>Select Geological system = “Accretionary complex” with the graphic selection of a subset of units east of Demon Fault</td>
</tr>
<tr>
<td>Sand and gravel - specific Quaternary units</td>
<td>M</td>
<td>Conmatag/M/B</td>
<td>H</td>
<td>Conmatapv/H/B</td>
<td>Qu, Qx, Qe</td>
</tr>
<tr>
<td>Tract Description</td>
<td>Conmatag/L</td>
<td>Conmatag/L-M/B</td>
<td>Conmatag/L-M/B</td>
<td>Select by stratigraphic name</td>
<td></td>
</tr>
<tr>
<td>--------------------------------------------------------------------------------</td>
<td>------------</td>
<td>----------------</td>
<td>----------------</td>
<td>-----------------------------</td>
<td></td>
</tr>
<tr>
<td>Drake Volcanics</td>
<td>L-M</td>
<td>H</td>
<td>Conmatag/H/B</td>
<td>Drake Volcanics</td>
<td></td>
</tr>
<tr>
<td>Chillingham Volcanics. These dense felsic volcanics have been used for construction materials just to the north of the region in Queensland</td>
<td>L-M</td>
<td>L-M/B</td>
<td>H</td>
<td>Select by stratigraphic name</td>
<td></td>
</tr>
<tr>
<td>Kangaroo Creek Sandstone - rippable to fine sand in many places</td>
<td>L</td>
<td>Conmatag/L/B</td>
<td>H</td>
<td>Conmatag/H/B</td>
<td></td>
</tr>
<tr>
<td>Tertiary sediments excluding fine sands</td>
<td>L</td>
<td>Conmatag/L/B</td>
<td>M-H</td>
<td>Conmatag/M-H/B</td>
<td></td>
</tr>
<tr>
<td>Ripley Road Sandstone except for at Suffolk Park (see above)</td>
<td>L</td>
<td>Conmatag/L/B</td>
<td>M</td>
<td>Conmatag/M/B</td>
<td></td>
</tr>
<tr>
<td>Bundamba Group except for Ripley Road sandstone - contains units rich in sands and gravels</td>
<td>L</td>
<td>Conmatag/L/B</td>
<td>L-M</td>
<td>Conmatag/L-M/B</td>
<td></td>
</tr>
<tr>
<td>Leucogranites. In places these units are deeply weathered and covered with thick sandy material</td>
<td>L</td>
<td>Conmatag/L/B</td>
<td>M</td>
<td>Conmatag/M/B</td>
<td></td>
</tr>
<tr>
<td>All granites except leucogranites and excluding Hillgrove suite and related granites</td>
<td>L</td>
<td>Conmatag/L/B</td>
<td>L-M</td>
<td>Conmatag/L-M/B</td>
<td></td>
</tr>
<tr>
<td>New England Batholith excluding Hillgrove suite and associated rocks and leucogranites</td>
<td>L</td>
<td>Conmatag/L/B</td>
<td>L</td>
<td>Conmatag/L/B</td>
<td></td>
</tr>
<tr>
<td>All other rock inside road buffer except near existing deposit</td>
<td>L</td>
<td>Conmatag/L/B</td>
<td>L</td>
<td>Conmatag/L/B</td>
<td></td>
</tr>
<tr>
<td>Rocks outside of roads buffer except where near existing deposit</td>
<td>L</td>
<td>Conmatag/L/B</td>
<td>L</td>
<td>Conmatag/L/B</td>
<td></td>
</tr>
</tbody>
</table>

**Tract descriptions**

- **Drake Volcanics**: L-M Conmatag/L-M/B H Conmatag/H/B Select by stratigraphic name. Drake Volcanics.
- **Chillingham Volcanics**: L-M L-M/B H Conmatag/H/B Select by stratigraphic name.
- **Kangaroo Creek Sandstone**: L Conmatag/L/B H Conmatag/H/B Select by stratigraphic name.
- **Tertiary sediments**: L Conmatag/L/B M-H Conmatag/M-H/B Geological system = “Tertiary sediments” excluding TT units.
- **Ripley Road Sandstone**: L Conmatag/L/B M Conmatag/M/B Select by stratigraphic name.
- **Bundamba Group**: L Conmatag/L/B L-M Conmatag/L-M/B Select by stratigraphic name.
- **Leucogranites**: L Conmatag/L/B M Conmatag/M/B Geological system = New England Batholith Leucogranites.
- **All granites**: L Conmatag/L/B L-M Conmatag/L-M/B New England Batholith excluding Hillgrove suite and associated rocks and leucogranites.
- **All other rock**: L Conmatag/L/B L Conmatag/L/B
- **Rocks outside of roads**: L Conmatag/L/B L Conmatag/L/B
### CONMATAG

<table>
<thead>
<tr>
<th>Tract name</th>
<th>Potential/Certainty</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conmatag/H/C</td>
<td>C</td>
<td>Sand and gravel (unconsolidated)</td>
</tr>
<tr>
<td></td>
<td>H</td>
<td>Coarse quartz sandstone, thick and friable and containing a large operating quarry in Ripley Road sandstone at Suffolk Park</td>
</tr>
<tr>
<td></td>
<td>C</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>Specific coastal granites. Granitoid body at Valla</td>
</tr>
<tr>
<td>Conmatag/M-H/C</td>
<td>C</td>
<td>Tertiary volcanics, especially basalts. Many aggregate quarries are present in Tertiary basalts especially in the Tweed and Lismore regions</td>
</tr>
<tr>
<td></td>
<td>H</td>
<td>Wandsworth Volcanic Group except Drake Volcanics</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>Accretionary complex rocks east of the Demon Fault including the Beenleigh block and Coffs Harbour block but excluding the Emu Creek block and Nambucca block</td>
</tr>
<tr>
<td>Conmatag/M/B</td>
<td>B</td>
<td>Sand and gravel - specific units</td>
</tr>
<tr>
<td>Conmatag/L-M/B</td>
<td>B</td>
<td>Drake Volcanics</td>
</tr>
<tr>
<td>Conmatag/L/B</td>
<td>B</td>
<td>Kangaroo Creek Sandstone - rippable to fine sand in many places</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tertiary sediments excluding fine sands</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ripley Road Sandstone except for at Suffolk Park (see above)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bundamba Group except for Ripley Road sandstone - contains units rich in sands and gravels</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Leucogranites. In places these units are deeply weathered and covered with thick sandy material</td>
</tr>
<tr>
<td></td>
<td></td>
<td>All granites except leucogranites and excluding Hillgrove suite and related granites</td>
</tr>
<tr>
<td></td>
<td></td>
<td>All other rock inside road buffer except near existing deposit</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rocks outside of roads buffer except where near existing deposit</td>
</tr>
</tbody>
</table>

### CONMATPV

<table>
<thead>
<tr>
<th>Tract name</th>
<th>Potential/Certainty</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conmatpv/H/B</td>
<td>B</td>
<td>Sand and gravel (unconsolidated)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Coarse sandstone baked by overlying Tertiary basalt and contain large operating quarry in Ripley Road sandstone at Suffolk Park</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Contact metamorphosed sedimentary rocks. Older sedimentary rocks within 500m of a granite body</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tertiary volcanics, especially basalts. Many aggregate quarries are present in Tertiary basalts especially in the Tweed and Lismore regions</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Wandsworth Volcanic Group except Drake Volcanics</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Accretionary complex rocks east of the Demon Fault including the Beenleigh block and Coffs Harbour block but excluding the Emu Creek block and Nambucca block</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sand and gravel - specific units</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Drake Volcanics</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Chillingham Volcanics. These dense felsic volcanics have been used for construction materials just to the north of the region in Queensland</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Kangaroo Creek Sandstone - rippable to fine sand in many places</td>
</tr>
<tr>
<td>Conmatpv/M-H/B</td>
<td>B</td>
<td>Tertiary sediments excluding fine sands</td>
</tr>
<tr>
<td>Conmatpv/M/B</td>
<td>B</td>
<td>Ripley Road Sandstone except for at Suffolk Park (see above)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Leucogranites In places these units are deeply weathered and covered with thick sandy material</td>
</tr>
<tr>
<td>Conmatpv/L-M/B</td>
<td>B</td>
<td>Specific coastal granites. Granitoid body at Valla</td>
</tr>
<tr>
<td>Conmatpv/L/B</td>
<td>B</td>
<td>All other rock inside road buffer except near existing deposit</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rocks outside of roads buffer except where near existing deposit</td>
</tr>
</tbody>
</table>
REFERENCES for Appendix B


Bookstrom A.A. 1977. The magnetite deposits of El Romeral, Chile. Economic Geology 72, 1101-1130.


Kacira 1982. Chromite occurrences of the Canadian Appalachians; The Canadian Institute of Mining and Metallurgy 75, 73-82


