a Appendices

APPENDIX 1: BIBLIOGRAPHY AND LIST OF REFERENCES

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APPENDIX 2: MINERAL AND PETROLEUM DEPOSIT MODELS

A2.1 Coal and Petroleum

Coal

Model Description: Coal measures.

Rock Types: Coal measures interbedded with various terrestrial and marine sedimentary sequences. Conglomerate, sandstone, siltstone, claystone, carbonaceous claystone and coal. Igneous rocks may intrude sequence.

Age Range: Devonian to Tertiary.

Depositional Environment: Peat swamps behind coastal barrier systems or within structural depressions further inland; swamps and peat bogs associated with and marginal to alluvial fans and deltaic plains; fluvial flood plains; lacustrine; and lagoonal. Depositional environment must be free from frequent incursions of clastic sediments or oxygenated waters, thus are generally low energy, anoxic and fresh to brackish **(Figure A-A)**.

Tectonic Setting: Small rifts and valleys, marginal and intracontinental sedimentary basins. Coal deposition is generally closely related to marine transgression and/or regression. Deposits are dominantly terrestrial, with marine influence common.

Associated Deposit Types: Oil shale, kaolin, bentonite, fullers earth, petroleum, coal seam methane (CSM).

Mineralogy/Composition: Coal composition varies depending on depositional environment and extent of coalification:

- brown coal - moisture content 50-70%, dry weight 60-75% carbon
- bituminous coal - moisture content 5-10%, dry weight 80-90% carbon
- anthracite - moisture content 2-5%, dry weight 90-95% carbon

Dominant components of coals are macerals and ash. Macerals are the organically derived components of coal. The major components of coal ash are silicate and sulfide minerals.

Texture/Structure: Generally laterally continuous seams. Can have various textures relating to sedimentary processes such as fluvial channels or marine incursion. Differing environments of deposition and subsequent decay and decomposition of plant material can also result in different lithotypes and banding within seams. Jointing in deformed coals.

Ore Controls: Limits of sedimentary basins; deformation subsequent to coalification; faults in basement; local structure; and differential compaction of coal seams may influence location of depocentres.

Examples: Gippsland Basin, Victoria; Sydney Basin, New South Wales; Bowen Basin, Queensland.

Economic Significance: Coal supplies a significant proportion of the world's energy needs. The Sydney-Bowen basin system in eastern Australia is one of the world's most prolific coal provinces, with past production and remaining resources amounting to well over several trillion dollars A$2003. Economic resources in these basins range from a few million to over ten billion tonnes of coal of varying quality and uses.

Special Assessment Criteria for Coal

Coal resource deposits differ markedly from most other mineral deposits in that they have a relatively low dollar per tonne ratio, are suitable for relatively large scale operations, are generally in relatively flat lying strata and hence involve a large aerial extent of the land surface. The mining potential of a coal resource is dependent on a large number of factors but there are five characteristics that can be used to provide an initial assessment potential. They are: depth; seam thickness; coal quality; lateral continuity; and constraints to mining.

Depth: The Department of Mineral Resources considers that for the foreseeable future, the maximum depth for the economic underground mining of thermal coals to be 600 metres.

Seam Thickness: In determining an open cut coal resource, the Department of Mineral Resources considers the minimum economic seam thickness to be 0.3 metres and the maximum coal to overburden linear ratio to be 1:10. For an underground resource, the Department considers the minimum economic seam thickness to be 1.5 metres. However, most longwall operations require a minimum working section of 1.8-2.0 metres for economic viability.

Coal Quality: Coal quality involves many coal characteristics that affect its end use and value. The first significant property is the raw ash content, that is, the percentage of non-combustible matter (ash) within the seam or working section. A raw ash of 35% is generally considered the maximum for an underground or open cut coal resource however higher ask coals may also be mineable in some circumstances. Coal quality can be upgraded by washing out the rock material to lower the ash content of the coal and some seams respond better to this process than others. Typical utilisation categories for coal based on ash percentage are set out below.

Lateral Continuity: The lateral continuity determines the extent of the mineable deposit and is primarily established by points of observation (usually boreholes). Confidence in the assessment is largely dependent on the distance between points of observation.

Table A-A. Typical utilisation categories for coal based on ash %

Raw Coal Ash % (a.d.)	Utilisation Category
<15%	Prime Export (Thermal, PCI, Coking)
15% to 20%	Prime Export and Standard Export (beneficiated)
	Domestic Thermal (raw and beneficiated)
20% to 30%	Domestic Thermal, Cement Manufacture (raw)
>30%	Cement Manufacture (raw)

Constraints to Mining: External factors may also place constraints on where mining can take place. These may be geological such as faults or igneous intrusions, topographical such as proximity to cliffs, rivers, dams and lakes, economic such as transport, industrial and agricultural infrastructure, environmental such as National Parks or other conservation reserves, or social such as proximity to dwellings.

The industry has a clearly defined code for reporting coal resources to the market, referred to as the JORC (Joint Ore Reserve Committee) code (Joint Ore Reserves Committee 1999). This categorises and assigns a specific status to a coal deposit. The categories are: Coal In Situ; Coal Resources; and Coal Reserves.

Coal In Situ includes any occurrence of coal in the Earth's crust which can be estimated and reported, irrespective of thickness, depth, quality, mineability or economic potential; and by definition, includes all Coal Resources.

Coal Resource is that part of the Coal In Situ category in such form and quantity that there are reasonable prospects for eventual economic extraction. A Coal Resource must be reported in terms of Inferred, Indicated or Measured status, depending on specific levels of confidence based on information gathered from points of observation that may be supported by interpretive data (such as aeromagnetic surveys). Trends may be extrapolated from Points of Observation up to two kilometres for Inferred Resources; one kilometres for Indicated Resources; and 500 metres for Measured Resources.

Coal Reserve is the economically mineable part of a Measured or Indicated Coal Resource at the time of reporting. It includes diluting materials and allowances for losses that may occur when the coal is mined. Coal Reserves are further categorised again depending on levels of confidence as Probable, Proved and Recoverable and then, depending on washing or other preparation as Marketable (Probable and Proved).

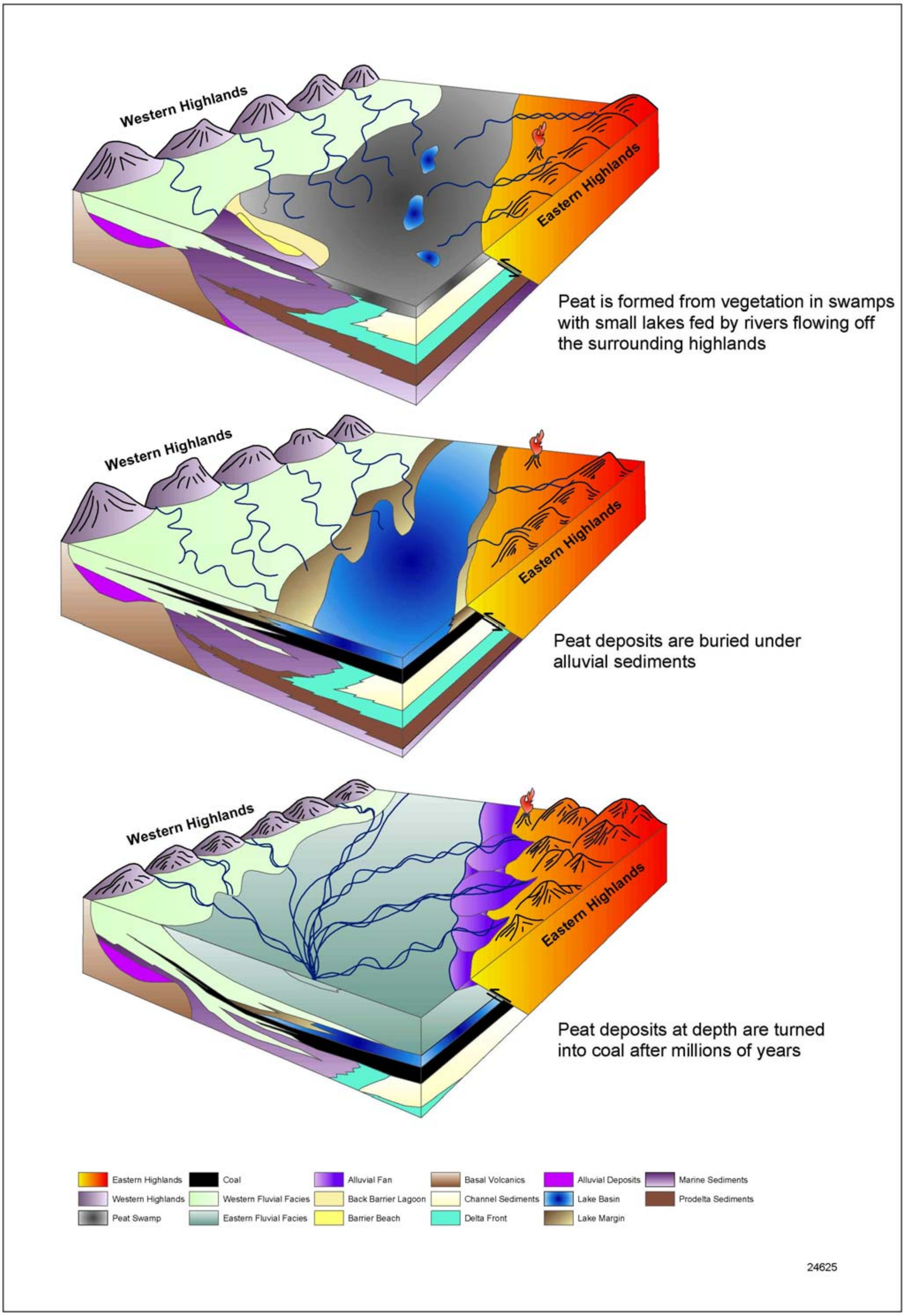

Figure A-A. Generalised model of coal formation for the Nandewar study area (modified after Tadros 1993).

Coal Seam Methane

Model Description: Coal seam methane (CSM).

Approximate Synonyms: Seam gas, coal bed methane, natural gas, biogenic gas.

Description: Coal and carbonaceous rocks within the coal measure sequences are the source rocks and the reservoirs for CSM.

General References: N/a.

Rock Types: Coal seams interbedded with conglomerate, sandstone, siltstone, and claystone.

Age Range: Carboniferous to Tertiary (within the Nandewar study area).

Depositional Environment: Deltaic, paludal, lacustrine and fluvial.

Tectonic Setting: Intracontinental, extensional sedimentary basin. Within the Nandewar study area thrusting, faulting and folding commenced in the Early Permian and continued periodically into the Triassic. Later folding and faulting in the Tertiary provided structural highs and lows with most of the coals being subjected to localised heating and permeability enhancement. Main plays in area where Gunnedah Basin is overthrust by New England Fold Belt **(Figure A-B)**.

Associated Deposit Types: Coal, peat, oil shale, conventional gas.

Composition: Gas composition comprises methane, ethane and minor other hydrocarbons, with varying amounts of carbon dioxide, and nitrogen. Reservoir and source rocks are coal seams.

Primary Reservoir Targets: Limits of the main sedimentary basin with sufficient cover to provide lithostatic pressure to confine gas (a minimum of 100 metres). Maximum depth for production operations is currently at 1200 metres.

Examples: Camden, Narrabri (Bohena) New South Wales; Powder River Basin, United States of America.

Economic Significance: CSM has come into the fore of late (in the last ten years) when the United States of America started to produce and supply around 15% of the gas requirements of the country. CSM has also broken through in Australia and the industry has come of age with Queensland and New South Wales spearheading all the efforts. It is projected that CSM will be a cleaner and more environmentally friendly source of energy within the next ten years.

Special Assessment Criteria for Coal Seam Methane

CSM is the natural gas formed during the coalification process whereby peat and other organically rich sediments are transformed into coal, as a consequence of compaction and heat associated with the processes of on-going deposition and burial. CSM is essentially similar to natural gas found in conventional sedimentary reservoirs, although it is generally higher in methane concentration. However, unlike conventional natural gas reservoirs, where gas is trapped in the pore or void spaces of a rock, such as sandstone, methane trapped in coal is adsorbed onto the coal grain surfaces or micropores of the coal and is held in place by reservoir (water) pressure.

The coal therefore acts as a source, reservoir and seal for the methane and as such is to be distinguished from a conventional gas accumulation within a sandstone reservoir rock. Because the micropore surface area is very large, coal can potentially hold significantly more methane per unit volume than most conventional reservoirs such as sandstone. CSM is generally regarded as an unconventional source of natural gas, and is distinguished from conventional gas which is produced from reservoir rocks that are typically not the origin of the gas.

In New South Wales, exploration activity has been carried out for some years in the Gunnedah Basin and in the Sydney Basin, further to the south. The potential for CSM is not governed exclusively by the presence of coal (Vanibe 2000). In order to establish viable, commercial production it is necessary to evaluate the coal seams in order to establish their potential to produce adequate gas volumes on production. The general criteria relevant to the successful discovery and development is as follows:

Areal Extent: This depends on the permeability and gas content and varies from area to area. Typically a producing field would comprise at least 250 wells at an 80 acre (approximately 32 hectare) spacing, requiring between 80 and 100 km^2, depending upon site conditions.

Ash: A low ash content is generally better for CSM recovery. Coals with high (incipient, or detrital) ash content tend to have fewer fractures. Fractures can be filled to varying amounts with 'mineral matter' and such mineral matter can also contribute to the ash content of the coal. Coals with high ash content also tend to have less adsorbed gas by volume.

Depth: In general terms, coal seams in the range of 250 metres to 1200 metres in depth are favoured for CSM production, otherwise overburden pressures are either too small or too great.

Cleat: Cleat is a fracture, or fracture system, developed in coal. Face cleat is the fracture system developed parallel to bedding, and butt cleat is the fracture system at right angles to the bedding. Good cleat development is generally more common in coals with high vitrinite and bright clarain. High cleat density is related to higher permeability.

Structuring: CSM prospectivity is enhanced when the coal seam has extensive lateral continuity. Significant fault displacement can restrict production potential from a coal reservoir. The dislocation of the reservoir into small unconnected or poorly connected blocks causes this. In some cases faulting can act to permit the escape of methane from the coal, which is deleterious for CSM reservoirs but could allow migration of methane to another reservoir, such as a conventional gas-in-sandstone reservoir. In this respect, there might be an inverse relationship between CSM and conventional oil and gas prospectivity in such areas. The presence, frequency, orientation and intensity of folds, faults, joints, and cleats influence the permeability and continuity of a coal reservoir. The presence of a tensional structural regime is preferred to enhance production potential, because such a regime favours dilation of cleats and hence facilitates greater permeability.

Density: There is a preference for coals, which have low bulk density or specific gravity. Specific gravities of less than 1.45 grams per cubic centermetre are generally regarded as being more suitable for CSM prospectivity, whereas coals with densities of greater than 1.0 gram per cubic centermetre have lower prospectivity.

Igneous Intrusions: Igneous intrusions can affect the composition of the gas in the coal reservoir by raising the proportion of carbon dioxide present. In some areas, the thermal maturity of the coals present may be altered, the consequences of which can be either favourable or unfavourable.

Insitu Stress: This is expressed in terms of effective stress, and is a major control on the cleat and fracture dilation and consequently coal seam permeability. Low effective stress favours good permeability.

Permeability: Permeability is a fundamental parameter for CSM production. Ideally, this should be greater than five millidarcies, but sometimes permeability values as low as one millidarcy can yield satisfactory gas flows.

Reservoir Pressure: Generally, depths below 250 metres are required to develop the hydrostatic pressure to ensure the gas is held adsorbed onto the coal, and also to promote production from the wells. If the pressure is low then a considerable amount of gas may have been lost.

Overpressuring: Although not prevalent in Australia, it is important because well completion techniques have been developed in the United States of America to produce gas from overpressured reservoirs.

Seam Thickness: Generally, the preferred values for coal seam and reservoir thickness are greater than ten metres for single and closely spaced completions, and greater than 15 metres for multiple completions.

Thermal Maturity: The maturation of the coal should be in the range of Ro of 0.7 to 2.0% vitrinite reflectance. Peak maturity for CSM is around 1.2%.

Petroleum (includes Conventional Gas)

Model Description: Petroleum.

Approximate Synonyms: Hydrocarbon accumulations, petroleum reservoirs, petroleum fairways, oil and gas reserves, petroleum system.

Description: In an ideal sedimentary basin there exists all the elements that constitute a petroleum system: source; reservoir; seal; traps; and optimum thermal and migration conditions **(Figure A-B)**.

General References: United States Geological Survey.

Geological Environment: Marine sediments interspersed with either extensive sandstone sequences or carbonate reefs involved in either dynamically tectonic regime or passive sedimentary.

Rock Types: Shales (seal and source), sandstones (reservoir), limestone reefs (reservoir).

Age Range: Palaeozoic to Tertiary.

Depositional Environment: Marine, deltaic, paludal, lacustrine and fluvial.

Tectonic Setting: Extensional regime with associated marine deposition, followed by thrusting, faulting and folding.

Associated Deposit Types: Coal seam methane (CSM) and Oil shale.

Composition: Oil and gas composition comprises various hydrocarbons, carbon dioxide, nitrogen and helium.

Examples:

Type	World Class	Australian Example
Structural:	Minas (Indonesia)	Barracouta (Gippsland)
Stratigraphic:	Tengiz (Kazakhstan)	Wandoo (NW Shelf)
Combination	Ampa (Brunei)	Goodwyn (NW Shelf)

Economic Significance: Conventional petroleum is one of the most valuable commodities in the world. Single accumulations can vary from five million barrels to three billion barrels for oil and 500 billion cubic feet to 25 trillion cubic feet for gas. Depending on the location and proximity to existing pipelines, economic sizes can start from five million barrels (onshore) to 100 million barrels (deep water offshore). Petroleum is still a major political agenda in any country and the securing of supply and reserves has always been critical to the nation's economy.

Special Assessment Criteria for Petroleum

The principles of conventional oil and gas prospectivity outlined in Upstream Petroleum Consulting Services (2002a, 2002b) and Vanibe (2000), are used to assess conventional petroleum resources.

Most sedimentary rocks contain some organic material, although not all rocks are capable of generating petroleum. Typically, rocks capable of generating conventional petroleum have at least 0.5% and preferably more than 1.0%, total organic carbon content. Coals and fine-grained sedimentary rocks, such as shales and siltstones, are the most common rock types containing sufficient organic material to constitute potential petroleum source rocks.

When subjected to appropriate depths of burial (associated with increased temperature), and for sufficient time, source rocks will generate and expel liquid or gaseous hydrocarbons. These hydrocarbons move through the microscopic voids in rocks under the influence of buoyancy and congregate in traps where their further movement is impeded by permeability barriers. Structural traps typically are associated with anticlines or faulting.

The most prospective traps involve very porous and permeable rock types (reservoirs), such as sandstone, in which significant quantities of petroleum may be contained. Seismic reflection surveys are used by explorers to image potential traps in the subsurface so that they may subsequently be drilled to test whether they contain petroleum bearing reservoirs. Unlike CSM, expelled conventional oil and gas may move tens of kilometres under the influence of buoyancy (a process called migration) out of the deep basin areas in which they were generated and across the flanks of adjoining structural highs.

A pod of actively generating source rock (kitchen area) and all related oil and gas, together with all of the essential elements and processes needed for oil and gas accumulations is referred to as a petroleum system. The occurrence of genetically related oil and gas accumulations implies that migration pathways exist, either now or in the past, connecting the kitchen with the accumulations. The goal of the explorer is to use seismic data, well data and other geophysical data, to map and delineate specific petroleum systems in order to locate undiscovered petroleum.

Traps are described as prospects or leads, depending upon the degree of confidence of their delineation. Typically the play fairway comprises a group of areally defined prospects and leads, which share similar or common trap type, seal, reservoir, and petroleum source within a petroleum system. Thus they share common elements of exploration risk relating to the possible occurrence of oil and gas. Exploration strategies are geared to targeting specific traps in a play fairway and previous exploration results in a specific fairway reflect the geological risk associated with that play type.

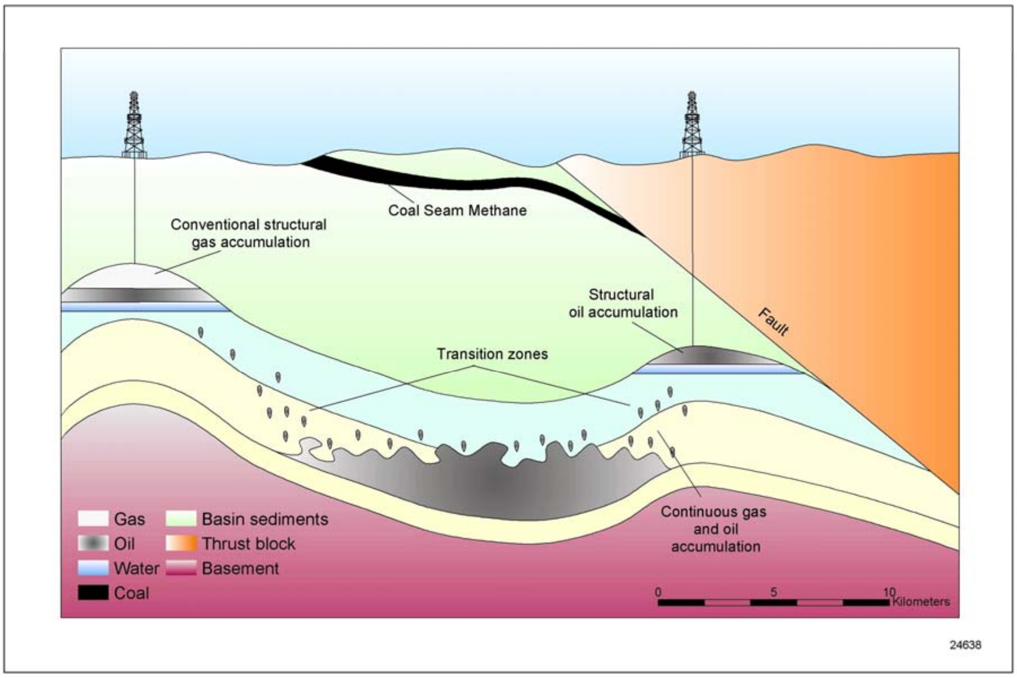

Figure A-B. Generalised model of gas and petroleum formation, Nandewar study area (modified after Shenk & Pollastra, 2002)

A2.2 Industrial Minerals and Construction Materials

Magnesium

Magnesium resources within the Nandewar study area are localised to the large resource present in mine tailings at the Woodsreef Asbestos mine. A detailed deposit model is therefore not presented here. Further discussion of the potential for magnesium in the Nandewar study area is contained within **Appendix 3**.

Primary Diamond

Model Description: Barron et al. (1996).

Description: Subduction diamond model.

General References: Barron et al. (1996), Davies et al. (2002).

Rock Types: Basanite, nephelinite, leucitite, melilitite, alkali basalt (?).

Textures: Fine grained to brecciated with inclusions of rocks from mantle, basement and overlying sequences.

Age Range: Most productive pipes worldwide are 80-100, 250, and 1,000-1,100 Ma in age, however eastern Australia alluvial diamonds exhibit two interpreted ages: Permo-Carboniferous, and pre-Cambrian age (Davies et al. 2002).

Depositional Environment: Mafic poor arc volcanics, lawsonite blueschists, and eclogite, with diamonds brought to surface by entrainment in ascending magmas. Diamonds in eclogite lenses. Regionally associated with blueschist eclogite belts and arc volcanics, leucocratic latite.

Tectonic Setting: Cratonic margin over palaeosubduction zone. Major structures. Associated with termination of subduction. In the New England Fold Belt sources inferred to intrude folded cover rocks that overlie terminated subducted slabs. Sources may occur at intersections and/or regional zones of weakness. There may also be an older association with deformed cratonic margins (Davies et al. 2003), or older decoupled lithospheric mantle sources now largely eroded. Sources in deformed margins are not correlated with orogenic events but occur in areas of epeirogenic warping or doming and along major basement fracture zones **(Figure A-C)**.

Associated Deposit Types: Alluvial diamond placers and deep leads.

Mineralogy: Diamond, garnets (orange, pink, brown) with elevated Na_2O, high K_2O pyroxene**.**

Texture/Structure: Diamonds are sparsely disseminated as phenocrysts or xenocrysts (mined kimberlites yield 0.1-0.6ppm diamond).

Alteration: N/a.

Ore Controls: Sources are rare and, at present, can only be identified by their diamond content. Regionally intersecting structures important. Major structures.

Weathering: Breccia sources may be weathered easily.

Geochemical Signature: Cr, Ti, Mn, Ni, Co, PGE, Ba. Anomalous Ni, Nb, and heavy minerals pyrope, garnet, phlogopite, and Mg-ilmenite indicate nearby pipes. Subduction model extends mineral indicators to emphasise high sodium garnets, and possibly include corundum (Barron et al. 1996).

Examples: Copeton, New South Wales (MacNevin 1977); Kazakstan (Davies et al. 2002); Kamchatcka (L. Barron Department of Mineral Resources, pers. comm. 1993).

Economic Significance: Grade and size characteristics of subduction related diamond deposits are not available. Subduction related diamond deposits are not currently considered as economically important as kimberlite or lamproite deposits, which vary from one to 350 million tonnes, and with values to many billions of dollars. Grades in these diatremes are usually 20 to 100 metric carats per 100 tonne (Argyle 650 metric carats per 100 tonne). Most economic deposits contain greater than 30% gem quality, worth tens to hundreds of dollars per metric tonne with industrial grades worth less than a few tens of dollars per metric tonne.

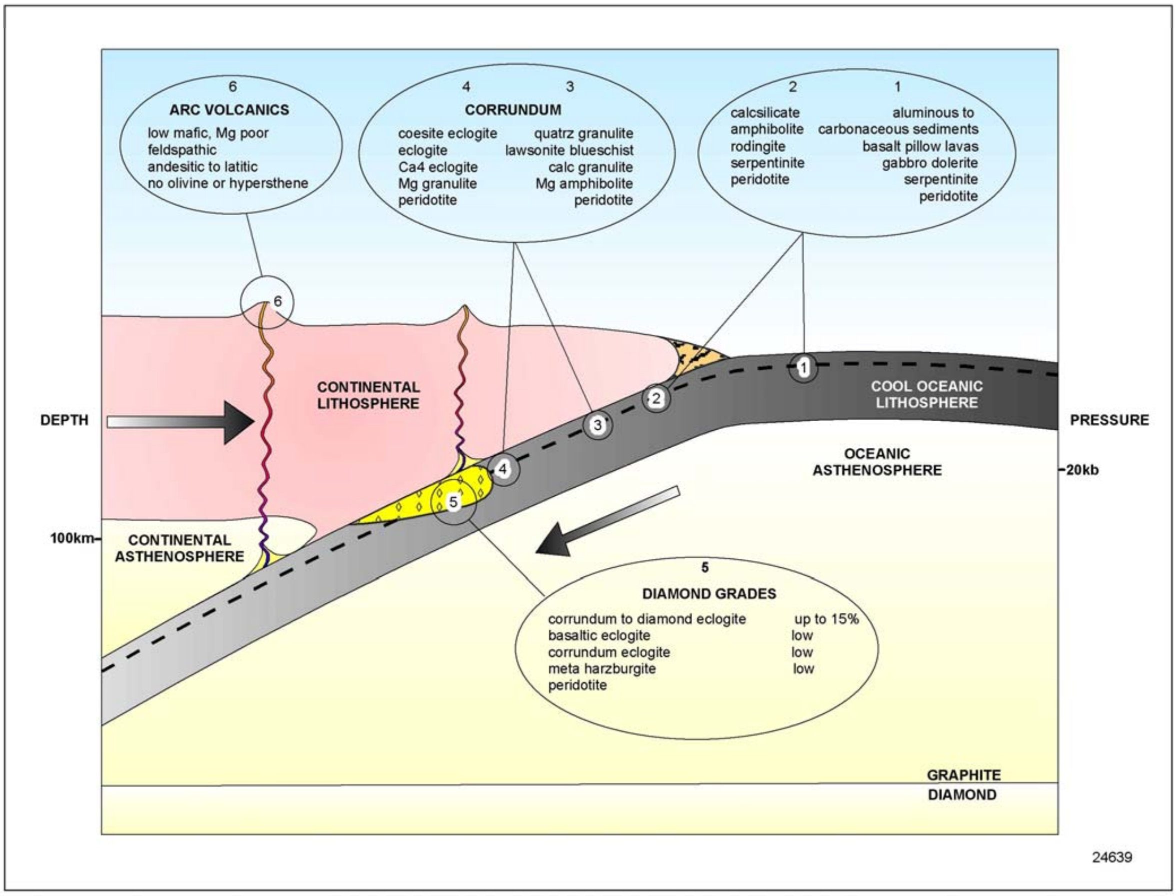

Figure A-C. Simplified subduction model for diamonds, Nandewar study area (modified after Barron et al. 1996)

Sapphire

Model Description: Based on the model of Cox and Singer (1986).

Approximate Synonym: Sapphire placers, placer gemstones.

Description: Sapphires and other gemstones in alluvial sediments.

General References: Pecover (1992), Coenraads et al. (1990), Pecover (1988).

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

Textures: Coarse clastic.

Age Range: Commonly Tertiary to Quaternary, but may be any age.

Depositional Environment: Streams or palaeostreams draining areas of alkali basalt, lamprophyre, nephelinite, basanite or phonolite dykes, flows and pyroclastics. Unconformities, palaeoregoliths, or current erosional surfaces intersecting sapphire/ruby-bearing lithologies provide a vector for identifying secondary deposits **(Figure A-D)**.

Tectonic Setting: Accreted fold belts. With regards to the primary source, host rocks occur in continental and pericontinental settings related to rifts, deep faults and/or hot spots. In some cases they are interpreted to be subduction zone-related (Simandl & Paradis 1999).

Associated Deposit Types: Placer zircon, placer gold, placer tin, placer platinum group elements, and placer diamond.

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 often with glossy crystal faces in Tertiary alluvial sediments, but more abraided 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 source.

Weathering: With regards to the primary source, volcaniclastic rocks that host sapphire are commonly clay-altered and ferruginised due to a combination of alteration and weathering.

Geochemical Signature: N/a.

Examples: Pailin, Cambodia; Bo Rai, Thailand; Anakie, Queensland; Kings Plains, New South Wales (Brown & Pecover 1988a,b; Desertstone & Sapphire Mines 1996).

Economic Significance: Economic primary (hard rock) sapphire-bearing deposits are relatively rare. Most sapphires are recovered from associated residual soils or placer deposits. Sapphire-bearing, alkali volcanic rocks are source rocks for some of the large alluvial sapphire deposits, such as the Pailin gem fields of Cambodia, Bo Rai deposits of Thailand, the Anakie district of Queensland and the Kings Plain deposit in New South Wales

(Simandl & Paradis 1999). Production from the Central Province within the New England region totals more than 50 million carats valued at more than A$250 million dollars (2003).

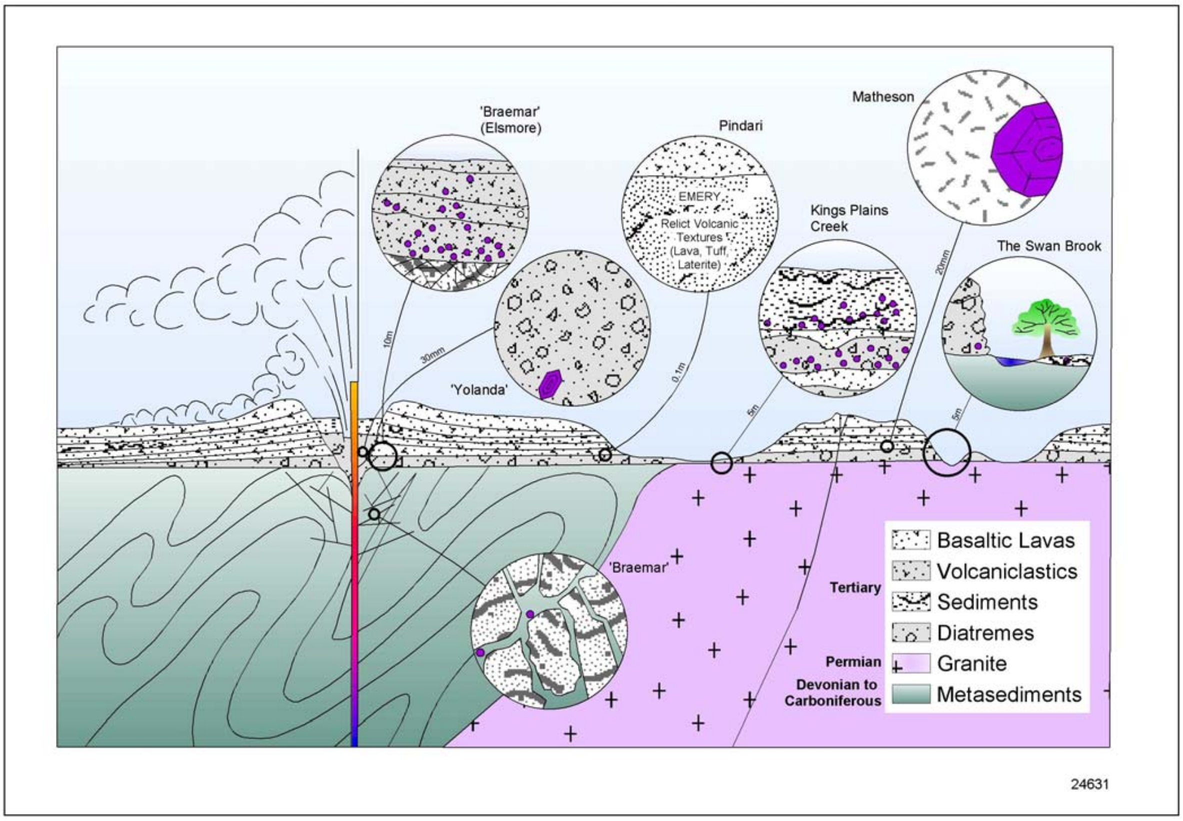

Figure A-D. Simplified model for the formation of sapphire deposits in the Nandewar study area (modified after Oakes et al. 1996).

Limestone

Model Description: Carr and Rooney (1983), Harben and Bates (1990), Lishmund et al. (1986).

Approximate Synonyms: Limerock, cement rock, calcium carbonate.

Description: Limestone deposits of economic importance are partly or wholly biologically derived from seawater; accumulating in a relatively shallow marine environment. The characteristics of the deposition environment determine the size, shape and purity of the carbonate rock. Limestone deposits are frequently of large areal extent and may be of considerable thickness (several hundred metres).

General References: Carr and Rooney (1983), Harben and Bates (1990), Lishmund et al. (1986).

Rock Types: Limestone, marble (metamorphosed limestone).

Age Range: Late Proterozoic to Holocene.

Depositional Environment: Shallow marine.

Tectonic Setting: Continental shelf and subsiding marginal marine basins.

Associated Deposit Types: Deposits of dolomitic limestone and dolomite.

Mineralogy: Limestone is a sedimentary rock consisting of 50% or more of calcite ($CaCO_3$) and dolomite ($CaMg(CO_3)_2$). There is a complete gradation from impure limestone to high calcium limestone (greater than 95% $CaCO_3$). 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 a contact or regional metamorphic process. Maximum limitations of overburden are 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.

Geophysical Signature: Resistivity has been used to identify karst features in covered terrain.

Examples: Jackson and Sulcor quarries, New South Wales; Marulan and Wombeyan limestones, New South Wales.

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, the coal industry, as roadbase, and fillers for paper and plastic. Currently around 55% of the state's limestone is used in the cement industry. Production within the Nandewar study area currently exceeds $8 million from 400 000 tonnes annually from the Jacksons and Sulcor quarries near Attunga.

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.

Construction Materials

Model Description: J.W. Brownlow, R.G. Barnes, and G.P. MacRae (New South Wales Geological Survey, pers.comm. 2003).

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 to markets as possible. 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. Their use in construction, road building and related uses, is an integral part of modern urban living and therefore supplies need to be assured for continued development.

Approximate Synonyms: The term extractive resource is used, as a synonym for construction materials, particularly in the sense of resources not covered by mining legislation. Various terms are used for construction aggregates depending on size and specific use. 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, shingle. Note that some of these terms describe products (for example, coarse aggregate, fine aggregate, and construction sand) whereas others describe geology (for example, gravel and sand) or a combination of geology and materials (for example, hard rock aggregate). Descriptive terms for clays used in construction include clay/shale, structural clay, brick clay, low cost clay, stoneware clay, pipe clay, terra cotta clay. Dimension stone is also referred to as building stone, ornamental stone or monumental stone depending on its end use.

General References: Carr (1994), Holmes, Lishmund and Oakes (1982).

Economic Significance: The economic significance of construction materials in the Nandewar study area is detailed in the main section of the report. Recent annual production from the Nandewar study area is $2 151 000.

Diatomite

Model Description: Description of the model after Shenk (1991) and Holmes et al. (1989).

Approximate Synonym: Diatomaceous earth, kieselguhr, tripolite.

Description: Diatomite is a soft, lightweight siliceous rock composed of the skeletal remains of diatoms, microscopic aquatic plants. Lacustrine diatomite deposits form in fresh to brackish water, are invariably associated with volcanism, and are found worldwide both in palaeosediments and in recent lake sediments. It is widely held that the large quantity of silica necessary for thick accumulations of diatoms is derived from the weathering and decomposition of silica rich volcanic rocks (Shenk 1991). However, some recently formed lacustrine diatomite deposits show no association with volcanic activity (Dolley 2002).

General References: Shenk (1991), Holmes et al. (1989).

Rock Types: Diatomaceous-bearing lake sediments can be hosted in either/or: volcanic rocks (craters, maars); volcanic and sedimentary rocks (interbedded volcanic flows and tuffs and fluvial or alluvial sediments); and sedimentary rocks. Diatomite is commonly interbedded with one or more of the following: sandstone; mudstone; volcanic ash; limestone or marls; or peat or lignite.

Textures: N/a.

Age Range: Commonly Miocene to Recent. Occurrences noted as early as Late Eocene. Some marine diatomite deposits reported to be as old as Cretaceous.

Depositional Environment: The depositional conditions required for a thick diatomite deposit include: an abundance of both silica and other nutrients; an absence of toxic growth and minimal clastic or chemical input; a shallow and extensive basin for photosynthesis; and a low energy environment for preservation of diatom structure.

Tectonostraphic Setting: Typically found in volcanic terrains, often a crustal extensional environment.

Associated Deposit Types: Possibly sand and gravel or clays (kaolin, bentonite).

Mineralogy: Diatomaceous silica, opal-cristobalite.

Gangue Mineralogy: Clays, quartz and feldspar grains, volcanic glass, calcite, organic matter and iron and manganese oxides and possibly gypsum and halite.

Texture/Structure: Flat lying to gently dipping, some minor folding and faulting. Usually found in volcanic terrain.

Alteration: N/a.

Ore Controls: The formation and localisation of ore is controlled by the physical and chemical boundaries of the regional depositional environment.

Weathering: Weathering will oxidise and remove organic contaminants, however it also produces iron staining and soil formation.

Metamorphism: During diagenesis, dissolution of diatomaceous silica will destroy diatom structure. Silica is then available to be redeposited as porcelainite, chert or silica cement.

Geochemical Signature: N/a.

Maximum Limitation of Overburden: Ratios up to 10:1, but typically less than 5:1.

Examples: Juntura and Otis Basins, United States of America (Brittain 1986); Kariandus, Kenya (Barnard 1950); Lake Myvatn, Iceland (Kadey 1983); Riom-les-Montagnes, France (Clarke 1980); Luneburger-Heide, Germany (Luttig 1980).

Economic Significance: World reserves are estimated to be 800 million tonnes which is about 400 times the current estimated world production of about 1.9 million tonnes per year as of 2002 (Dolley 2002). World resources of crude diatomite are adequate for the foreseeable future, but the need for diatomite to be near markets encourages development of new sources for the material.

There is insufficient data on diatomite deposits to give likely indications of size and grade on a worldwide basis.

Alluvial Diamonds

Model Description: Cox and Singer (1986).

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

General References: Barron et al. (1996), Pecover (1988), Sutherland (1982).

Rock Types: Sand and gravel in alluvial and beach deposits. Conglomerate units may contain palaeoplacers.

Textures: Coarse clastic.

Age Range: Commonly Tertiary and Quaternary, but may be any age.

Depositional Environment: Streams draining areas of lamproite pipes or other mantle derived igneous intrusives or diamond concentrations in sedimentary or metamorphic rocks. Alluvial diamond deposits may be 1 000 kilometres from source. Some diamonds may have been derived from Palaeozoic or older fold belts associated with subduction.

Tectonic Setting: Stable craton, accreted fold belts.

Associated Deposit Types: Primary diamond deposits, other placer deposits.

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: African deposits (Sutherland 1982); Bow River, Australia (Fazakerley 1990).

Economic Significance: There is insufficient data on alluvial diamond deposits to give likely indications of size and grade on a worldwide basis.

Serpentinite Related Deposits

Deposits in this generic class are many and varied, but have been grouped together for modelling purposes. This class of deposits includes podiform chromite, synorogenic/synvolcanic nickel-copper deposits, sediment-hosted and hydrothermal magnesite, ultramafic-hosted asbestos, serpentine, and olivine (dunite). Models are presented for podiform chromite and synorogenic/synvolcanic nickel-copper deposits.

Podiform Chromite

Model Description: Description of the model modified after Cox and Singer (1986).

Approximate Synonym: Alpine type chromite (Thayer 1964).

Description: Pod-like masses of chromitite in ultramafic parts of ophiolite complexes.

General Reference: Dickey (1975), Duke (1996).

Rock Types: Highly deformed dunite and harzburgite of ophiolite complexes. Commonly serpentinized.

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

Age Range: Any age.

Tectonic Setting: Magmatic cumulates in elongate magma pockets along spreading 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, ultramafic-hosted asbestos, lateritic/saprolitic nickel.

Mineralogy: Chromite ± ferrichromite ± magnetite ± ruthenium-osmium-iridium 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; Thetford mines ophiolite complex (Kacira 1982).

Economic Significance: There is insufficient data on chromite deposits to give likely indications of size and grade on a worldwide basis.

Synorogenic-Synvolcanic Nickel-Sulphide

Model Description: Description of the model modified after Cox and Singer (1986).

Approximate Synonyms: Nickel-copper in mafic rocks; Stratabound sulphide-bearing nickel-copper; gabbroid associated nickel-copper.

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

General References: Cox and Singer (1986).

Rock Types: Host rocks include norite, gabbro-norite, pyroxenite, peridotite, troctolite, anorthosite, and hornblendite; forming layered or composite igneous complexes.

Textures: Phase and cryptic layering sometimes present. Rocks are usually cumulates.

Age Range: Archaean to Tertiary, predominantly Archaean and Proterozoic; Cambrian in Tasmania, Devonian in Victoria.

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

Tectonic Setting: Mobile belts, metamorphic belts and greenstone belts.

Associated Deposit Types: Stratiform mafic-ultramafic nickel-copper (Stillwater); Stratiform mafic-ultramafic platinum group elements (Merensky Reef, Bushveld Complex); placer platinum group elements.

Mineralogy: Pyrrhotite, pentlandite, chalcopyrite ± pyrite ± titanium-magnetite ± chromium-magnetite ± graphite, with possible by-product cobalt and platinum group elements.

Texture/Structure: Predominantly disseminated sulphides in stratabound layers up to three metres thick. Commonly deformed and metamorphosed so primary textures and mineralogy may be modified.

Alteration: Serpentinisation.

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

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

Geochemical Signature: Ni, Cu, Co, PGE, Cr.

Geophysical Signature: Strong magnetic signature where not extensively serpentinised.

Examples: Sally Malay, Western Australia; Radio Hill, Mount Sholl, Western Australia; Rana, Norway; Cuni deposits (Five Mile), Tasmania.

Economic Significance: According to grade/tonnage models for synorogenic–synvolcanic deposits: 90% contain at least 0.26 million tonnes of ore; 50% at least 2.1 million tonnes; and 10% at least 17 million tonnes. In these types of deposits: 90% contain at least 0.35wt%

Ni and 0.13wt% Cu; 50% contain at least 0.77wt% Ni and 0.47wt% Cu; and 10% at least 1.6wt% Ni and 1.3wt% Cu (Cox & Singer 1986).

According to grade/tonnage models for komatiite nickel–copper deposits: 90% of deposits contain at least 0.2 million tonnes of ore; 50% at least 1.6 million tonnes; and 10% at least 17 million tonnes. In these types of deposits: 90% contain at least 0.71wt% Ni and 0.13wt% Cu; 50% at least 1.5wt% Ni and 0.094wt% Cu; and 10% at least 3.4wt% Ni and 0.28wt% Cu (Cox & Singer 1986).

The gabbroid associated stratabound nickel-copper sulphide deposit type has been of limited commercial importance in Australia in the past. However, this deposit type is of world significance overseas as an important source of nickel and as a source of strategically important platinum group elements.

Kaolin

Model Description: Description of the model after Hora (1998).

Synonyms*:* Primary kaolin, secondary kaolin, fireclay, flint clay, ball clay.

General References*:* Hora (1992), Harben and Bates (1990).

Rock Types: Kaolinised feldspathic rocks, for example gneiss, granites to diorites and their volcanic equivalents. Secondary alluvial kaolinitic clays.

Age Range: Can be any age.

Tectonic Setting: In tectonically stable areas. Down-faulted sedimentary basins.

Depositional Environment: Alteration (weathering) of aluminium silicates in a warm, humid environment. Primary kaolin is formed in situ as a result of weathering or of hydrothermal alteration. Continued intensive weathering may remove the silica from kaolinite to produce a bauxite mineral. Kaolinitic clays (Harben & Bates 1990) underlie most bauxite. Secondary kaolin is formed from sedimentation in fresh or brackish water (Tertiary and Quaternary river channels and lakes). Secondary sand kaolin deposits may also result from post depositional alteration of feldspar clasts in arkosic sand. Selective dissolution of carbonate from argillaceous limestone or dolomites can also leave an insoluble residue comprised mostly of clay.

Associated Deposit Types: Bentonite, diatomite, bauxite, coal, ceramic and cement shales. In the Nandewar study area, kaolin may occur with hydrothermal tin deposits.

Mineralogy: Kaolinite, quartz, feldspar, with minor biotite and hornblende.

Alteration Mineralogy: N/a.

Ore Controls: Kaolin contaminated with iron oxides and other mineral pigments (in red and brown soils) are unsuitable for refined industrial use. Kaolin in the subsoil area, which forms the pallid zone, can contain pure kaolin. The primary texture of the parent rock and the presence of unconformities, shears and fracture zones are important for water penetration.

Fracture zones are also important for hydrothermal kaolin. Secondary kaolin is deposited in low energy environments. Typical kaolin concentrations in sandy sediments are located at the tops of fining-upward sand sequences. Quantity and quality of kaolinitic clays can be increased by beneficiation (Harben & Bates 1990).

Examples: Merrygoen, New South Wales.

Economic Significance: For 2001, the worldwide production of kaolin was 42 million tonnes (Virta 2001). There is insufficient data on kaolin deposits to give likely indications of size and grade on a worldwide basis.

High-grade kaolin is used in porcelain, ceramics, as a filler and for paper coating. Brick and cement clays, 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 industry and construction. Competing land uses are a constant pressure on the availability of these resources.

Zeolite

Model Description: Description of the model after Flood (1987, 1995) and Holmes and Pecover (1987).

Approximate Synonym: Natural zeolites.

Description: Naturally occurring crystalline hydrated aluminosilicates containing positively charged metallic ions (cations) of the alkali and alkaline earth elements within three-dimensional crystal frameworks.

General References: Flood (1987, 1995), Holmes and Pecover (1987).

Geological Environment: Varied. In the New England Fold Belt, Late Carboniferous vitric ash fall tuffs deposited within lacustrine, fluvial overbank, and shallow marine environments appear to have the highest zeolite content.

Textures: N/a.

Age Range: Most are Cainozoic on a world scale, but they can be older. Their physio-chemical instability renders them unlikely to be older than Palaeozoic. In the New England Fold Belt, the highest concentration of zeolite-rich rock appears to be in the continental to marine Late Carboniferous sequence, which are amongst the oldest known economically viable zeolite-rich rocks in the world. Zeolitic pyroclastics within the Currabubula Formation appear to have highest prospectivity (Flood 1987).

Depositional Environment: In the New England Fold Belt, Late Carboniferous vitric ash fall tuffs deposited within lacustrine or similar environments appear to have highest zeolite content. Welded and non welded ignimbrite ash-flow units and ash-flow tuffs show evidence of having contained high vitric contents at the time of their deposition. Alteration of these vitric components to zeolite minerals appears to have occurred mainly in the non-welded ash-flow pyroclastic units and in ash-fall tuffs. Factors which have influenced the formation of zeolite include the porosity of the original host, and the availability of water during and after emplacement (Flood 1987).

Tectonic Setting: In New England Fold Belt active continental margin arc (both fore-arc and back-arc)

Associated Deposit Types: Epithermal gold-silver, bentonite.

Deposit Description: Altered volcanic ash-flow units and tuffs.

Mineralogy: Zeolite minerals which are most widely used in industry and agriculture are: clinoptilolite; mordenite; chabazite; phillipsite; and erionite. Escott Mine: Ca-type clinoptilolite, modenite ± quartz ± albite ± sanidine (Flood & Taylor 1991).

Texture/Structure: N/a.

Alteration: N/a.

Ore Controls: In New England Fold Belt high vitric content of original ash-flow units. Style of eruption, porosity of the original host, and the availability of water during and after emplacement (Flood 1987). Burial and metamorphic history (Homes & Pecover 1987).

Weathering: N/a.

Geochemical Signature: N/a.

Examples: Death Valley Junction, United States of America; Lake Tecopa, United States of America; Lake Magadi, Kenya.

Economic Significance: Worldwide production of natural zeolite is estimated to be between three and four million tonnes based on reported production by some countries and production estimates published in trade journals. Several companies focused on penetrating markets that were previously ignored, such as specialty concretes, and creating more innovative and possibly more marketable products, such as soil amendment blends. If these are successful, they may spur more interest in the use of zeolite as the commercial potential of these functional minerals is recognised (Virta 2002).

There is insufficient data on zeolite deposits to give likely indications of size and grade on a worldwide basis.

A2.3 Metallic Minerals

Orogenic Gold

Model Description: Description of the model after Berger and Bethke (1985), Phillips and Hughes (1998), Robert (1996), Ash and Aldrick (1996), and Groves et al. (1998, 2003).

Approximate Synonyms: Slate belt gold veins, mesothermal quartz veins, mother lode veins, turbidite-hosted gold veins, low sulphide gold-quartz veins, metahydrothermal gold, structurally controlled gold, quartz-stibnite ore, Victorian gold deposits.

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: Forde and Bell (1994); Hodgson, Love and Hamilton (1993), White (1962), Miller (1973), Knight (1978), Philips and Hughes (1998).

Rock Types: Regionally metamorphosed volcanic rocks, greywacke, chert, shale, and quartzite, especially turbidite-deposited sequences, greenstone belts and oceanic metasediments. Alpine gabbro and serpentine. Late-stage 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. Regionally high background gold sources may be important on a province scale (for example, Victorian Cambrian boninites), Ordovician shoshonites, New South Wales and Late Permian I-type granites in New England (Ashley et al. 1994).

Age Range: Archaean to Tertiary.

Depositional Environment: Continental margin mobile belts, accreted margins. Vein age is pre to post-metamorphic and locally cut granitic rocks.

Tectonic Setting: Fault and joint systems produced by regional compression; high strain zones.

Associated Deposit Types: Placer gold-platinum group elements, Homestake gold. Fosterville-Nagambie style gold (stockworks), alluvial gold. 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.

Some orogenic type gold deposits may contain input from other gold deposit styles and sources (Ashley et al. 1994; Groves et al. 2003). These deposits have been suggested to exist on a spectrum of association with other gold mineralisation styles, which may provide a source for the gold in some cases (Groves et al. 2003, Ashley et al. 1994). Some overprint pre-existing deposits (Groves et al. 2003). In the New England region, a major influx of heat and development of I-type magmas, in association with regional uplift and deformation, has been suggested to potentially influence the distribution and formation of these types of deposits (Ashley et al. 1994).

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 calcium, magnesium, and iron abundant.

Antimony-gold vein deposits contain stibnite, quartz ± pyrite ± calcite; minor other sulphides frequently less than one 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 include 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). The deposits 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 with minor chloritisation and 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, for example shale/sandstone contacts and intrusive contacts may be important. Fold hinge zones also locally 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.

Genetic Model: After Ash and Aldrick (1996). Gold quartz veins form in lithologically heterogeneous, deep transcrustal fault zones that develop in response to terrane collision. These faults act as conduits for CO_2 and H_2O rich (5-30 mol% CO_2), low salinity (less than 3 wt% NaCl) aqueous fluids, with high Au, Ag, As, (±Sb, Te, W, Mo) and low Cu, Pb, Zn metal contents. These fluids are believed to be tectonically or seismically driven by a cycle of pressure build-up that is released by failure and pressure reduction followed by sealing and repetition of the process. Gold is deposited at crustal levels within and near the brittle-ductile transition zone with deposition caused by sulphidation (the loss of H_2S due to pyrite deposition), primarily as a result of fluid-wallrock reactions. Other significant factors may involve phase separation and fluid pressure reduction. The origin of the mineralising fluids remains controversial, with metamorphic, magmatic and mantle sources being suggested as possible candidates. Within an environment of tectonic crustal thickening in response to terrane collision, metamorphic devolitisation or partial melting (anatexis) of either the lower crust or subducted slab may generate such fluids.

Examples:

Gold-low sulphide quartz vein association: Bendigo Goldfield, Victoria (Sharpe & MacGeehan 1990); Ballarat East Gold Deposits, Victoria (d'Auvergne 1990); Mother Lode (Knopf 1929); Goldfields of Nova Scotia (Malcolm 1929).

Antimony-gold association: Amphoe Phra Saeng (Gardner 1967); Coimadai, Victoria (Fisher 1952); Costerfield, Victoria (Stillwell 1953); Hillgrove (Boyle 1990).

Gold in chert/jasperoid association: Fortnum, Western Australia (Hill & Cranney 1990); Dalmorton, New South Wales (Henley et al. 2001); Limbri?, New South Wales (Brown et al. 1992).

Economic Significance: Orogenic gold deposits are one of the largest types of gold deposit and are an important source of gold and silver, although there is a lack of consensus concerning classification. According to the grade/tonnage models for low-sulphide gold-quartz veins: 90% of these deposits contain at least 0.001Mt of ore; 50% contain at least 0.03Mt; and 10% contain at least 0.91Mt (Cox & Singer 1986). In 90% of these deposits ores contain at least 6g/t Au; 50% contain at least 15g/t Au and 10% contain 43g/t Au.

There is insufficient data and lack of consensus about orogenic gold deposits associated with chert and jasper to give indications of grades and tonnages. The Yarlaweelor pit at the Fortnum gold mine in Western Australia is hosted in tension quartz vein arrays within folded jasperoid lenses and has produced around two million tonnes at about 2.5g/t Au during the late 1990s (approximately A$100 million). The Dalmorton gold field in New South Wales is hosted within stratabound chert lenses. The mineralising fluids are thought to be sourced largely by orogenic ('metahydrothermal') sources, although a regional association with fractionated I-type Permian-Triassic granites is also possible. Identified Inferred resources amount to some 232 000t at 3.27ppm Au.

The grade/tonnage model for simple antimony-gold vein deposits (Cox & Singer 1986) indicate: 50% of deposits contain more than 180 tonnes of ore; and 10% contain more that 4 900 tonnes. In 90% of these deposits ores contain at least 18% Sb; 50% of them contain at least 35% Sb; while 10% of them contain at least 66% Sb, 1.3g/t Au and 16g/t Ag.

Porphyry Copper-Gold

Model Description: Description of the model in Cox and Singer (1986), Cook et al. (1998), and Corbett and Leach (1998).

Description: Stockwork veinlets of chalcopyrite, bornite, and magnetite in porphyritic intrusions and coeval volcanic rocks and other country rocks. Ratio of gold (ppm) to molybdenum (%) is greater than 30.

General References: Sillitoe (1979, 1989), Cook et al. (1998).

Rock Types: Tonalite to monzogranite; dacite, andesite flows and tuffs coeval with intrusive rocks. Also syenite, monzonite, and coeval high potassium, low titanium volcanic rocks (shoshonites). In Lachlan Fold Belt shoshonitic geochemistry is a major control (Downes 1998).

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

Age Range: Mainly Palaeozoic to Quaternary, but can be any age. In the southern New England Fold Belt they are mostly Permo-Triassic.

Depositional Environment: In porphyritic stocks and dykes intruding coeval volcanic rocks. Large-scale breccias common. Evidence for volcanic centre. One to two kilometres depth of emplacement.

Tectonic Setting: Subduction related, for example Island-arc volcanic setting, especially in the waning stage of volcanic cycle. Active continental margin. Also continental margin rift-related volcanism.

Associated Deposit Types: Porphyry copper-molybdenum, gold-porphyry, epithermal gold-silver, copper-gold skarn, orogenic gold, gold placers.

Mineralogy: Chalcopyrite ± bornite. Traces of native gold, electrum, sylvanite, and hessite. Quartz, K-feldspar. Anticipated to provide adequate fault related trapping potential both within and adjacent to the major graben.

Texture/Structure: Veinlets and disseminations.

Alteration: Quartz ± magnetite ± biotite (chlorite) ± K-feldspar ± actinolite ± anhydrite in interior of system. Outer propylitic zone. Late quartz, pyrite, white mica ± clay may overprint early feldspar-stable alteration.

Ore Controls: Veinlets and fractures of quartz, sulphides, K-feldspar, magnetite, biotite, or chlorite are closely spaced. Ore zone has a bell shape centred on the volcanic-intrusive centre. Highest grade ore is commonly at the level at which the stock divides into branches.

Weathering: Surface iron staining may be weak or absent if pyrite content is low in protore. Copper silicates and carbonates. Residual soils contain anomalous amounts of rutile.

Geochemical Signature: Anomalous Cu, Au, Mo, Ag, Zn, Pb, As, Sb, Hg, Te, Sn, S (Cook et al. 1998). Central Cu, Au, Ag; peripheral Mo. Peripheral Pb, Zn, Mn anomalies may be present if late sericite pyrite alteration is strong. Gold (ppm) to molybdenum (%) ratio is greater than 30 in ore zone. Gold enriched in residual soil over ore body. System may have magnetic high over intrusion surrounded by magnetic low over pyrite halo.

Examples: Goonumbla (Heithersay et al. 1990); Cadia, New South Wales (Wood & Holliday 1995).

Economic Significance: Generally these deposits are important sources of copper and gold. Pre-mining resources at Cadia-Ridgeway in central New South Wales amount to greater than A$10 billion (2003).

The grade/tonnage model (Cox & Singer 1986) for porphyry copper gold deposits indicate: 90% of these deposit contain at least 25Mt of ores; 50% contain at least 100Mt; and 10% contain at least 400Mt. In 90% of these deposits ores contain at least 0.35wt% Cu and 0.2ppm Au; in 50 % of the deposits ores have at least 0.5wt% Cu and 0.38ppm Au and in 10% of the deposits the ores contain at least 0.72wt% Cu and 0.72ppm Au.

Epithermal Gold-Silver

Model Description: Description of the model after Cox and Singer (1986).

Approximate Synonym: Epithermal gold (quartz-adularia) alkali-chloride type, polymetallic veins, low/high sulphidation, epigenetic.

Description: Galena, sphalerite, chalcopyrite, sulfosalts, tellurides and gold in quartz-carbonate veins hosted by felsic to intermediate volcanics. Older basin evaporites or rocks with trapped seawater are associated with these deposits.

General References: Buchanan (1980), White and Hedenquist (1990), Henley et al. (1984), Berger and Bethke (1985).

Rock Types: Host rocks are usually andesite, dacite, quartz latite, rhyodacite, rhyolite, and associated sedimentary and/or plutonic rocks. Earlier non-associated units may also be affected. Mineralisation related to calc-alkaline or bimodal volcanism.

Textures: Porphyritic.

Age Range: Most are Tertiary on a worldwide basis, but can be any age. For southern parts of the New England Fold Belt major mineralising events are identified in the Permian.

Depositional Environment: Bimodal and calc-alkaline volcanism. Deposits related to sources of saline fluids in prevolcanic basement such as evaporites or rocks with entrapped seawater and hot springs.

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

Associated Deposit Types: Placer gold, epithermal quartz alunite gold, polymetallic vein and replacement, porphyry copper-gold, Carlin.

Mineralogy: Galena, sphalerite, chalcopyrite, copper sulfosalts, silver sulfosalts ± gold ± tellurides ± bornite ± arsenopyrite. Gangue minerals are quartz, chlorite ± calcite, pyrite, rhodochrosite, barite ± fluorite ± siderite ± ankerite ± sericite ± adularia ± kaolinite. Specular haematite and alunite may be present.

Texture/Structure: Banded veins, open space filling, lamellar quartz, stockworks, colloform textures.

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

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

Weathering: Bleached country rock, goethite, jarosite, and alunite. Supergene processes often important factor in increasing grade of deposit.

Geochemical Signature: Higher in system Au, As, Sb, Hg; Au, Ag, Pb, Zn, Cu; Ag, Pb, Zn, Cu, Pb, Zn. Base metals generally higher grade in deposits with silver. Tungsten and bismuth may be present.

Examples: Pajingo, Queensland (Bobis et al. 1996); Mount Terrible, New South Wales.

Economic Significance: Epithermal gold-silver deposits are important sources for gold and silver. Grade/tonnage model for deposits of this type indicate: 90% of deposits contain more than 0.065Mt of ore; 50% more than 0.77Mt and 10% contain more that 9.1Mt (Cox and Singer, 1986). In 90% of these deposits ores have at least 2.0g/t Au and 10g/t Ag; 50% have at least 7.5g/t Au and 110g/t Ag; and In 10% of have at least 27g/t Au and 1300g/t Ag.

Tin (Greisen and Vein)

Tin Greisen

Model Description: Description of the model after Reed (1982).

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

General References: Reed (1982), Solomon and Groves (1994).

Rock Types: Specialised biotite and/or muscovite leucogranite (S-type) granite. Distinctive accessory minerals include topaz, fluorite, tourmaline, and beryl. Tin greisens are generally post-magmatic and associated with late fractionated melt.

Textures: Common plutonic rock textures, miarolitic cavities may be common. Generally nonfoliated. Equigranular textures may be more evolved (Hudson & Arth 1983). Aplitic and porphyritic textures common.

Age Range: May be any age.

Depositional Environment: Mesozonal plutonic to deep volcanic environment.

Tectonic Setting: Fold belts of thick sediments and/or volcanic rocks deposited on stable cratonic shield. Accreted margins. Granites generally postdate major folding.

Associated Deposit Types: Quartz-cassiterite sulphide lodes, quartz-cassiterite ± molybdenite stockworks. Late complex tin-silver-sulphide veins.

Mineralogy: Cassiterite, molybdenite, arsenopyrite, beryl, wolframite, bismuthinite, copper-lead-zinc 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 granites may have high contents of SiO_2 (greater than 73%) and K_2O (greater than 4%), and are depleted in CaO, TiO2, MgO, and total FeO. They are enriched in Sn, F, Rb, Li, Be, W, Mo, Pb, B, Nandewar study area, Cs, U, Th, Hf, Ta, and most rare earth elements, and impoverished in Ni, Cu, Cr, Co, V, Sc, Sr, La, and Ba.

Examples: Lost River (Dobson 1982; Sainsbury 1964); Anchor Mine (Solomon & Groves 1994).

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

Tin Veins

Model Description: Description of the model after Reed (1982).

Approximate Synonym: Cornish type lodes.

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

General References: Solomon and Groves (1994), Hosking (1974), Taylor (1979).

Rock Types: Close spatial relation to multiphase granites. Specialised biotite and (or) muscovite leucogranite common. Pelitic sediments generally present.

Textures: Common plutonic textures.

Age Range: Palaeozoic and Mesozoic most common but may be any age.

Depositional Environment: Mesozonal to hypabyssal plutons. Extrusive rocks generally absent. Dykes and dyke swarms common.

Tectonic Setting: Fold belts and accreted margins with late orogenic to postorogenic granites, which may in part, be anatectic. Regional fractures are common.

Associated Deposit Types: Tin greisen, tin skarn, and replacement tin deposits.

Mineralogy: Extremely varied. Cassiterite ± wolframite, arsenopyrite, molybdenite, haematite, scheelite, beryl, galena, chalcopyrite, sphalerite, stannite, bismuthinite. Although variations and overlaps are ubiquitous, many deposits show an inner zone of cassiterite ± wolframite fringed with lead, zinc, copper and silver sulphide minerals.

Texture/Structure: Variable. Brecciated bands, filled fissures, replacement, open cavities.

Alteration: Sericitisation (greisen development) and/or tourmalisation common adjacent to veins and granite contacts; silicification, chloritisation, and haematisation. An idealised zonal relation might consist of quartz-tourmaline-topaz, quartz-tourmaline-sericite, quartz-sericite-chlorite, quartz-chlorite, and 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, Nandewar study area, Cs, U, Mo, REE).

Examples: Cornwall (Hosking 1969); Herberton (Blake 1972).

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

Tungsten-Molybdenum and Copper-Gold Skarn

Tungsten-Molybdenum Skarn

Model Description: Description of the model after Cox and Singer (1986) modified by Kwak (1987) and Blevin and Chappell (1995)

Description: Scheelite and molybdenite in calcsilicate contact metasomatic rocks.

Approximate Synonyms: Scheelite skarns of the tungsten type (Solomon & Groves, 1994).

General References: Kwak (1987), Einaudi and Burt (1982), Meinert 1992, Einaudi et al. 1981.

Rock Types: Tonalite, granodiorite, quartz monzonite. Fractionated granitoids, commonly leucocratic quartz monzonite to granite intruding calcareous bearing sequences. Wallrock composition may have an effect on the oxidation state of the skarn system.

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: Orogenic belts. Syn-late orogenic. Typically occur in marginal to continental margins settings and may have geochemical signatures indicating a mantle influence (Kwak 1987).

Associated Deposit Types: W skarns, Mo skarns, Zn skarns.

Mineralogy: Scheelite ± molybdenite ± pyrrhotite ± sphalerite ± chalcopyrite ± bornite ± arsenopyrite ± pyrite ± magnetite and traces of wolframite, fluorite, cassiterite, and native bismuth. Progression from copper-gold, to tungsten-molybdenum mineralisation is related to progressively more fractionated, oxidised, I-type magmas which can often be traced within single supersuites (Blevin & Chappell 1995).

Alteration: High garnet to pyroxene ratio, iron-rich andradite garnet dominates over grossularite. Diopside-hedenbergite pyroxene. Late stage spessartine-almandine garnet. Outer barren wollastonite zone. Inner zone of massive quartz may be present. For most tungsten-molybdenum skarns there is a similar zonation pattern of proximal/late subcalcic-garnet-quartz, intermediate (and large) zone of garnet-pyroxene skarn, and a thin skarn front of vesuvianite and/or wollastonite surrounded by less than one meter bleached marble.

Ore Controls: Carbonate rocks in thermal aureoles of intrusions. Fault 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, Tasmania (Solomon & Groves 1994); Pine Creek, United States of America (Newberry 1982); MacTung, Canada (Dick & Hodgson 1982); Strawberry, United States of America (Nokleberg 1981).

Economic Significance: Grades 0.4-2% WO_3 (typically 0.7% WO_3). Deposits vary from 0.1 million tonnes, to greater than 30 million tonnes. Skarn deposits have accounted for nearly 60% of the western world's production of tungsten (Ray 1995a).

Worldwide, grades 0.1-2% MoS_2 and tonnages between 0.1 million tonnes to two million tonnes (Ray 1995a). Molybdenum skarns tend to be of a smaller tonnage and less economically important than porphyry molybdenum deposits (Ray 1995a).

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

Copper-Gold Skarns

Model Description: Modified by L. David and S. Jaireth (Geoscience Australia), after D.P. Cox and T.G. Theodore.

Description: Chalcopyrite and gold in calcsilicate contact metasomatic rocks.

General References: Einaudi and Burt (1982), Einaudi et al. (1981), Kwak (1987), Meinert (1992).

Rock Types: Tonalite to monzogranite intruding carbonate rocks or calcareous clastic rocks. I-type, magnetite-bearing, oxidised porphyritic plutons. Gold skarns are also associated with reduced (ilmenite bearing) calc-alkaline to alkaline synorogenic to late orogenic granitoids, with little or no economic copper. Wallrock composition may have an effect on the oxidation state of the skarn system.

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

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

Depositional Environment: Fold belt sequences intruded by felsic plutons. Also oceanic island arc setting associated with mafic to intermediate intrusives with no disseminated and/or stockwork copper mineralisation.

Tectonic Setting: Continental margin belts with epizonal calc-alkaline granodioritic to quartz monzonitic rocks. Late orogenic magmatism. Typically occur in marginal to continental margins settings and may have geochemical signatures indicating a mantle influence (Kwak 1987). Many plutons have cogenetic volcanic rocks, stockwork veining, brittle fracturing and brecciation and intense hydrothermal alteration, all features indicative of a relatively shallow emplacement. Oceanic island arc setting.

Associated Deposit Types: Porphyry copper, zinc-lead-silver skarn, gold skarn, polymetallic replacement, iron skarn.

Mineralogy: Chalcopyrite, pyrite ± haematite ± magnetite ± bornite ± pyrrhotite. Also molybdenite, bismuthinite, sphalerite, galena, cosalite, arsenopyrite, enargite, tennantite, loellingite, cobaltite, and tetrahedrite may be present. Gold and silver may be important products. Base and precious metal mineralisation often in peripheral parts. Gold skarns rich in arsenic, bismuth and tellurium, and have calcic skarn assemblage low in manganese.

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

Alteration: High garnet to pyroxene ratio, iron-rich andradite garnet dominates over grossularite. Diopside-andradite centre; wollastonite-tremolite outer zone; marble peripheral zone. Igneous rocks may be altered to epidote-pyroxene-garnet (endoskarn). The ‘rotten wood-like’ appearance of boulders containing wollastonite has been used successfully as an exploration guide in British Columbia (Simandl et al. 1999). Retrograde alteration to actinolite, chlorite, and clays may be present. Retrograde skarn assemblage is followed by low temperature (less than 350 degrees Celsius) veins during which there is influx of oxidised meteoric water.

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

Weathering: Copper carbonates, silicates, iron-rich gossan. Calcsilicate minerals in stream pebbles are a good guide to covered deposits.

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

Examples: Mason Valley (Harris & Einaudi 1982); Victoria (Atkinson et al. 1982); Copper Canyon (Blake et al. 1979); Carr Fork (Atkinson & Einaudi 1978); Red Dome (Ewers et al. 1990); OK Tedi (Rush & Seegers 1990).

Economic Significance: Average 1-2% Cu. Worldwide they generally range from 1-100Mt, although some exceptional deposits exceed 300Mt. Historically these deposits were a major source of copper, although porphyry deposits have become much more important during the last 30 years. However, major copper skarns are still worked throughout the world, including China and the United States of America (Ray 1995b).

According to grade/tonnage models for copper skarn deposits: 90% of deposits contain at least 0.034Mt of ore; 50% at least 0.56Mt; and 10% at least 9.2Mt. 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 & Singer 1986).

Tungsten-Molybdenum Veins, Pipes and Disseminations

Model Description: Description of the model after Cox and Singer (1986).

Approximate Synonym: Quartz-wolframite veins (Kelly & Rye 1979).

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

General Reference: Solomon and Groves (1994).

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

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

Age Range: Paleozoic to Late Tertiary.

Depositional Environment: Tensional fractures in epizonal granitic plutons and their wallrocks.

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

Associated Deposit Types: Tin-tungsten veins, pegmatites.

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 rare earth element minerals. Upper zones, vein selvedges of dark-grey 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 & Rye 1974); Xihuashan, China (Hsu 1943; Giuliani 1985); Isla de Pinos, Cuba (Page & McAllister 1944); Hamme District, United States of America (Foose et al. 1980); Round Mountain, United States of America (Shawe et al. 1984).

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

Besshi-Cyprus Volcanic Hosted Massive Sulphides (VHMS)

Model Description: Description of the model after Cox and Singer (1986) and L. David (Geoscience Australia).

Approximate Synonym: Keislager.

Description: Consist of thin, sheet-like bodies of massive to well-laminated pyrite, pyrrhotite, chalcopyrite, and sphalerite within thinly laminated clastic sediments and mafic lavas and tuffs.

General References: Ishihara (1974), Franklin et al. (1981), Hutchinson et al. (1982), Ohmoto and Skinner (1983), Large (1992), Allen and Barr (1990), Gemmel et al. (1998).

Rock Types: Occur in interbedded clastic marine sedimentary rocks and tholeiitic to andesitic tuff and breccia (or their metamorphosed equivalents such as schist and amphibolite). Some areas contain ultramafic units such as peridotites (often serpentinised) and locally, black shale, oxide-facies iron formation, red chert, and exhalative carbonate material. The amount of mafic rock can vary. In the type area, rocks are metamorphosed to blueschist facies.

Textures: Diabase dykes, pillow basalts, and in some cases thinly laminated clastic rocks, quartzose and mafic schist. All known examples are in strongly deformed metamorphic terrain.

Age Range: Archaean through to Cainozoic.

Depositional Environment: Generated by submarine hot springs along axial grabens in oceanic or back-arc spreading ridges, or related to submarine volcanoes producing seamounts. Besshi/Cyprus ores may be localised within permeable sediments and fractured volcanic rocks in anoxic marine basins in an epicontinental rifting environment.

Tectonic Setting: Associated with mid-oceanic spreading ridge/centres but within a narrow oceanic arm adjacent to emerged lands, which serve as the source of abundant sediments swamping the basaltic volcanism.

Associated Deposit Types: Manganese and iron-rich cherts regionally. Podiform chromite. Copper-nickel-cobalt-iron sulphides. Exhalative tin (-tungsten) deposits.

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

Texture/Structure: Generally of tabular shape, or cigar-shaped when deformed, and contain fine-grained, massive to laminated ore (with colloform and framboidal pyrite), breccia or stringer ore and cross-cutting veins containing chalcopyrite, pyrite, calcite or galena, sphalerite, calcite.

Alteration: Besshi/Cyprus deposit alteration is difficult to recognise because of metamorphism but chloritisation of adjacent rocks is noted in some deposits.

Ore Controls: Mineralisation is stratigraphically controlled at the margin of mafic, volcanic-rich unit and overlying argillite-rich unit. Lenticular bodies occur in hinge zones of isoclinal folds. Clastic sediments (argillite, chert) or their metamorphic equivalents predominantly host mineralisation.

Weathering: Massive limonite gossans. Gold in stream sediments.

Geochemical Signature: Cu, Zn, Co, Ag, Ni, Cr, Co/Ni ratio greater than 1.0. Au up to 4ppm, Ag up to 60ppm.

Geophysical Signatures: Magnetic surveys may detect associated magnetite and/or pyrrhotite within orebody or magnetite within wallrocks. Induced polarisation techniques may detect pyritic schists. Electromagnetic techniques may detect massive sulphide mineralisation. Radiometrics may show potassium depletion in the alteration envelope.

Examples: Besshi, Japan (Kanehira & Tatsumi 1970); Girilambone, Australia (Suppel 1975).

Economic Significance: Besshi VHMS deposits are a significant source for copper, silver and zinc. Some of these deposits can have a few tens of parts per million of silver and at least one part per million of gold. Global grade/tonnage models for this type of deposit indicate: 90% of these deposits have more than 0.012Mt of ore; 50% have more that 0.22Mt; and 10% have more than 3.8Mt. Similarly, 90% of these deposits the ores have more than 0.56% Cu; 50% have more than 1.5% Cu and 2.0% Zn; and 10% have more than 3.3% Cu. Besshi deposits are highly skewed in their size distribution (Cox & Singer 1986).

Grade and tonnage data (Cox and Singer 1986) for Cyprus type deposits indicate: 90% of these deposits contain at least 0.1Mt of ore; 50% of the deposits contain at least 1.6Mt; and 10% of these deposits can contain at least17 Mt. The largest 10% of these deposits have at least 3.9% Cu in the ore.

Alluvial Tin

Model Description: Description of the model after Reed (1982).

Description: Cassiterite and associated heavy minerals in silt to cobble-size nuggets concentrated by the hydraulics of running water in modern and fossil streambeds (deep leads). Includes colluvial and residual (secondary) deposits of tin.

General References: Hosking (1974), Taylor (1979), Sainsbury and Reed (1973).

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 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: Alluvial deposits derived from Palaeozoic to Cainozoic accreted terranes or stable cratonic fold belts that contain highly evolved granites or their extrusive equivalents. Tectonic stability during deposition and preservation of alluvial deposits.

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

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 with euhedral crystals indicating close proximity to primary source. Where a marine shoreline intersects or transgresses a stream valley containing alluvial cassiterite the shoreline placers normally have a large length-to-width ratio.

Ore Controls: Cassiterite tends to concentrate at the base of stream gravels and in traps such as natural riffles, potholes, and bedrock structures transverse to the direction of water flow. The richest placers lie virtually over the primary source. Streams that flow parallel to the margin of tin-bearing granites 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: Southeast Asian tin fields (Westerveld 1937; Newell 1971; Hosking 1974; Simatupang et al. 1974).

Economic Significance: There is insufficient data on alluvial tin deposits for indications on worldwide grades and tonnages.

Alluvial Gold

Model Description*:* Modified after Yeend (1974).

Approximate Synonyms: Lead, shallow lead, deep lead, auriferous deep lead, lead system, alluvial deposit, alluvial placer, eluvial gold, alluvial terrace, colluvial gold detrital gold, wash, washdirt, drift, reef wash (terrace deposits), gutter wash (channel fill).

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), and Hughes et al. (1998).

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

Textures: Coarse clastic, as breccias and/or conglomerates.

Age Range: Cainozoic. Older deposits are known but their preservation is uncommon.

Depositional Environment: Occur in steep gradient sections of river channels in headwaters at shallow levels, and where gradients flatten and river velocities lessen, such as at the inside of meanders, below rapids and falls, beneath boulders, in terrace deposits and in vegetation mats. Winnowing action of surf caused gold concentrations in raised, present, and submerged beaches.

Tectonic Setting: Tertiary conglomerates along major fault zones, shield areas where erosion has proceeded for a long time producing multicycle sediments, high-level terrace gravels.

Associated Deposit Types: Black sands (magnetite, ilmenite, areaomite), platinum group elements, yellow sands (zircon, monazite). Gold placers commonly derive from various gold vein type deposits but also other gold deposits, for example porphyry copper-gold, gold skarn, massive sulphide deposits and replacement deposits. Reworking of older gold-bearing gravels and regolith.

Mineralogy: Gold, 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, areaomite, 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. Decrease in gold coarseness away from source. Crystalline gold is common where supergene gold or gold remobilisation within alluvium has occurred. Fine gold, with lower silver contents occurs in ferricrete cements at higher stratigraphic levels in palaeoplacers due to fluid remobilisation.

Ore Controls: Economic gold grades occur mainly at base of gravel deposits in various gold ‘traps’ such as natural riffles in floor of river or stream or structures trending transverse to direction of water flow such as fractured bedrock, and may include changes in lithology competence (interbedded lithologies, dykes etc) that cause formation of waterfalls and waterholes. Gold may also be localised within steep gradient (dendritic) tributaries near headwaters, at tributary intersections with main channels, or in the main channels for distances of over 100 kilometres downstream (Phillips & Hughes 1996). Within channels, gold concentrations occur mainly within narrow width ‘wash’ horizons (less than two metres thick) in semi-continuous layers and/or lenses. Gold occurs within these layers in gravel deposits above clay layers that constrain the downward migration of gold particles. In some channels gold, thought to have been remobilised during later weathering processes, was recovered from duricrust cements at higher stratigraphic levels.

Geochemical Signature: Anomalous high amounts of Ag, As, Hg, Sb, Cu, Fe, S, and heavy minerals magnetite, areaomite, ilmenite, haematite, pyrite, zircon, garnet, rutile. Gold nuggets have decreasing silver content with distance from source. Maghemite pisoliths may also be important.

Geophysical Signature: High resolution aeromagnetic and airborne electromagnetic techniques define buried channels (Lawrie et al. 1999). Other methods which have been used to define buried channels/deep leads, but which have had limited success, include seismic methods (both reflection and refraction), ground resistivity, magnetics and microgravity (Sedmik 1963; O'Connor 1964). Ground penetrating radar may, in some circumstances, be used to identify shallow channels.

Examples: Sierra Nevada (Lindgren 1911; Yeend 1974); Victoria (Knight 1975).

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

Silver-Bearing Polymetallic Vein

Model Description: Sangster (1984).

Approximate Synonyms: Felsic intrusion-associated silver-lead-zinc veins, low/high sulfidation hydrothermal.

Description: Quartz-carbonate veins with base metal sulphides and silver, and/or gold and tin related to hypabyssal granitic intrusions in sedimentary, igneous and metamorphic terranes.

General References: Sangster (1984).

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 porphyroaphanitic.

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

Associated Deposit Types: Tin/tungsten veins, mesothermal gold veins, tin-gold polymetallic veins, porphyry copper-molybdenum, porphyry molybdenum low-fluorine, disseminated tin, polymetallic replacement, skarns, epithermal deposits, greisens, etc.

Mineralogy: galena, sphalerite, pyrite ± tetrahedrite-tennantite ± chalcopyrite ± arsenopyrite ± silver ± gold, sulphosalts ± argentite ± copper-lead 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 iron-manganese oxide stains. Zinc and lead carbonates and lead 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 Island (Williamson & Rogerson 1983); St Anthony (Mammoth) (Creasey 1950); Wallapai District (Thomas 1949); Magnet (Cox 1975).

Economic Significance: Silver-bearing lead-zinc veins have been mined for lead, zinc, copper and silver. Some deposits have also served as an important source for gold. Global grade and tonnage data show: 90% of deposits contain more than 290t, 50% contain more than 7 600t; and 10% contain more than 200 000t of ore. In 90% of deposits the ores contain more than 140g/t Ag and more than 2.4% Pb; 50% of contain more than 820g/t Ag, more than 0.13g/t Au, more than 9% Pb, more than 2.1% Zn and more than 0.89% Cu; 10% of deposits contain more than 4700g/t Ag, more than 11g/t Au, more than 33% Pb, more than 7.6% Zn and more than 0.89% Cu.

APPENDIX 3: REVIEW OF SIGNIFICANT MINING PROJECTS AND AREAS

A3.1 The Bickham Coal Project (November 2003)

The Bickham open cut coal resource is located east of the New England Highway between the townships of Wingen and Blandford **(Figure A-G).** The area includes an old coalmine that operated between the early 1900s and 1930s, and Commercial Minerals Pty Ltd chamotte (naturally occurring flint clay) mine (six pits) that operated between 1970 and 1994. There are two exploration licences over the area (EL 5888 and EL 5306) held by the Bickham Coal Company Pty Ltd.

The economic seams in the Bickham area are contained within the Koogah Formation. There are seven potentially economic coal seams that vary in thickness from 0.5 to 11.5 metres with the lowest three seams containing 75% of the resources. Ash (a.d.) varies from 4% to 9% in the three lowest seams and 15.5% to greater than 30% in the upper seams. A higher than average iron content in the ash of the Bickham coal may prove to be problematic. Total sulphur (a.d.) varies between 0.29% to 0.52% in all but the top seam with 8.8% sulphur (a.d.). Potential open cut resources in the area are 40 million tonnes with an average stripping ratio of 4.2:1. Preliminary estimates of underground/highwall coal resources are expected to be of the order of tens of millions of tonnes.

The area is structurally complex with NW-SE trending regional folds having variable plunges and limbs dipping at high angles (greater than 70 degrees in places). Large-scale faults are also thought to exist in the Bickham area. A feature of the area is ancient deep cindering along seam subcrops and deep weathering oxidation is common.

The company has submitted a Review of Environmental Effects that was on public display October-November 2002. Bickham Coal Company Pty Ltd proposes to extract approximately 25 000 ROM tonnes of coal from a bulk sampling site located within EL 5306. Bulk sampling will allow a better understanding of the performance of the coal during extraction, the practicalities of physical separation of 'problem horizons' and the efficiencies of beneficiation in reducing sulphur and iron in ash.

A3.2 Creek Resources Coal Project (November 2003)

Exploration Licence (EL) 5993 was granted to Creek Resources Pty Ltd in 2002. The licence is located five kilometres southwest of Werris Creek and covers an area of 531 hectares including the now closed Werris Creek Colliery **(Figure A-G).**

The company has drilled 34 boreholes with a combined total of 2 080 metres (cored 308 metres) of drilling. All but five boreholes have been geophysically logged with a full suite of tools, with some holes including downhole televiewer and dip meter. Piezometers were installed in several holes to enable assessment of hydrological properties of the interburden strata and coal seams.

The exploration undertaken by Creek Resources Pty Ltd has identified potential in situ open cut coal resources of approximately ten million tonnes. The nine coal seams in the area vary in thickness from 0.40 to 8.0 metres. Coal quality is summarised as moisture (a.d.) 3.2-6.6%, Sulphur 0.25-0.35%, HGI 44-54 and SE 6 250-7 050 kcals/kg. Raw ash (a.d.) ranges from 5.1-19.2%.

The deposit is contained within a synclinal structure that accommodates nine coal seams in the Willow Tree Formation, part of the Werris Creek Coal Measures. The coal measures are early Permian and stratigraphically the unit is the equivalent of the Maules Creek Formation. The area contains several faults with a maximum displacement of less than two metres and several igneous intrusions affect the area.

Selective mining of the Werris Creek coal seams should produce very low sulphur, export thermal coal. A small quantity of contaminated coal requiring washing could be sold as domestic power station fuel.

A3.3 The Woodsreef Magnesium Project (November 2003)

The Woodsreef mine, which closed in 1983, is located 17 kilometres east of Barraba **(Figure A-H).** Between 1918 and 1983, the mine produced 550 000 tonnes of white, chrysotile asbestos from 100 million tonnes of serpentinite ore, leaving millions of tonnes of tailings.

The tailings dump has been confirmed, by 15 vertical air-core drillholes, to contain 24.2 million tonnes of serpentinite tailings with an average 23.1% Mg (38.3% MgO). The contained magnesium content is 5.5 million tonnes. Chemical analyses were consistent throughout the dump.

The Woodsreef Asbestos mine tailings represent a very large potential source of magnesium. Current forecasts for future global magnesium requirements by the end of 2020 range widely but could be upwards of 2 400 000 tonnes per year from a current production capacity of 536 000 tonnes per year. This increase in demand is principally driven by the need for the automotive industry to reduce exhaust emissions contributing to carbon dioxide build-up in the atmosphere. Reduction in fuel consumption, through the reduction in vehicle weight, is seen as one solution to the problem. Magnesium alloys used in this capability, without sacrificing strength and safety, add to the potential for recycling that may become a future requirement of automotive manufacturers. From an average of three kilograms of magnesium per vehicle today, the aim is to reach at least 100 kilograms per vehicle.

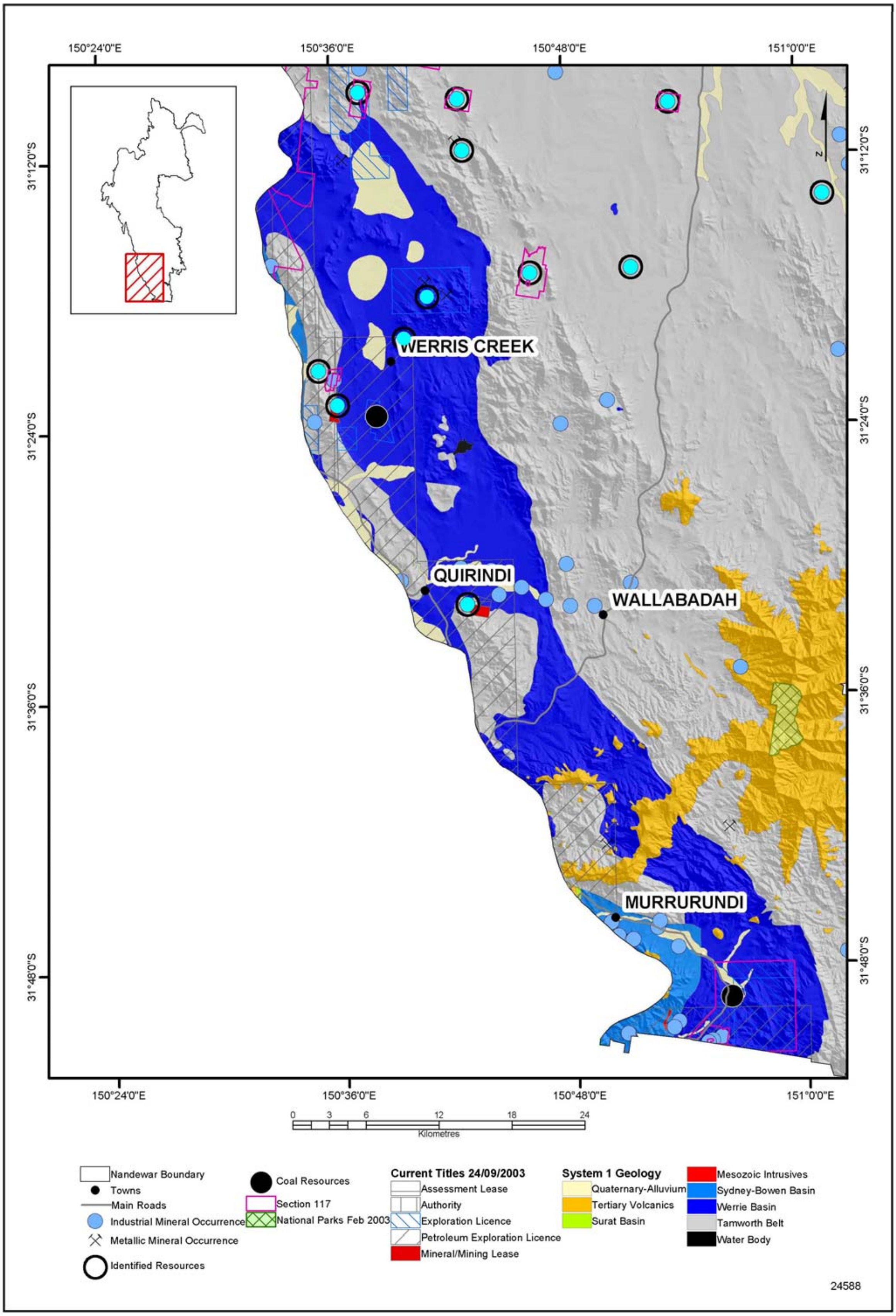

Figure A-G. Geology and Tenure, Werrie Basin

A hydrometallurgical-electrowinning process is planned to extract the magnesium from the tailings. The pre-feasibility study carried out by Bateman Brown & Root (Asia-Pacific) indicated that the required refinery would cost A$680 million (2003) and employ 350 people.

The biggest cost factor in the production of magnesium using the hydrometallurgical-electrolytic process is the energy requirement. To minimise costs, a study was carried out by Gutteridge, Haskins & Davey to examine the alternatives of either locating the refinery at the Woodsreef Mine site or locating the refinery in the Hunter Region alongside an electricity generating plant. The former would require a new electricity transmission line from Tamworth to the mine site. The latter would require restoration of the Tamworth-Barraba railway line with a branch line to the mine site. A variety of options are under consideration resulting from this study.

A staged program of activities was commenced in the 1990's by the Department of Mineral Resources and the former Department of Land and Water Conservation and Environment Protection Authority to minimise on-site and off-site effects resulting from previous mining activities at Woodsreef. The plan to use the tailings as a source of magnesium will assist in the clean up of the site, eliminating a potential environmental and safety hazard. The refinery location will determine where the residues from magnesium-extracted tailings are to be located. Residues will be made up of a benign iron-silica material. The open pits would provide the most practical location in the mine area.

A3.4 Attunga State Forest and Adjacent Areas (November 2003)

Current Titles

Current exploration titles over the Attunga area include EL 5869, ML 204 and PLL 3683, all held by Goldrap Pty Ltd. Goldrap Pty Ltd also holds ML L38 for limestone and a private mining agreement for serpentine in the area.

Unimin Lime (NSW) Pty Ltd holds ML 1470 and ML 1394 for limestone and marble quarrying at the Jacksons and Sulcor quarries, northwest of the Inlet Monzonite skarn deposits.

Tundi Pty Ltd holds MC 143 for serpentine.

Deposits

The following deposits are found within the Attunga area (only major deposits listed**)** **(Figure A-I)**:

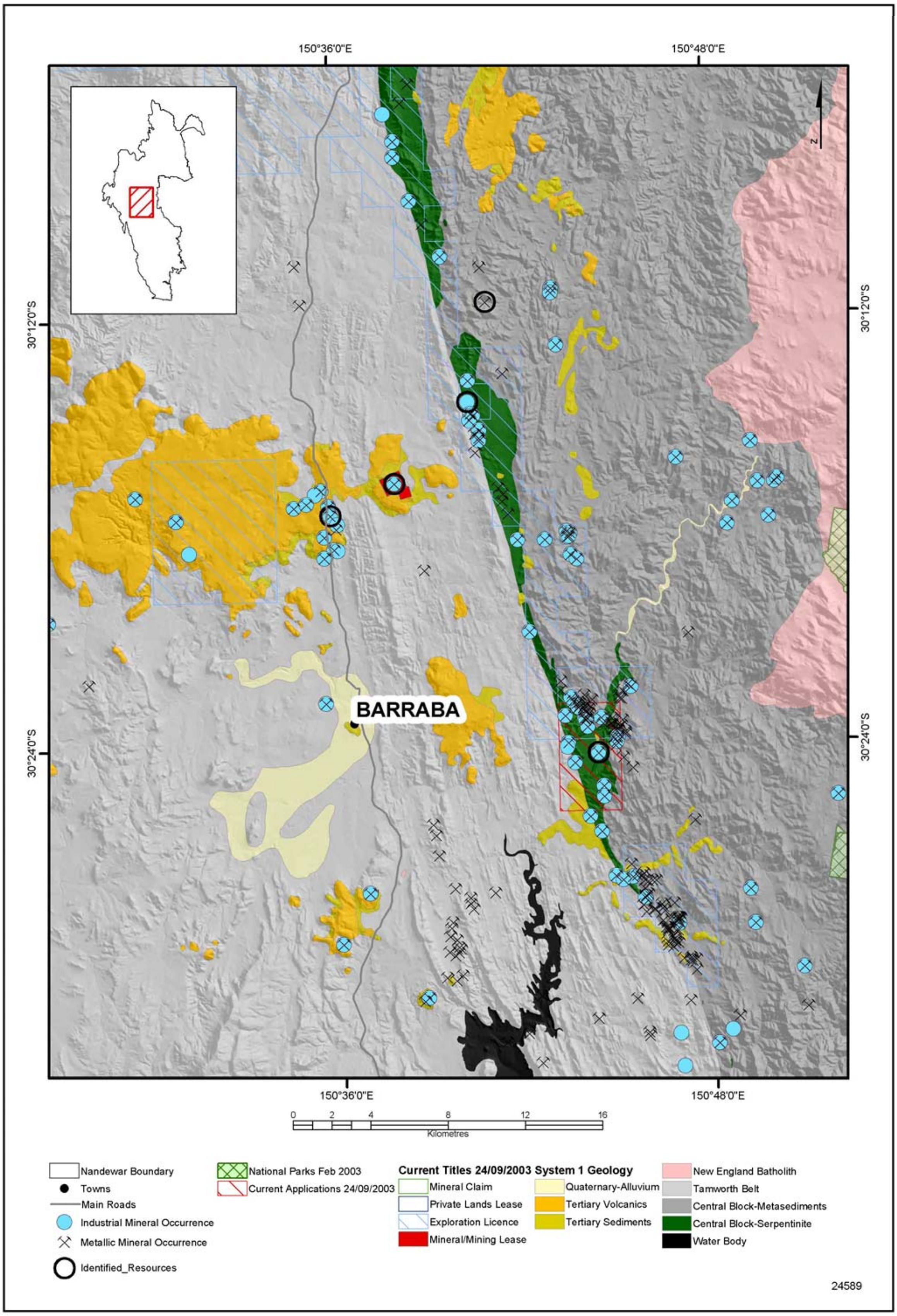

Figure A-H. Geology and tenure, Barraba area

- Attunga scheelite (southern skarn) deposit and tungsten-molybdenum skarns surrounding the Inlet Monzonite (Prospects W2-W6)
- Attunga copper (northern skarn) mine
- Mt Paterson gold mine
- Namoi copper mine
- Betts molybdenite deposits
- Attunga molydenite deposit
- Kensington scheelite deposit
- Kensington copper-gold deposits (the Attunga Creek gold mine)
- the Jacksons and Sulcor quarries

Mining History

The Attunga copper mine, to the north of the Inlet Monzonite, was discovered in 1902 with sporadic mining being undertaken between 1904 and 1916. The ore was comprised of copper, gold and silver skarn with minor molybdenum and bismuth recorded. The ore occurred as irregular lenses and bunches replacing favourable beds of garnet (prograde) skarn and along faults and fractures, with large blocks of recrystallised, unmineralised limestone. Mining recovered at least 1 600 tonnes of high grade copper ore at 6.2% Cu and 7.75g/t Au from open cut and underground workings that went to a depth of 79 metres (Fisher 1943). Production is recorded at 140 tonnes of copper and 12.44 kilograms of gold (Weber et al. 1978). The shaft was deepened during World War II when the mine was reopened briefly, but only minor production was undertaken.

The Attunga scheelite (or southern skarn) deposit was discovered in Horse Arm Creek in 1968 by the Attunga Mining Corporation Pty Ltd (Endurance Mining Company). Five other tungsten-molybdenum skarn deposits, surrounding the Inlet Monzonite (Prospects W2-W6), were subsequently delineated by this company. No further exploration of significance has taken place on prospects W5 and W6 to the southeast and south of the Inlet Monzonite since their discovery.

Following World War I, the Mt Paterson Gold Mine was worked unsuccessfully up until 1927. Only 50 tonnes were extracted from the mine, yielding 90 grams of gold with a grade of 1.86g/t Au (Department of Mines 1926). Only minor production was recorded from a small trial shipment at the Namoi copper mine, which was discovered in 1903 (Carne 1908).

The Attunga Creek molybdenite deposits were prospected between 1914 and 1920 but had been recognised since 1906. Prior to 1918, 0.86 tonnes of molybdenum was removed from an unknown tonnage of ore, with an estimation of a few hundred tonnes of ore having been extracted from this area. Numerous open cut and shafts are noted in the area and include small underground workings (Challenger Resources & Meszaros 1983).

The Betts molybdenite deposits were worked during World War I for molybdenite with an estimated 0.5 tonnes of 2-3% Mo have been extracted. In the past the deposit has been worked for scheelite, with production recorded as 1.4 tonnes of WO_3 (Weber et al. 1978).

The Attunga Magnesite deposit is comprised of extensive magnesite stockwork veins within serpentinite. Over 100 000 tonnes of magnesite have been obtained from the deposit via open cut operations, with one large and several smaller quarries (Challenger & Meszaros 1983).

Identified Resources

Drilling of the scheelite (southern) skarn by Attunga Mining Corporation Pty Ltd led to the company estimating an initial indicated reserve of 500 000 tonnes of ore containing 1.4% wolfram metal after their first two drill holes assayed 0.8% wolfram over a 126 metres depth and 1.44% over a 183 meter depth. Further drilling led to downgraded calculations of 220 000-240 000 tonnes of Proven ore at 0.35% WO_3 and 280 000 to 305 000 tonnes of Inferred and Potential reserves at 0.35% WO_3. However, the drilling programmed failed to delineate the northern and western limits of the skarn.

A low grade deposit, with three small higher grade masses, at the scheelite (southern) skarn was delineated by Attunga Mining Corporation Pty Ltd, Endurance Mining Corporation NL and Geopeko Ltd, with a total Inferred resource of 13 600 tonnes at 2.8% WO_3, 0.337% Mo using a 0.5% WO_3 cut-off. The tungsten-molybdenum W5 prospect was estimated to have 162 000 tonnes of skarn with a possible average of 0.182% WO_3 (Attunga Mining Corporation et al. 1970).

Challenger Resources Pty Ltd (Doyle et al. 1981) reassessed Attunga Mining Corporation Pty Ltd data and calculated a resource of 260 500 tonnes at 0.82% WO_3 and 0.136% Mo when using a 0.25% WO_3 cut-off grade.

Brown et al. (1992) indicated a total contained resource for tungsten-molybdenum mineralisation associated with the Inlet Monzonite of 113 600 tonnes at 2.8% WO_3 and 0.337% Mo.

Remaining open cut reserves at the Attunga copper mine were estimated by the Attunga Mining Corporation Pty Ltd at 10 000-15 000 tonnes at 2-3% Cu (Department of Mineral Resources 1968-1970; Attunga Mining Corporation et al. 1970). A remaining resource was recalculated for the Attunga copper mine of 20 000 tonnes at 4-10% Cu, 0.6-15ppm Au, 100-200ppm Ag, 0.1-1.0% Mo and 0.2% Bi (Doyle et al. 1981).

A 60 hole percussion drilling program was undertaken by the Attunga Mining Corporation Pty Ltd at the Kensington deposits. Challenger Resources & Meszaros (1986) defined a resource from the Attunga Mining Corporation Pty Ltd data, of 4.2 million tonnes at 0.174% WO_3 using a cut-off grade of 0.1% WO_3 at the Kensingston scheelite and gold prospects.

Geology

Oxidised, unfractionated I-type granites of the southern Moonbi Supersuite have intruded Tamworth Group sedimentary sequences (Tamworth Belt) **(Figure A-I).** These granites are associated with molybdenum, tungsten, copper and gold ± silver-bismuth mineralisation both hosted within the granite as veins and disseminations and in the country rock as skarn and veins. These deposits include:

- tungsten-molybdenum skarn and copper-gold skarn and vein deposits associated with the Inlet Monzonite;
- skarn and granite-hosted vein deposits associated with the Moonbi Monzogranite;
- granite-hosted vein deposits of the Attunga Creek Monzogranite; and
- skarn-like, and vein deposits where the mineralisation style is unknown at the Kensington deposits.

Roberts (1982) defined five metamorphic zones within the sediments of the Tamworth Group surrounding the Inlet Monzonite and Moonbi Monzogranite. Two skarn deposits were noted by Roberts associated with the Moonbi Monzogranite, one of which had previously been identified as uneconomical by the Attunga Mining Corporation et al. (1970). The zones are correlated with distance from the contact of both granites, defining the limit of the metamorphic aureoles at two kilometres for the Inlet Monzonite and three kilometres for the Moonbi Monzogranite.

Skarn is developed both within the sedimentary and volcanic rocks of the Silver Gully Formation (Tamworth Group) and developed within the Inlet Monzonite. Skarn developed in the monzonite is in places rich in scheelite constituting up to 50% of the rock (Attunga Mining Corporation et al. 1970). Diopside rich skarn, with diopside accounting for 30-40% of the rock, is also developed within the monzonite. Skarn developed in the monzonite grades into skarn developed in the wallrocks of the Tamworth Group. The Inlet Monzonite also hosts a small skarn roof pendant (Challenger & Meszaros 1983).

Tungsten-molybdenum skarn occurs immediately adjacent to, and surrounds, the Inlet Monzonite, the most prospective of these skarns is the Attunga scheelite (southern) skarn 800 metres south of the Attunga copper mine. Rock samples assayed from prospect W5 at 0.32% WO_3 and from prospect W6 at 0.74% WO_3 (Attunga Mining Corporation et al. 1970). The skarn has developed in calcareous rocks of the Silver Gully Formation and consists of andradite garnet-diopside ± epidote-quartz-zoisite-magnetite-hematite-calcite. Locally the development of this skarn is associated with garnet-rich skarn where garnet can constitute up to 70% of the rock (Attunga Mining Corporation et al. 1970). Copper, gold and silver are also noted to occur in the tungsten-molybdenum skarns (Challenger Resources & Meszaros 1986). The western and northern extensions of the Attunga scheelite (southern) skarn have not been defined, but it is possible that the tungsten-molybdenum skarn grades into or overprints the copper-gold skarn 800 metres to the north.

The Attunga copper mine, to the north of the scheelite (southern) skarn, comprises grossular garnet-diopside-epidote skarn with associated copper-gold mineralisation. Tungsten and molybdenum as well as silver and bismuth mineralisation has also been noted in the copper-gold skarn (Fisher 1943; Suppel 1968; Snape 1994). The ore is hosted in zones of shearing/faulting and as irregular lenses in skarn next to unmineralised recrystallised limestone. The ore body is northerly plunging with an outcrop strike of 49 metres (Suppel 1968). Mining was undertaken in the oxidised section of the ore body with sulphides remaining at depth (Doyle et al. 1981). The 'P' shaft occurs 150 metres to the south of the copper mine. The deposit comprises garnet-rich skarnified veins hosted by andesitic country rock (Brown & Brownlow 1990).

The Mount Paterson gold mine, to the east of the Inlet Monzonite, consists of a north-south trending brecciated zone of andesite with skarn fill hosting a low grade copper-gold as well as silver, molybdenum, bismuth, tungsten mineralisation (Geoservices Pty Ltd 2000). The breccia consists of andesite fragments rimmed by epidote which have been cemented with diopside and later andradite garnet and wollastonite-calcite skarn. East-west trending quartz veins cut the breccia, which have given highly anomalous assays up to 42g/t Au, 220ppm Bi, and 60ppm Te (Renison & Gold Fields Exploration 1985). A brecciated 15 metre wide shear zone also trending north-south, to the west of the gold mine gave highly anomalously gold grades with up to 17.77ppm (New England Gold 1986).

The Namoi Gold mine deposit, to the northeast of the Inlet Monzonite, comprises a northeast trending quartz vein varying from 0.15 metres to 0.6 metres in width, hosted in quartz-veined metamorphosed sediments and andesite. Grades of 10.8% Cu, 3.4ppm Au and 23.7ppm Ag were reported, with associated very high bismuth contents (Carne 1908; Trigg 1986; Geoservices 1999).

Allanite (orthite) has been reported in the skarns at Attunga, however there has been no systematic exploration for rare earth elements (Attunga Mining Corporation et al. 1970; Challenger Resources & Meszaros 1986).

Within the Moonbi Monzogranite, mineralisation is associated with quartz veins or disseminated within the granite itself. The Betts molybdenite deposits occur as quartz veins and leucocratic dykes within the Moonbi Monzogranite. These deposits are associated with tungsten, molybdenum, copper and gold mineralisation (Weber et al. 1978; Geoservices 2000). Smaller quartz vein deposits are associated with molybdenite and tungsten mineralisation and include the Moonbi deposit and the Russ and Edwards claims/Potters mine (Brown et al. 1992).

The Attunga Creek molybdenite deposit and strike-equivalent deposit, consist of quartz veins and stockworks near the margin of the Attunga Creek Monzogranite. The veins are up to 40 centimetres wide and consist of disseminated molybdenite, scheelite and pyrite. Not all veins are molybdenite and/or scheelite bearing (Weber et al. 1978). An assay of the veins gave 2.0% Mo, 6.6ppm Au, 5.1ppm Ag, 866ppm W and 0.22% Bi (Brown et al. 1992).

Wollastonite-garnet skarn has been located 3.5 kilometres north of the Inlet Monzonite (Ray et al. 2003) and it is possible that this skarn is associated with the Attunga Creek Monzogranite.

The Kensington deposits are associated with sporadic tungsten-molybdenum-gold mineralisation occuring along a 4.6 kilometre strike from the Attunga Creek to the south to the Spring Creek to the north. The ore body is approximately parallel to the serpentinites and fault splays of the Peel Fault System (Challenger Resources & Meszaros 1983). The Kensington deposits comprise disseminated scheelite and molybdenite in veins within unaltered limestone, siltstone and sandstone (Challenger & Meszaros 1986). Scheelite was initially detected in limestone mullock from the shaft of the old gold mine with the Attunga Creek gold mine now regarded as part of the Kensingston deposits (Challenger & Meszaros 1983).

The Tamworth Group hosts large economic deposits of limestone and marble, which are currently being mined at the Jacksons and Sulcor quarries.

Geological Models for Mo-W-Cu-Au skarn mineralisation

Two geological models have been put forward to explain the juxtaposition of tungsten-molybdenum and copper-gold skarn mineralisation. The first model is based on a zoned polymetallic mineralising system, whereby tungsten-molybdenum mineralisation is developed close to the intrusive body and copper-gold mineralisation distally. With regards to the Inlet Monzonite, tungsten-molybdenum skarn mineralisation is developed within 300 metres of the granite at the scheelite (southern) skarn and surrounding the monzonite, at prospects W2-W6. Copper-gold skarn is located 800 metres to the north of the Inlet Monzonite, and to the east of the granite body as distal copper-gold mineralisation at Mt Paterson and Namoi. The skarn is also zoned vertically with molybdenum mineralisation occurring sporadically below the copper-gold skarn to the north of the Inlet Monzonite and some copper-gold mineralisation noted below the scheelite (southern) skarn. The skarn/granite contact is thought to be shallowly dipping on the northern side of the Inlet Monzonite, which may indicate a greater extension of skarn mineralisation than previously thought and a possibility of new discoveries to the north (Geoservices 1994).

Snape (1994) proposed two separate mineralising events in the Attunga area to explain the juxtaposition of the tungsten-molybdenum skarn and the copper-gold skarn. Through geochemical analysis, Snape found that the copper-gold skarn mineralisation was related to a previously unrecognised dacitic plug located to the north of the granite. The dacite and associated copper-gold mineralisation was proposed to predate the intrusion of the Inlet Monzonite and subsequent tungsten-molybdenum mineralisation. The tungsten-molybdenum mineralisation was thought to be associated with the quartz monzonite phase of the zoned Inlet Monzonite pluton (Challenger & Meszaros 1985; Snape 1994). This model, however, does not taken into account distal copper-gold skarn (Mt Paterson) and vein (Namoi) mineralisation to the east of the Inlet Monzonite.

Potential Resources

Metallic mineral potential resources in the Attunga area include: tungsten; molybdenite; gold; copper; and silver. Industrial mineral potential resources in the Attunga area include: garnet; wollastonite; limestone; marble; and serpentinite.

The Mt Paterson gold mine and associated breccia and the tungsten-molybdenum W6 prospect is partially covered by the property ‘Monrepo’. Geoservices Pty Ltd were denied access to this property during 1994-1995 to undertake stream sediment sampling. As a result, the potential of skarn mineralisation to the southeast of Inlet Monzonite has not been fully explored.

The Attunga State Forest is located immediately to the northwest of the adjoining Monrepo property and covers most of the Inlet Monzonite and the tungsten-molybdenum W5 prospect.

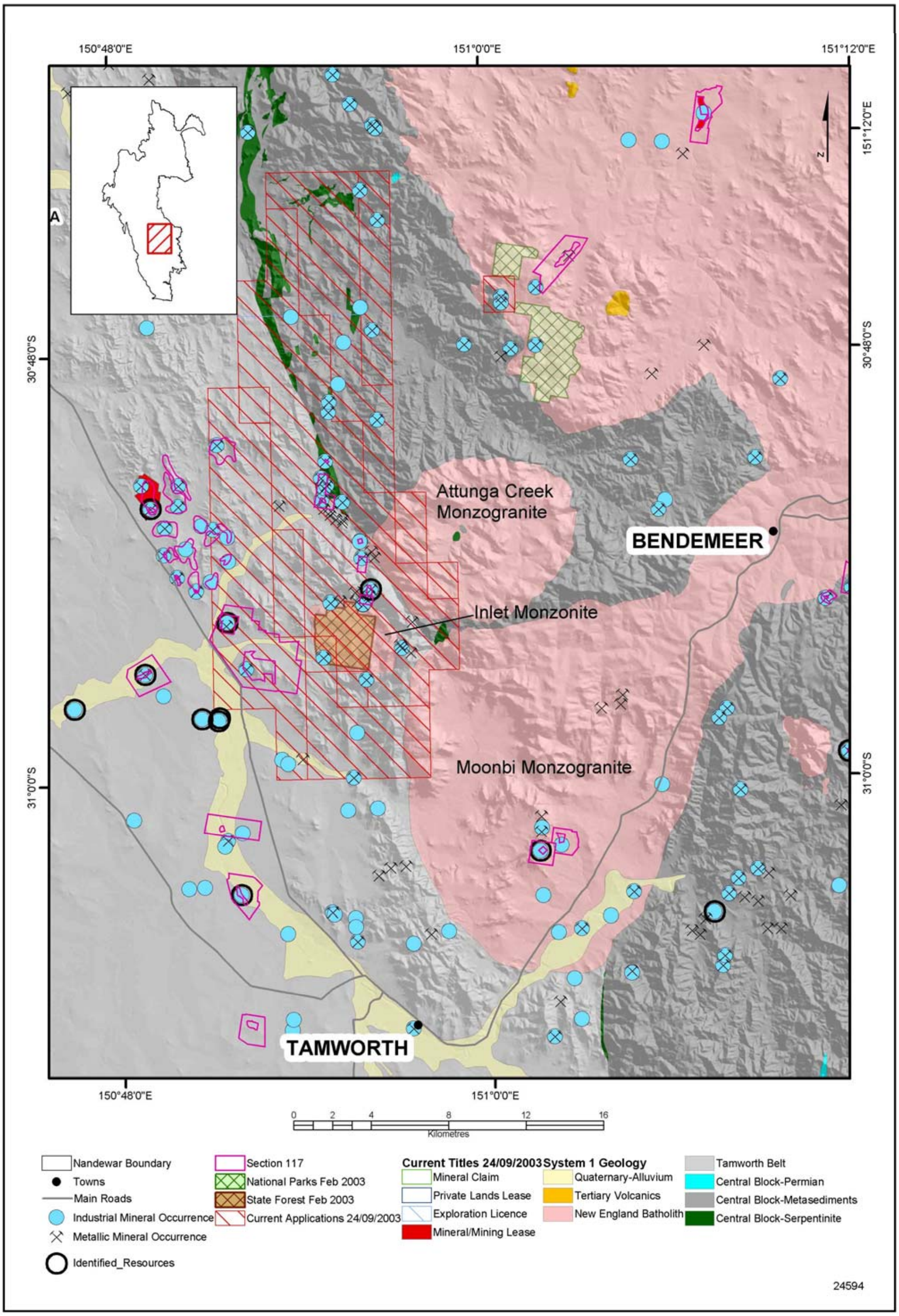

Figure A-I. Geology and Tenure, Attunga area.

APPENDIX 4: MINERAL AND PETROLEUM TITLES AND APPLICATIONS

A4.1 Mining Titles (September, 2003)

Table A-A Mining and Assessment Leases, Nandewar study area

Commodities	Title	Main Holder	Area (ha)	Granted	Expires	Notes (Jan 2004)	Location
Mining Leases							
Diamond, tin	ML6153	Cluff Resources Pacific NL	29.9	31/1/1969	31/1/1989	Renewal pending	SW Inverell
Diamond, gold	MC194	Cluff Minerals Pty Ltd	2	17/10/1996	16/10/2007		Bingara
Diatomaceous earth, diatomite	ML1195	Australian Diatomite Mining Pty Ltd	1.89	27/1/1988	26/1/2009		Barraba
Diatomaceous earth, diatomite	ML1256	Australian Diatomite Mining Pty Ltd	3.75	30/4/1992	29/4/2018		Barraba
Diatomaceous earth, diatomite	ML1217	Australian Diatomite Mining Pty Ltd	1.54	21/9/1989	20/9/2010		Barraba
Diatomaceous earth, diatomite	ML1178	Australian Diatomite Mining Pty Ltd	10.8	11/12/1986	10/12/2007		Barraba
Diatomaceous earth, diatomite	ML1096	Australian Diatomite Mining Pty Ltd	8.34	28/9/1983	27/9/2004		Barraba
Diatomaceous earth, diatomite	ML976	Australian Diatomite Mining Pty Ltd	31.58	31/3/1982	30/3/2024		Barraba
Diatomaceous earth, diatomite	ML975	Australian Diatomite Mining Pty Ltd	106	31/3/1982	30/3/2024		Barraba
Diatomaceous earth, diatomite	MC238	Australian Diatomite Mining Pty Ltd	1	1/7/1999	30/6/2004		Barraba
Diatomaceous earth, diatomite	MC239	Australian Diatomite Mining Pty Ltd	0.365	1/7/1999	30/6/2004		Barraba
Gold	GL5890	Myer, Paul Douglas	1.99	10/6/1970	10/7/2009	(Act 1906)	Bingara
Gold	MC181	Riley, Rodney George	2	31/1/1996	30/6/2006		Bingara
Gold	MC133	Sorenson, Ven	1.2	21/2/1994	20/2/2007		Bingara
Gold	MC134	Sorenson, Ven	2	21/2/1994	20/2/2005		Bingara
Gold	MC165	Miller, Barry Thomas	1.36	30/3/1995	29/3/2005		Nundle
Jade-nephrite	ML791	Barlow, Michael John	17.95	17/10/1979	16/10/07		NE of Nundle
Limestone, dolomite, marble	ML1394	Unimine Lime Pty Ltd	75.01	4/6/1996	3/6/2017		NNW Tamworth
Limestone, marble	ML1470	Unimine Lime Pty Ltd	188.5	29/8/2000	28/8/2021		SE Manilla

Rhodonite	ML1004	Taggart, Alexander Clyde	1.99	25/8/1982	24/8/2006		ESE Manilla
Rhodonite	ML1246	Warden, Oliver Tex	2	16/10/1991	15/10/2012		Nundle
Rhodonite	ML1213	Warden, Oliver Tex	256	31/10/1988	30/10/2003	Renewal pending	Nundle
Sapphire	ML1251	Gemfame Pty Ltd	195.6	19/2/1992	19/2/2012		Inverell
Sapphire	ML181	Wilson, David Brandon	5.822	2/4/1976	1/4/2017		ENE Inverell
Sapphire, corundum, diamond	ML1374	GTN Resources Ltd	150	14/7/1995	13/7/2005		W Glenn Innes
Sapphire, zircon	ML549	Wilson, David Brandon	16.94	7/12/1977	6/12/1998	Renewal pending	ENE Inverell
Sapphire	ML240	Wilson, David Brandon	19.75	21/7/1976	20/7/1997	Renewal pending	ENE Inverell
Sapphire, zircon, corundum	ML1505	Frazier, Ronald Allen	267.6	20/3/2002	21/3/2023		W Glenn Innes
Sapphire, corundum, zircon	ML860	Wilson, David Brandon	55.53	30/7/1980	29/7/2001	Renewal pending	ENE Inverell
Sapphire, zircon	ML881	Rynne, David Colin	17.4	1/10/1980	30/9/2013		ENE Inverell
Sapphire, diamond, zircon	ML1205	Rainville Mining Pty Ltd	192.9	16/6/1988	15/6/2016		WSW Glenn Innes
Sapphire	ML1492	Australian Sapphire Corporation Pty Ltd	134.8	17/8/2001	16/8/2022		W Glenn Innes
Sapphire	ML1142	Wilson Gems and Investments Pty Ltd	24.57	30/7/1985	29/7/16		ENE of Inverell
Sapphire, zircon	ML645	Airlie Brake Pty Ltd	15.1	6/9/1978	5/9/2020		ENE of Inverell
Sapphire, zircon, corundum	MC111	Walker, Noel Thomas	2	15/6/1993	14/6/2003	Expired 10/11/2003	W Glenn Innes
Sapphire, corundum	MC234	Horwood, Dennis George	1.954	2/3/1999	1/3/2004		Inverell
Sapphire, corundum	MC235	Horwood, Dennis George	1.976	2/3/1999	1/3/2004		Inverell
Sapphire, corundum, zircon	MC112	Walker, Noel Thomas	2	15/6/1993	14/6/2003	Expired 10/11/2003	W Glenn Innes
Sapphire	MC182	De Torrens, Bruno Valerio	2	6/2/1996	5/2/2001	Renewal pending	SW Emmaville
Sapphire	PLL1393	Colley, Clive Robert	7.82	27/3/1974	27/3/2015	Act 1924	Inverell
Sapphire	PLL3859	Colley, Clive Robert	15.63	27/4/1974	27/3/2015	Act 1906	Inverell
Serpentine	ML1310	Abra, Edward Lyle	1.805	25/2/1993	24/2/2014		ESE Manilla
Serpentine	MC156	English, Peter Warren	1.95	7/12/1994	6/12/2004		NNE Barraba
Serpentine	MC143	Tundi Pty Ltd	1.96	19/4/1994	18/4/2005		N Tamworth
Zeolites	ML1356	Zeolite Aust. Pty Ltd	96.96	2/8/1994	1/8/2004		Quirindi

Zeolites	ML1395	Castle Mountain Enterprises Pty Ltd	152.8	4/6/1996	3/6/2011		Quirindi
11 minerals (main) kaolin	ML1086	Shinagawa Thermal Ceramics Pty Ltd	8.5	8/6/1983	7/6/2004		S of Barraba
8 minerals (main) tin	ML1312	Green, Ronald Russell	49.31	25/2/1993	24/2/2014		W Uralla
6 minerals (main) sapphire	ML1320	Rainville Mining Pty Ltd	388.3	1/6/1993	30/6/2003	Renewal pending	W Glenn Innes
4 minerals (main) kaolin	PLL1204	Shinagawa Thermal Ceramics Pty Ltd	6.7	21/2/1968	21/2/2008	Act 1924	Barraba
14 minerals (main) molybdenum, tungsten, copper, gold	PLL3683	Goldrap Pty Ltd	11.736	21/2/1968	21/2/2009	Act 1906	N of Tamworth
8 minerals (main) rhodonite	ML1073	Warden, Oliver Tex	103.13	13/4/1984	12/4/2003	Renewal pending	NE of Nundle
12 minerals, (main) copper, gold, molybdenite, tungsten	ML204	Goldrap Pty Ltd	28.33	21/5/1976	20/5/2004		N Tamworth
Assessment Leases							
Commodities	**Title**	**Main Holder**	**Area (ha)**	**Granted**	**Expires**	**Notes**	**Location**
Sapphire, corundum, zircon	AL2	Jesasu Pty Ltd	106.5 ha	15/3/2001	14/3/2006		W Glenn Innes
Zeolites	AL3	Castle Mountain Enterprises	233 ha	31/10/2001	30/10/2006		Quirindi
Zeolites	AL7	Zeolite Australia Pty Ltd	129 ha	29/11/2002	28/11/2007		NW Quirindi

A4.2 Exploration Titles (September, 2003)

Mining Act (1992)

Table A-B. Exploration Licences, Nandewar study area

EL Group	EL No.	Main Title Holder	Units	Grant	Expiry	Comments (Jan 2004)	Location
Group 1-metallic minerals	EL5550	Rimfire Pacific Mining NL	19	27/1/1999	26/1/2004		E Bingara
Group 1-metallic minerals	EL6004	Hibernia Gold Pty Ltd	39	3/10/2002	2/10/2004		Nundle
Group 1-metallic minerals	EL5977	Malachite Resources NL	40	27/8/2002	26/8/2004		SW Inverell
Group 1-metallic minerals	EL6008	Alsop, Peter John	4	14/10/2002	13/10/2004		S Bingara
Group 1-metallic minerals	EL6120	Getz, Arnold	35	27/8/2003	26/8/2005		NE Barraba
Group 1-metallic minerals	EL5960	Alsop, Peter John	3	5/7/2002	4/7/2004		E Bingara
Group 1-metallic minerals	EL5551	Rimfire Pacific Mining NL	14	27/1/1999	26/1/2004		E Barraba
Group 1-metallic minerals	EL6118	Thompson, David	8	19/8/2003	18/8/2005		Nundle
Group 1-metallic minerals	EL5855	Alphadale Pty Ltd	8	10/5/2001	9/5/2003	Renewal pending	N Quirindi
Group 1-metallic minerals	EL5869	Goldrap Pty Ltd	50	12/6/2001	11/6/2005		N Tamworth
Group 1-metallic minerals	EL5550	Rimfire Pacific Mining NL	19	27/1/1999	26/1/2004		E Bingara
Group 1-metallic minerals	EL6114	Mount Conqueror Minerals NL	20	14/8/2003	13/8/2005		NE Torrington
Group 1, Group 6 metallic minerals, gemstones	EL5689	Goldrap Pty Ltd	45	1/2/2000	31/1/2004		SW Bingara
Group 1, Group 6- metallic minerals, gemstones	EL5680	Goldrap Pty Ltd	50	25/1/2000	24/1/2004		NW Bingara
Group 1, Group 6- metallic minerals, gemstones	EL5900	Regional Exploration Management Pty Ltd	100	26/10/2001	25/10/2003	Renewal pending	N Bingara
Group 2-non-metallic minerals	EL5978	Rimfire Pacific Mining NL	18	27/8/2002	26/8/2004		SW Tamworth
Group 2-non-metallic minerals	EL5549	Zeomin Technologies Pty Ltd	2	27/1/1999	26/1/2005		SW Tamworth

Group 2-non-metallic minerals	EL4642	English, Peter Warren	1	11/3/1994	10/3/2004		N Barraba
Group 2-non-metallic minerals	EL5400	Zeolite Australia Pty Ltd	3	11/12/1997	10/12/2003	Renewal pending	NW Quirindi
Group 2-non-metallic minerals	EL5944	Supersorb Minerals NL	16	22/5/2002	21/5/2004		NW Barraba
Group 2-non-metallic minerals	EL5635	Snowmist Pty Ltd	3	14/10/1999	13/10/2003	Renewal pending	SW Nundle
Group 2-non-metallic minerals	EL5490	Pacific Magnesium Pty Ltd	6	10/6/1998	9/6/2002	Renewal pending	Barraba
Group 6-gemstones	EL6106	Rimfire Pacific Mining NL	148	29/7/2003	28/7/2005		SW Bingara
Group 6-gemstones	EL6073	Cluff Minerals (Aust) Pty Ltd	14	2/5/2003	1/5/2005		SW Inverell
Group 6-gemstones	EL3325	Cluff Minerals (Aust) Pty Ltd	22	23/8/1989	22/8/2003	Renewal pending	W Bingara
Group 6-gemstones	EL5998	Pan Gem Resources (Aust) Pty Ltd	7	30/9/2002	29/9/2004		W Glenn Innes
Group 6-gemstones	EL5927	Pan Gem Resources (Aust) Pty Ltd	7	20/3/2002	19/3/2004		W Glenn Innes
Group 6-gemstones	EL4278	Jesasu Pty Ltd	12.6 ha	23/6/1992	22/6/2003	Approved	W Glenn Innes
Group 6-gemstones	EL5352	Cosgrove, Judith Patricia	2	29/9/1997	28/9/2003	Expired 28/9/03	W Glenn Innes
Group 6-gemstones	EL5880	Rimfire Pacific Mining NL		31/7/2001	30/7/2003	Renewal pending	ESE Moree
Group 9-coal	EL5993	Creek Resources Pty Ltd	491 ha	18/9/2002	17/9/2005		NW Quirindi
Group 9-coal	EL5888	Bickham Coal Company Pty Ltd	2040 ha	4/9/2001	27/5/2006		NNE Scone
Group 9-coal	AUTH 216	Department of Mineral Resources	249 square km	9/5/1980	24/4/2003	(ACT 1973)	Curlewis
Group 9-coal	EL5306	Bickham Coal Company Pty Ltd	3040 ha	28/5/1997	27/5/2006		NNE Scone

Petroleum (Onshore Act) 1991

Table A-C. Current petroleum exploration titles

Permit no.	Permit Holder	Expiry
PEL 437	Pangaea Oil and Gas P/L	5 May 2007
PEL 6	Eastern Energy Australia P/L	8 Dec 2005
PEL 238	Eastern Star Gas	2 Aug 2005
PEL 1	Australian Coalbed Methane P/L	10 Feb 2005
PEL 286	Australian Coalbed Methane P/L	10 May 2005

A4.3 Title Applications (September 2003)

Table A-D. Title applications Nandewar study area, September 2003

Commodities	Application No.	Main Applicant	Area	Date	Notes (Jan 2004)	Location
Serpentine	ALA28	Pacific Magnesium Pty Ltd	17.875 km2	18/12/2002	Pending	Barraba
Coal	MLA220	Centennial Hunter Pty Ltd	3.996 ha	15/11/2002	Pending	N Denman
Group 1-metallic minerals	ELA2112	Mount Dockerell Mining Pty Ltd	100 units	29/5/2003	Withdrawn 8/10/2003	ESE Manilla
Group 1, 5, 6-metallic minerals, clay minerals, gemstones	ELA2135	Malachite Resources	42 units	11/6/2003	Withdrawn 13/11/2003	ESE Inverell
Group 3-semi-precious stones	ELA2119	Kapitany, Thomas	1 unit	23/6/2003	Granted 12/12/2003	E Manilla
Group 3-semi-precious stones	ELA2118	Kapitany, Thomas	1 unit	23/6/2003	Granted 12/12/2003	ENE Tamworth
Group 6-gemstones	ELA2149	Bruderhof Communities in Australia Pty Ltd	4 units	18/8/2003	Pending	E Inverell
Group 6-gemstones	ELA2088	Hazelgrove Enterprises Pty Ltd	36 units	18/4/2003	Pending	ENE Inverell
Group 6-gemstones	ELA2078	Wilson Gems and Investments	3 units	28/3/2003	Pending	SW Emmaville
Group 6-gemstones	ELA2063	Big Dam Diamonds Pty Ltd	24 units	24/2/2003	Granted 29/9/2003	SW Inverell
Group 6-gemstones	ELA2059	Berger, Anthony Claude	17 units	17/2/2003	Granted 10/11/2003	ENE Inverell
Group 9 (coal)	ELA2077	Renison Bell Holdings Pty Ltd	800 ha	26/3/2003	Granted Nov 2003	Ashford
Sapphire, corundum	ALA19	Mingem Resources Pty Ltd	2.2 km2	22/7/1999	Pending	W Glenn Innes

APPENDIX 5 TERMINOLOGY FOR ASSESSMENT OF RESOURCE POTENTIAL

A qualitative assessment of the resource potential of an area is an estimate of the likelihood of occurrence of mineral deposits, which may be of sufficient size and grade to constitute a resource.

The mineral potential of an area is assessed for specific types of mineral deposits. For each type of deposit considered in a given area, the mineral potential is ranked in qualitative terms as ‘high’, ‘moderate’, ‘low’, ‘no’ or ‘unknown’, based upon professional judgements of geoscientists involved in the assessment. A qualitative mineral potential assessment is not a measure of the resources themselves.

A general rule of thumb is that the more data there is, the smaller and better defined a single tract becomes, and the higher the certainty. Variations to this include the reliability and understanding of a particular model type (eg for diamonds), changes in international prices (eg for gold) and new developments in technology (eg for coal seam methane). Sometimes more data or exploration can also make tracts become larger.

The rankings are defined as follows:

H: An area is considered to have a high mineral resource potential if the geological, geophysical or geochemical evidence indicate a high likelihood that mineral concentration has taken place and that there is a strong possibility of specific type(s) of mineral deposit(s) being present. The area has characteristics that give strong evidence for the presence of specific types of mineral deposits. The assignment of high resource potential does not require that the specific mineral deposit types have already been identified in the area.

M: An area is considered to have a moderate mineral resource potential if the available evidence indicates that there is a reasonable possibility of specific type(s) of mineral deposit(s) being present. There may or may not be evidence of mineral occurrences or deposits. The characteristics for the presence of specific types of mineral deposits are less clear.

L: An area is considered to have a low mineral resource potential if there is a low possibility of specific types of mineral deposit(s) being present. Geological, geophysical and geochemical characteristics in such areas indicate that mineral concentrations are unlikely, and evidence for specific mineral deposit models is lacking. The assignment of low potential requires positive knowledge and cannot be used as a valid description for areas where adequate data are lacking.

N: The term ‘no’ mineral resource potential can be used for specified types of mineral deposits in areas where there is a detailed understanding of the geological environment and geoscientific evidence indicates that such deposits are not present.

U: If there are insufficient data to classify the areas as having high, moderate, low or no potential, then the mineral resource potential is unknown.

To reflect the differing amount of information available, the assessment of mineral potential is also categorised according to levels of certainty, denoted by letters A to D **(Table 7-A).**

A: The available data are not adequate to determine the level of mineral resource potential. This level is used with an assignment of unknown mineral resource potential.

B: The available data are adequate to suggest the geological environment and the level of mineral resource potential, but either the evidence is insufficient to establish precisely the likelihood of resource occurrence or the occurrence and/or genetic models are not well enough known for predictive resource assessment.

C: The available data give a good indication of the geological environment and the level of resource potential.

D: The available data clearly define the geological environment and the level of mineral resource potential.