Assessment of
Mineral and Hydrocarbon Resources
in the South-West Forest Region
of Western Australia

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MINERALS AND HYDROCARBONS

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SUMMARY

The main Precambrian geological provinces of the South-West Forest region are the south western part of the Archaean Yilgarn Craton, the Proterozoic Albany–Fraser Orogen along the south coast, and the Proterozoic Pinjarra Orogen along the west coast (Map 1, Table 1). Phanerozoic sediments of the Perth Basin overlie the Pinjarra Orogen and are bounded to the east by the Darling Fault. Phanerozoic sedimentary rocks of the Collie, Wilga and Boyup Basins are preserved in fault-bounded grabens and are surrounded by metamorphic rocks of the Yilgarn Craton (Map 2).

A veneer of regolith (Tertiary to Recent in age) covers much of the South-West Forest region. The regolith comprises drainage-related sediments, coast-related sediments and weathering products. Weathering products include laterite and bauxite, lateritic gravel, residual and transported sand, and clay (Map 3).

The SW Forest region is the world's leading bauxite producer. These extensive deposits formed as a result of lateritic weathering of Archaean granites and also of mafic volcanics of the Saddleback Greenstone Belt. Most of the mineralisation is in State Forest, and because of the risk of spreading dieback disease, all exploration and mining activities must be carefully planned.

The four currently operating bauxite mines are Jarrahdale, Huntly (incorporating the previous Del Park mine), Willowdale and Saddleback. Following crushing, the ore from these mines is transported by train or conveyer belt to the Kwinana, Pinjarra, Wagerup and Worsley refineries respectively. During 1996, 8.246 Mt of alumina valued at $1968 million was produced from these refineries. In addition 24,309 kg of gallium valued at $9.8 million was produced as a byproduct. Proved and probable reserves are 1052 Mt with additional resources of 1107 Mt in the measured and indicated categories and 653 Mt in the inferred category; the average grade of these resources is greater than 27.5 % available Al_2O_3.

The Collie Coalfield is the only commercial producer of coal in the State. Coal is mined by open cut methods, and in the year 1996, 5.8 Mt of coal valued at $268.4 million was produced from the Collie Coalfield. Proved and probable resources in the Collie Basin total approximately 2400 Mt. Additional proved and probable coal resources in the South-West Forest region include 264 Mt in the Wilga Basin, 90 Mt in the Boyup Basin and 600 Mt in the Vasse Shelf.

The Boddington mine in the Saddleback Greenstone Belt is the second largest gold producer in Australia. Lateritic gold mineralisation has been mined by openpit methods at the Boddington mine by Worsley Alumina and the BGM group of companies since 1987, and at the adjacent Hedges mine by Hedges Gold Pty Ltd since 1988. Drilling of the Boddington deposit has located a number of bodies of supergene (ie oxidised) and primary Archaean gold–copper mineralisation(see Appendix B). Some high grade primary mineralisation has in the past, been mined by underground mining techniques, but most of the ore is low grade and will continue to be mined by openpit methods. Total production from the Boddington–Hedges mines in the year 1996 was 13.6 t gold valued at $217.0 million. Production between 1987 and the end of 1995 for the Boddington and Hedges Mines was 131.4 t gold from 73

Mt of ore. Indicated and measured resources for Boddington at end 1995 totalled 182.9 Mt at 1.08 g/t with additional inferred resources of 74.1 Mt at 1.0 g/t; for Hedges, indicated and measured demonstrated resources as at the end of 1995 were 4.53 Mt at 1.25 g/t.

Heavy mineral sands production from the Capel Shire and Bunbury City Local Government areas during 1996 was valued at $269 million. Most of this production came from the Swan Coastal Plain to the west of the South-West Forest region. Heavy mineral bearing strandlines on the Swan Coastal Plain which are partially within the South-West Forest region include the Yoganup–Happy Valley strandlines and the Waroona Shoreline North and Waroona Shoreline South. Estuarine/fluviatile heavy mineral sand deposits (eg Beenup) and deposits associated with strandlines on the Scott Coastal Plain (eg Jangardup) are significant heavy mineral sand resources within the South-West Forest region. Production at Jangardup commenced in 1993 and at Beenup in 1996. The Beenup project is expected to produce 600 000 t per annum of ilmenite and 20 000 t per annum of zircon which will make the South-West Forest region a very significant producer of heavy mineral sands.

The Greenbushes pegmatite is one of the world's largest producers of tantalum and lithium. Most production to date has come from weathered pegmatite and alluvial deposits, but mining of the hard rock pegmatite by deep openpit methods commenced in 1992 when the emphasis changed from tin to tantalum production. Spodumene is mined from a separate open-pit. A new lithium carbonate plant has recently been commissioned and is expected to produce 5000 t per annum of lithium carbonate powder. In the year 1996, Greenbushes produced 286 t of tantalite valued at $26.0 million, 148 t of cassiterite valued at $2.5 million and 131 900 t of spodumene (4.92% Li_2O) valued at $17.1 million.

Kaolin (halloysite) suitable for use in high-grade ceramics is mined by open-cut from the weathered portion of the Greenbushes pegmatite. In the year 1996, 400 t of kaolin valued at $58 000 was produced.

Other mineral resources within the South-West Forest region include deposits of beryl, mica and felspar in pegmatites, vanadium-bearing titaniferous magnetite in lateritised gabbro, iron-bearing laterite, graphite, kyanite, silica sand, talc, and peat.

A large natural gas resource in the Whicher Range is currently being investigated to determine if the gas can be extracted economically.

Assessment of potential mineral resources has shown that within the South-West Forest region there is potential for 13 metalliferous types of deposits, 5 industrial types, and 3 types of deposits for energy resources. Within the South-West Forest region there is potential for the following types of deposits:

- metalliferous deposits: lateritic-type bauxite, lateritic/saprolite gold, Archaean/Precambrian gold, rift-related epithermal gold, placer gold, shoreline-fluviatile placer titanium (heavy mineral sands), rare-metal pegmatite, alluvial tin and tantalum, synorogenic/synvolcanic nickel-copper-chromium-platinum, lateritic/saprolitic nickel, vanadiferous titaniferous magnetite, banded iron-formation, volcanic massive sulphide,

- industrial minerals deposits: silica sand and quartzite, clay, pegmatite-related industrial minerals, graphite, kyanite,

- coal, hydrocarbons, peat/lignite.

The host rocks and geological setting for each of these deposit types are summarised under 'Potential mineral and hydrocarbon resources', and the models are described in detail in Appendix B. Mineral potential tracts were defined for each of these deposit types (Figs 2 - 22).

The mineral potential of the region was summarised in a weighted composite map (Map 9, Table 4) which highlights the significance of extensive areas with potential for bauxite, laterite/saprolite gold, Archaean/Precambrian gold over the Balingup and Jimperding/Chittering, and the Archaean granite-greenstone belts. The map also highlights the tracts for heavy mineral sands and coal in the southwest part of the region over the Perth Basin and the Leeuwin Complex, and for epithermal gold along the east flank of the Darling Fault.

Within each tectonic region, there is potential for the following deposit types:

- Balingup Complex — for deposits of bauxite (maximum weighted score in this tectonic region for bauxite is 144 (refer explanation below); includes tracts of high and moderate-high potential), lateritic/saprolitic gold (126; h, m-h), rare-metal pegmatites (90; h, m-h), synorogenic/synvolcanic nickel–copper–chromium–platinum (108; h, m), Archaean/Precambrian gold (108; m-h), lateritic nickel (90; h, m-h), epithermal gold (84; m-h), silica sand and quartzite (72; h), vanadiferous/titaniferous magnetite (72; h, m-h), alluvial tin and tantalum (54; h, m), placer gold (48; m-h), pegmatite-related industrial minerals (36; m-h, m), clay (36; m-h), graphite (24; m-h) and kyanite (24; m-h);
- Jimperding/Chittering Complex — for deposits of bauxite (144; h, m-h), lateritic/saprolitic gold (126; h, m-h); Archaean/Precambrian gold (162; h, m-h), epithermal gold (126; h, m-h), synorogenic/synvolcanic nickel–copper–chromium–platinum (108; h, m), lateritic nickel (90; h, m), vanadiferous/ titaniferous magnetite (72; h, m), silica sand and quartzite (72; h), clay (36; m-h), placer gold (48; m-h), pegmatite-related industrial minerals (36; m-h, m), graphite (24; m-h) and kyanite (24; m-h);
- Archaean granite/greenstones of the Yilgarn Craton — for deposits of bauxite (144; h, m-h), lateritic/saprolitic gold (126; h, m-h), Archaean/Precambrian gold (162; h, m), epithermal gold (126; h, m), titaniferous and vanadiferous magnetite (72; h, m-h), clay (36; m-h), pegmatite-related industrial minerals (36; m-h, m);
- Biranup Complex — for deposits of bauxite (144; h, m-h), lateritic nickel (30; m), silica sand and quartzite (72; h), clay (36; m-h), placer gold (48; m-h), graphite (24; m-h), and kyanite (24; m-h);
- Nornalup Complex — for deposits of bauxite (144; h, m), clay (36; m-h, m), silica sand (48; m-h), and pegmatite-related industrial minerals (36; m-h, m);
- Leeuwin Complex — for deposits of heavy mineral sands (126; h, m-h);
- Collie Basin — for deposits of coal (108; h), silica sand (72; h), clay (36; m-h) and

bauxite (144; h, m);

- Perth Basin — for deposits of heavy mineral sands (126; h, m-h), coal (108; h, m-h), and silica sand (48; m-h).

To assist with land use decisions, the mineral tract maps were also combined (overlain) to produce another three summary maps of mineral potential - ie composite mineral potential (Map 7), cumulative mineral potential (Map 8), and weighted cumulative mineral potential (Map 10).

1 INTRODUCTION

Known mineral resources and potential (undiscovered) mineral resources of the South- West Forest Region of Western Australia have been assessed as part of the Comprehensive Regional Assessment (CRA) of environment, heritage, social, and economic values in the region, leading to the development of a Regional Forest Agreement between the Commonwealth and State governments. The South-West Forest region of WA is also referred to in this report as the 'region'.

Mineral resources were assessed on a regional scale of 1:250 000 by the professional staff of the Geological Survey of Western Australia (GSWA) and the Bureau of Resource Sciences. The assessment team also included geoscientists who were familiar with the geology and resources of the region from the minerals industry and one from a research institution.

Prior to the assessment of mineral resources, the Geological Survey of Western Australia undertook the major task of assembling the available geoscientific data for the region. Part of the task was to translate hard-copy data into electronic formats suitable for Geographic Information Systems (GIS) processing. Assembled data on which the mineral resource assessment is based include:

- a spatial index of mineral exploration activity and geochemical anomalism, that provides standardised information on the type of exploration activity including geochemical and geophysical surveys, type of drilling, number of holes, number of geological samples, elements analysed, etc.
- an updated mineral occurrence database (WAMIN) for the region which could be used to recognise district-scale controls on mineral occurrences and deposits,
- estimates of known in-ground mineral resources in GIS format linked to GSWA's MINEDEX database,
- a seamless coverage of digital 1:250 000 geological maps for regolith and solid geology, including structural elements, and
- magnetics and Landsat images.

The sources for the above data include over 1500 reports on exploration programs conducted in the area.

2 LEGISLATION AND REGULATIONS RELEVANT TO THE MINING AND PETROLEUM INDUSTRIES IN WESTERN AUSTRALIA

Most mining and mineral exploration in Western Australia is carried out under the provisions of the *Mining Act 1978 (and amendments);* and the *Mines, Safety and Inspection Act 1994* administered by the Department of Minerals and Energy (DME), Western Australia. Some major mining developments, which are carried out under State Agreement Acts, are administered by the Department of Resources Development.

The *Mining Act* contains provisions which cover the application, processing, approval and procedures for exploration and mining, surrender of mining titles, conditions of access to public and private land, payment of royalties and settlement procedures for title disputes. The *Mines, Safety and Inspection Act* covers occupational health and safety requirements for the mining sector. State Agreement Acts are essentially mining development contracts between the developer and the Government, ratified by Parliament. They include conditions and obligations specific to an individual project. These include provisions requiring detailed environmental investigation, monitoring and reporting for the duration of each project. Reporting is usually on a three year cycle of two annual reports and a detailed triennial report, in which past performance is evaluated and plans for the next three year period are put forward.

Petroleum exploration in Western Australia is governed by three Acts but only one of these, The *State Petroleum Act 1967,* covering operations on land, islands and internal waters, is applicable to the South-West Forest region. The *Schedule of Onshore Petroleum Exploration and Production Requirements 1991* covers environmental and safety restrictions related to petroleum exploration and production.

There are three categories of land open for mining: Crown Land, Public Reserves, etc. and Private Land.

Tenements available under the *Mining Act 1978* include Prospecting Licences, Special Gold Prospecting Licences, Exploration Licences, Retention Licences, Mining Leases, General Purpose Leases and Miscellaneous Licences. Exploration licences grant to the holder the exclusive right to occupy the land for exploration purposes. This does not preclude other forms of land use. In all cases, the holders of exploration and development tenements are required to meet expenditure or work commitments and comply with the conditions of approval to retain the rights to explore and develop.

Standard conditions have been developed to cover mineral exploration and mining in the different types of conservation reserves, proposed conservation reserves, State forests and other environmentally sensitive areas. These guidelines are summarised in the Department of Minerals and Energy Information Series No. 11.

The conditions of tenements issued under the *Mining Act* also draw attention of the licensee to the provisions of other Acts including the *Environmental Protection Act 1986*, the *Conservation and Land Management Act 1984*, the *Wildlife Conservation Act 1950*, the *Bushfires Act 1954*, the *Country Areas Water Supply Act, 1947* and the *Aboriginal Heritage Act 1972–1980*. New mining proposals are subject to environmental impact assessment and community consultation is required. Environmental reporting, auditing and monitoring of operations is undertaken. An annually renewable environmental bond system is maintained to ensure that mining companies comply with their environmental obligations. Petroleum companies must have insurance funds to clean up the environment should any company be unable to meet its environmental commitments in the event of an environmental accident. Rehabilitation of mine sites must be compatible with future use. In addition to the legislative requirements, a number of industry associations have developed environmental codes of practise, eg. the Minerals Council of Australia has a Code for Environmental Management, the Western Australian Chamber of Minerals and Energy has produced guidelines for exploration in sensitive areas and the Australian Petroleum Production and Exploration Association has a Code of Environmental

Practice. There is recognition of environmental excellence through a government award system.

On reserved land, varying degrees of access are available as defined under Section 24 of the *Mining Act*. The concurrence of the Minister for the Environment is required for exploration in class–A nature reserves, national parks, class–A conservation parks and State forests. Mining in national parks and class–A nature reserves requires the consent of both houses of Parliament. For other reserved lands, including conservation parks and Aboriginal reserves, the Department of Conservation and Land Management (CALM) is consulted and the recommendation of the relevant Minister is required before the grant of mining approvals. An entry permit under the *Aboriginal Affairs Planning Authority Act* is also required in the case of Aboriginal reserves.

The *Mining Act* allows for the granting of mining tenements in relation to the surface and to a depth of 30m on private land only after consent of the owner has been obtained.

All new tenements and exploration licence renewals are subject to the legislation and procedures of the Commonwealth Native Title Act 1993 except where it is determined that the applications are over land where native title has been extinguished.

3 GEOLOGICAL SETTING

The main Precambrian geological features of the South-West Forest region include the south western part of the Archaean Yilgarn Craton, the Proterozoic Albany–Fraser Orogen along the south coast, and the Proterozoic Pinjarra Orogen along the west coast (Map 1, Table 1). The Phanerozoic Perth Basin is superimposed directly on the Pinjarra Orogen and is bounded to the east by the Darling Fault; sedimentary rocks of the Phanerozoic Bremer Basin overlie part of the Albany Fraser Orogen along the southern margin of the area; and Phanerozoic sedimentary rocks of the Collie, Wilga and Boyup Basins are preserved in fault-bounded grabens in the Yilgarn Craton (Myers, 1995) (Map 2). Most of the Precambrian and Phanerozoic rocks are covered by a veneer of unconsolidated or partly consolidated deposits called regolith (Map 3).

PRECAMBRIAN

Yilgarn Craton

The Yilgarn Craton consists mainly of late Archaean granite with narrow strips of greenstones. At least three episodes of granite-greenstone evolution have been recognised. Gneisses, which are older than the granites and greenstones, form the Balingup and Jimperding–Chittering Complexes.

- Balingup and Jimperding–Chittering Complexes (3340–2950 Ma)
  These metamorphic complexes are inferred to have consisted originally of predominantly sedimentary rocks with some granitic intrusive rocks that have

subsequently been repeatedly deformed and highly metamorphosed to form paragneiss, schist, granofels and orthogneiss. Ultramafic and layered mafic/ultramafic intrusive rocks are inferred to have intruded the sedimentary rocks prior to deformation and are preserved as remnants within the complexes. Pegmatites were later intruded along fault and fracture zones during deformation and metamorphism.

Styles of mineralisation accompanying these geological events include:

•Tin–tantalum–lithium mineralisation in pegmatites (Greenbushes rare-metal pegmatite)
•Gold mineralisation associated with banded iron-formation and other metasedimentary rocks (Archaean/Precambrian gold)
•Platinum group metal, chromite, nickel, vanadium, ilmenite and talc mineralisation associated with the remnants of ultramafic and layered mafic intrusions
•Kyanite deposits in schists formed by metamorphism of aluminous sedimentary rocks
•Graphite deposits in schists formed by metamorphism of carbonaceous shale
•Beryllium–feldspar–mica mineralisation in pegmatites (industrial mineral pegmatites)
•Iron deposits in banded iron-formation
•The metaquartzites also provide a source of dimension stone (Toodyay quartzite) and a potential source of silica.

- Granite–greenstones of the Yilgarn Craton (3000–2650 Ma)

Granite is the most widespread rock-type in the Yilgarn Craton. Some of the granite has been moderately to strongly deformed whilst other granites have been much less deformed. At least three phases of greenstone development have been recognised by Wilde et al (1996). The earliest greenstones are about 3000 Ma. Discontinuous strips of greenstones of this age are present to the east of the region, but none have yet been recognised within the region. Greenstones dated at 2800-2700 Ma also occur in the Yilgarn Craton to the east of the study area. The youngest greenstones in the Yilgarn are dated at 2700-2650. They include the Saddleback and Morangup greenstone belts within the South-West Forest region (Wilde et al. 1996). The granites and greenstones have been intruded by pegmatites and dolerite dykes.

Styles of mineralisation accompanying these geological events include:

•gold mineralisation in greenstone belts (eg the primary Boddington/Hedges gold deposit)
•nickel mineralisation occurs in the older greenstone belts to the east of the region
•vanadiferous and titaniferous magnetite deposits in dolerite and layered mafic intrusions
•molybdenum mineralisation in granites
•beryllium, tantalum and rare earth mineralisation in pegmatites

The granites are also a source of construction material and dimension stone.

Albany–Fraser Orogen

The Albany–Fraser Orogen trends in an easterly direction along much of the south coast but at the western end turns abruptly southward and is partly truncated by the Darling Fault. Within the South-West Forest region, the main components are the Biranup Complex and the Nornalup Complex.

- Biranup Complex (3100–1190 Ma)

  The Biranup Complex forms the northern part of the Albany–Fraser Orogen. It consists of gneisses and schists derived from sedimentary and granitic rocks and metamorphosed mafic and ultramafic rocks. These rocks range in age from Archaean to Proterozoic. The rocks were intensely deformed and recrystallised during the Proterozoic. They form a number of steeply dipping tectonic sheets separated by zones of intense deformation (Myers,1995).

  Styles of mineralisation found in the Biranup Complex include:

  •gold mineralisation associated with amphibolites and gneisses (this is probably deformed Archaean gold mineralisation)
  •graphite deposits in graphitic schists
  •iron ore in magnetite-rich banded iron-formation occurs outside the South-West Forest region (Southdown).

- Nornalup Complex (1300–1180 Ma?)

  The Nornalup Complex forms the southern part of the Albany–Fraser Orogen. It consists of granite and gneisses that have been derived from granitic and sedimentary rocks. The gneisses have been strongly deformed and recrystallised but are generally much less intensely deformed than the rocks of the Biranup Complex. The granites were intruded at about 1180 Ma (Myers, 1995).

  •gold mineralisation in gneiss is the only known style of mineralisation in the Nornalup Complex.

Pinjarra Orogen

The Pinjarra Orogen extends along the western coast and is bounded to the east by the Darling Fault. The orogen is largely covered by sedimentary rocks of the Perth Basin but is exposed as the Leeuwin Complex west of the Dunsborough Fault and in a narrow belt of metasedimentary rocks known as the Cardup Group along the edge of the Darling Fault. A 30 km wide belt of sheared rock to the east of the Darling Fault, and known as the Darling Fault Zone, is also related to the Pinjarra Orogen (Myers, 1995).

- Leeuwin Complex (780–540 Ma)

  The Leeuwin Complex consists mainly of deformed granite and granitic gneiss with some anorthosite and gabbro.

  •minor gold mineralisation is present in the Leeuwin Complex but is probably of Permian to Lower Cretaceous age

- Cardup Group (750–600 Ma)

  Deformed and metamorphosed shale, sandstone and minor conglomerate outcrop in a narrow belt along the eastern edge of the Darling Fault.

  • minor base metal mineralisation is associated with metasedimentary rocks of the Cardup Group.

  •the Cardup Group is a major source of brickmaking clay

PHANEROZOIC

- Silurian – Carboniferous (420–298 Ma)

  The Perth Basin developed over the Pinjarra Orogen as a result of a major rift that initially formed in the Silurian at about 420 Ma and continued to be intermittently active until the early Cretaceous at about 135 Ma. During the earliest phase of rifting from the Silurian to Carboniferous, marine and fluvial sedimentary rocks accumulated in the northern part of the Perth Basin; they are known from boreholes to the west of the northern part of the South-West Forest region (Myers,1995).

- Permian – Cretaceous (298–65 Ma)

  During the Early Permian, a second phase of development related to interior fractures in the basin commenced in the Perth Basin. Sedimentation extended into the southern part of the Perth Basin and was mainly fluvial and lacustrine. During this phase, the Permian Sue Coal Measures were deposited in the Perth Basin followed conformably by the Triassic Sabina and Leseur Sandstones and the Jurassic sandstones and siltstones of the Cockleshell Gully and Yarragadee Formations. An extensive Permian fluvial–fluvioglacial sequence including coal measures probably extended across the Yilgarn Craton, but has been preserved only in fault-bounded grabens in the Collie, Wilga and Boyup Basins and in a basin at Donnybrook.

  At the beginning of the Cretaceous, there was a third phase of development of the Perth Basin related to the rifting and separation of Greater India and Australia. The Bunbury Basalt was erupted at this stage (about 135 Ma) as lava flows within valleys incised into the Jurassic sedimentary rocks. Cretaceous sediments of the Leederville Formation were deposited over the older sedimentary rocks and the Bunbury Basalt in the Perth Basin. These range from lacustrine–fluviatile sedimentary rocks with thin peaty coal seams to higher energy estuarine–fluviatile sedimentary rocks. Fluviatile sedimentary rocks of Cretaceous age were also deposited over the Permian sedimentary rocks of the Collie Basin (Nakina Formation) and over Permian sedimentary rocks at Donnybrook.

  Mineral and fossil fuel deposits related to these geological events include:

  •coal deposits formed within the Collie, Wilga and Boyup Basins and in the Perth Basin during the Permian

  •gas and petroleum accumulation in the Sue Coal Measures

  •coal seams developed in the Cockleshell Gully and Yarragadee

Formations in the Perth Basin during the Jurassic
•epithermal gold mineralisation and base metal mineralisation related to faulting and rifting which took place between the Early Permian and Early Cretaceous
•gold placer deposits formed by erosion of Permian and Archaean gold deposits
•heavy mineral sand deposits developed in the estuarine–fluviatile sediments of the Leederville Formation during the Cretaceous
•thin peaty coal seams formed in the lacustrine–fluviatile sediments of the Leederville Formation during the Cretaceous.

The Donnybrook Sandstone is also a source of dimension stone.

- Eocene (54 Ma–38 Ma)

During the Eocene, a veneer of fluviatile and shallow marine sediments known as the Plantagenet Group was deposited in the Bremer Basin which onlaps the Albany–Fraser Orogen and the Yilgarn Craton in the southern part of the South-West Forest region.

•thin peaty coal seams are associated with fluviatile sediments in the Bremer Basin

Spongolites (sedimentary rocks composed of sponge spicules) are a source of building stone.

- Tertiary – Recent Regolith Formation (45 Ma – present)

A veneer of regolith covers much of the South-West Forest region. The regolith includes drainage-related sediments, coast-related sediments and weathering products. The drainage-related sediments include sand, silt, clay and conglomerates deposited in creeks, lakes and estuaries. Coast-related sediments include cemented, windblown calcareous sand formed during periods of low sea level at the peaks of Pleistocene glaciation and recent and fossil beach and dune sand deposits. Weathering products include laterite and bauxite, lateritic gravel, residual and transported sand, and clay.

Mineral deposits related to these geological events include:

•bauxite deposits formed by the chemical weathering of rocks resulting in concentration of alumina
•heavy mineral sand deposits formed by concentration of heavy minerals in recent and fossil beach and dune deposits
•lateritic gold deposits developed in laterite over primary gold deposits
•lateritic iron deposits formed by the chemical weathering of rocks resulting in concentration of iron
• lateritic nickel and lateritic vanadium deposits formed by weathering of mafic and ultramafic rocks
•alluvial tin, tantalum and gold deposits in stream channels
•kaolin deposits formed by weathering of feldspars in rocks
•colluvial kyanite, tin and titanium mineral deposits formed by in situ weathering and concentration of the heavy mineral fraction
•silica sand deposits formed by removal of impurities from fossil beach and dune deposits, and by the concentration of residual silica sand over

quartz-rich rocks.

Coast-related sedimentary rocks and sediments are also a source of limestone and limesand.

Table 1: South-West Forest region - Summary of geological and mineralising events.

4 HISTORY OF MINING AND EXPLORATION

Gold was discovered at Kendenup just outside the South-West Forest region in 1853 but development in the mid-1870s proved unsuccessful. The first payable gold discovery in the South-West Forest region was at Donnybrook in 1897. Proclamation of the Donnybrook Goldfield occurred in 1899 after 501 oz of gold production was recorded in that year. Although Donnybrook Goldfields was floated in 1900 and several hundred metres of underground development took place, virtually no ore was stoped and the company went into liquidation in 1904.

The Collie coalfield was discovered in 1883 but was not reported to the Government until 1887. Production, which commenced in 1898 when the railway between Perth and Collie was completed, continues to the present day and is used to generate most of the State's power.

Alluvial tin was discovered at Greenbushes in 1898. Although initially tin was the only product mined, the Greenbushes mine is currently the world's largest tantalite producer and yields a significant proportion of the world's lithium.

The first production of iron ore in the State was from lateritised BIF at Clackline between 1899 and 1907.

The occurrence of bauxite within the South-West Forest region was first recorded in 1902 on the Darling Range. In 1919 the Geological Survey of WA mapped the extent of laterite which might contain economic bauxite. The Electrolytic Zinc Company of Australia Pty Ltd explored the Darling Range bauxite deposits in 1918 but at that time it was thought that the bauxite was restricted to the lateritic caprock and the deposits were regarded as being of low grade and therefore subeconomic. No further exploration took place until 1957 when Western Mining Corporation began to explore for bauxite in the Darling Range. Following regional exploration, a joint venture company, Western Aluminium NL, was formed to explore temporary reserves over a large portion of the southwest. By late 1961, the company had delineated reserves of 37 Mt of bauxite at an average grade of 33% available Al_2O_3. Commercial mining commenced in 1963 after construction of a refinery at Kwinana to treat the ore. Subsequently, bauxite mining commenced at Huntly-Del Park in 1972, Mount Saddleback in 1983, and Willowdale in 1984. The ore from these mines is treated at refineries at Pinjarra, Worsley and Wagerup respectively.

Significant heavy mineral sand (titanium, zirconium and rare-earth) production in the south west commenced on the Capel shoreline near Bunbury, just outside the South-West Forest region in 1956. The Waroona and Yoganup Shoreline deposits, which lie partially within the South-West Forest region, were also tested in 1956. A significant discovery of heavy mineral sands at Beenup within the southern part of the region was announced in 1988. This deposit started production in 1995. Other recent discoveries of heavy mineral sands in the South-West Forest region include Jangardup, Jangardup South and Metricup.

Petroleum exploration in the southern Perth Basin commenced in 1902 with the drilling of three shallow wells (Warren River 1, 2 and 3) but these were barren. In 1968, gas was intersected in Whicher 1. Amity Oil and Penzoil Exploration are currently investigating the gas deposit to determine if it can be extracted economically.

Geochemical investigations over the Mount Saddleback Greenstone Belt by the Geological Survey of Western Australia during the late 1970s defined a base metal and gold anomaly northwest of Boddington. Further exploration by Reynolds Australia and Alcoa of Australia led to the discovery of a large tonnage, low-grade, laterite-hosted gold deposit that straddled State Agreement Act bauxite leases held by Worsley Alumina and Alcoa of Australia. Separate gold mines (Boddington and Hedges) were developed on the lateritic gold deposit in 1987 and 1988 respectively. Subsequently, drilling beneath the laterite located primary gold mineralisation that can be mined by openpit and underground mining operations.

Modern Exploration Activity

Legislation requires that reports be submitted on exploration activities carried out on all mineral and petroleum tenements. These reports are held in confidential archives and indexed in the WAMEX and WAPEX computerised bibliographic database systems of the Geological Survey of Western Australia. For the purpose of the RFA project, all exploration reports in the WAMEX and WAPEX systems have been reviewed and used to construct exploration activity and anomaly layers in a multi-layer GIS data base. In the activity layer all exploration activities are represented by polygons, lines and points. Appendix C contains metadata relating to these. A linked attribute table indicates the type of exploration activity, number of samples taken, number of holes drilled, elements assayed for, number of line kilometres of aeromagnetic data flown etc. Map 5 shows the distribution of mineral exploration activities except those within the State Act Leases (as these are not included in the WAMEX system). Apart from exploration for gold, coal, tin, tantalum, lithium, bauxite, and petroleum, there has been exploration for nickel, chromium, platinum group elements, vanadium, titanium, base metals, iron, silica sands, kyanite, graphite, beryllium, feldspar, mica and limesand in recent years. The anomaly layer has been used in the assessment of mineral potential and will be discussed further in Chapter 7.

During 1996, $616.1 million was spent on mineral exploration and $419 million on petroleum exploration in Western Australia. Figures for the South-West Forest region are not available but it is estimated that only a small percentage of the above figure was spent in the South-West Forest region due to the difficulty of land access.

5 MINERAL RESOURCES AND MINERAL PRODUCTION

Bauxite–alumina

The South-West Forest region is the World's leading bauxite producer. These extensive deposits (Map 6) have formed as a result of lateritic weathering of Archaean granites and of mafic volcanic rocks of the Saddleback Greenstone Belt. Appendix B describes the mineralisation in more detail. Most of the mineralisation is in State Forest, and because of the risk of spreading dieback disease, all exploration and mining activities must be closely monitored. Alcoa have developed a sophisticated Geographic Information System to incorporate environmental management into their mine planning (Elliott and Wake, 1992). Once a mining area has been defined by grade control drilling, the forest is logged and cleared. Topsoil is removed and either stockpiled or utilised directly in the rehabilitation of another mining site. The bauxitic caprock is fractured by blasting or ripping and mined together with the underlying friable bauxite ore. Because of the shallow nature of the bauxite mineralisation (generally 2–7m but locally up to 20 m), all mines are open-pit. Mined-out areas are recontoured and overburden and topsoil returned. The soil is then ripped and native trees and understorey shrubs seeded or planted. All rehabilitation work and environmental planning is carried out prescription in consultation with CALM.

The four currently operating mines are Jarrahdale, Huntly (incorporating the previous Del Park mine), Willowdale and Saddleback. Following crushing, the ore from these mines is transported by train or conveyer belt to the Kwinana, Pinjarra, Wagerup and Worsley refineries respectively.

In the year 1996, 8.246 Mt of alumina valued at $1968 million was produced from these refineries. In addition 24,309 kg of gallium valued at $9.8 million was produced as a byproduct. Since production began in 1963, till the end of 1996, 136.8 Mt of alumina has been won from 440 Mt of bauxite. Proved and probable reserves are 1052 Mt with additional resources of 1107 Mt in the measured and indicated categories and 653 Mt in the inferred category (Table 2); the average grade of these resources is greater than 27.5 % available Al_2O_3. Some of these resources are no longer available for mining because they lie within current conservation reserves or areas of urban development.

Coal

The Collie Coalfield (Maps 4 & 6) is the only commercial producer of coal in the State. The coal occurs in a fault bounded basin approximately 226 km^2 in area (Appendix B). Approximately 60 significant coal seams, ranging from a few centimetres to 15m in thickness, have been recognised over a stratigraphic thickness of about 1000 m. The coal rank varies from bituminous to sub-bituminous and has a specific energy of 18–22 MJ/kj, a moisture content of approximately 25%, an ash content of 3–10% and contains 0.29–0.49% sulphur (Le Blanc Smith, 1993). In the past, coal was mined from opencut and underground mines but the last underground mine closed in 1994 and all coal is now produced from opencut mines. Two new opencut mines, Western Collieries Premier and Griffin’s Ewington II, have made up for the reduction in production caused by the closure of the underground mines. Most of the coal is used to produce the State’s electricity. Construction of a 300-megawatt coal fired station at Collie has commenced and is expected to become operational by 1999.

Table 2: Bauxite - Past Production, Resources and Reserves

DEPOSIT	PAST PRODUCTION Mt	RESOURCES Mt		RESERVES Mt
		Measured and Indicated	Inferred	
Bombala		28		
Brigadoon-Bells		12	4.7	
Brookton Hwy- Bannister Group		145		
Cameron		16		
Churchman		11		
Clarke Hill		30		
Clinton		36		
Collie-Balingup General			1.3	
Del Park- Huntly	190			233
Dingo Knob		17		
Dwellingup-Waroona General			220	
Gidgeganup		2.9	2.5	
Hoffman		22		
Holmes		43		
Holyoake		41		
Howse		70		
Inglehope		51		
Jarrahdale/Alcoa	130			140
Julimar West		5.5	1.7	
Kalamunda-Dale General			69	
Karnet		27		
Little Jimperding Hill-Bindoon		30	8.4	
Lower Chittering		32	1.4	
Manjimup Bauxite			26	
Mt Solus		32		
Mt Wells		16		
Mundaring-Wundowie General			63	
Mungalup		8		
Munnapin Brook- Julimar East		4.9	1.2	
Myarra		33		
Nanga		17		
O'Neil		13		
Pindalup		28		
Plavins		74		
Red Hill - South Bindoon		8.3	2.5	
Saddleback - Tunnel Road	56			
Saddleback Group				390
Smiths Mill Hill		13		
Spion Kop		38		
Taree		22		
Tower Hill Bauxite		21		
Wagerup - Harvey General			240	
Wannamal - Chittering General			6	
Waroona Bauxite		73		
Willowdale	39			289
Wundowie Bauxite		16		
Wundowie Northeast Bauxite		10	5.4	
Yarragil		60		
Totals	415	1106.6	653.1	1052

In the year 1996, 5.8 Mt of coal valued at $268.4 million was produced from the Collie Coalfield. Production between 1898 and the end of 1996 was 133 Mt. Proved and probable resources in the Collie Basin total approximately 2400 Mt (Le Blanc Smith, 1993). Additional proved and probable coal resources in the South-West Forest region include 264 Mt in the Wilga Basin, 90 Mt in the Boyup Basin and 600 Mt in the Vasse Shelf (Le Blanc Smith, 1990). The outline of the coal resources is shown on Map 6.

Gold

The Boddington mine in the Saddleback Greenstone Belt is the second largest gold producer in Australia. Lateritic gold mineralisation has been mined by openpit methods at the Boddington mine by Worsley Alumina and the BGM group of companies since 1987, and at the adjacent Hedges mine by Hedges Gold Pty Ltd since 1988. Drilling of the Boddington deposit has located a number of bodies of supergene (ie oxidised) and primary Archaean gold–copper mineralisation (Appendix B). Some high grade primary mineralisation has in the past, been mined by underground mining techniques, but most of the ore is low grade and will continue to be mined by openpit methods. The Boddington mine is on cleared private land whilst the Hedges Mine is in State where access is restricted to reduce the risk of introduction of jarrah dieback.

Total production from the Boddington–Hedges mines in the year 1996 was 13.6 t gold valued at $217.0 million. Production between 1987 and the end of 1995 for the Boddington and Hedges Mines was 131.4 t gold from 73 Mt of ore. Total demonstrated indicated and measured resources for Boddington at end 1995 were 182.9 Mt at 1.08 g/t with additional inferred resources of 74.1 Mt at 1.0 g/t; for Hedges, indicated and measured resources at end 1995 were 4.53 Mt at 1.25 g/t.

Apart from Boddington–Hedges, there are a number of small gold workings in the South-West Forest region. In the Donnybrook area, a number of mines worked epithermal gold in Permian sediments and the underlying Archaean rocks between 1897 and 1904; total recorded production was 26.1 kg (839 oz) from 1613 t. Small workings in the Leeuwin Complex (eg. Petterd and Cross Reef and Boodgidup Brook) are also epithermal (Appendix B); no production has been officially recorded from these mines. Gold has also been reported from Redmond where it is associated with amphibolites in the Proterozoic Nornalup Complex and from the Archaean metamorphic complexes (Jimperding, Wundowie, Majenup, Mine Hill, Mitchell, Waterfall Gully, Crooked Brook, Ironstone Road and Yornup). Of these, only Jimperding has a recorded production of 10.17 kg of lode gold and 7.3 kg of placer gold. Map 4 shows the location of these gold occurrences.

Heavy mineral sands

Heavy mineral sand production from the Capel Shire and Bunbury City Local Government areas during 1996 was 846 900 t of ilmenite, 198 100 t of upgraded ilmenite, 17 080 t of leucoxene, 8 700 t of rutile and 94 400 t of zircon with a total value of $ 269 million. Most of this production came from the Swan Coastal Plain to the west of the South-West Forest region. Heavy mineral bearing strandlines on the Swan Coastal Plain which are partially within the South-West Forest region include the Yoganup–Happy Valley strandlines and the Waroona Shoreline North and Waroona Shoreline South. Deposits associated with estuarine/fluviatile sequences (eg Beenup) and strandlines on the Scott Coastal Plain (eg Jangardup) are significant heavy mineral sand resources within the South-West Forest region. Production at Jangardup commenced in 1993 and at Beenup in 1996. The Beenup project is expected to produce 600 000 t per annum of ilmenite and 20 000 t per annum of zircon which will make the South-West Forest region a very significant producer of heavy mineral sands in Western Australia. Demonstrated and inferred heavy mineral sand resources for sites within and partially within the South-West Forest region are given in Table 3.

Tantalum, tin and lithium

The Greenbushes pegmatite is one of the World's largest producers of tantalum and lithium. Most production to date has come from weathered pegmatite and alluvial deposits, but mining of the hard rock pegmatite by deep openpit methods commenced in 1992 when the emphasis changed from tin to tantalum production. Spodumene is being mined from a separate open-pit. A new lithium carbonate plant has recently been commissioned and is expected to produce 5000 t per annum of lithium carbonate powder. During 1996, Greenbushes produced 286 t of tantalite valued at $26.0 million, 148 t of cassiterite valued at $2.5 million and 131 900 t of spodumene (4.92 % Li_2O) valued at $17.1 million. Production between 1889 and the end of 1996 was 22 400 t of tin, 5 300 t of tantalite and 560 000 t of spodumene. Total demonstrated resources at end 1995 were 33.0 Mt at 0.29 kg/t Ta_2O_5 containing 9500 t Ta_2O_5, 13.88 Mt at 3.83 % Li_2O containing 0.53 Mt Li_2O and 5.7 Mt at 0.25 kg/t SnO_2 containing 1400 t SnO_2 with additional inferred resources of 7.9 Mt at 0.31 kg/t Ta_2O_5 containing 2500 t Ta_2O_5.

Minor tin production has also taken place at Smithfield, Native Dog Gully and Willow Springs. Production from these centres was probably attributed to Greenbushes as there are no official production statistics, although production from Smithfield is estimated to have been about 600 kg tin concentrate (Blockley, 1980).

Kaolin

Kaolin (actually halloysite) suitable for use in high-grade ceramics is mined by open-cut from the weathered portion of the Greenbushes pegmatite. In the year 1996, 400t of kaolin valued at $58 000 was produced. A total of 38 400 t of kaolin had been produced up to the end of 1996 and there is a demonstrated resource of 2.3 Mt at 30.0% kaolin. Prior to 1952, 2800t of kaolin, suitable for use as a filler material, was produced from Glen Forest.

Table 3: Demonstrated and inferred heavy mineral sand resources for sites within and partially within the South-West Forest region

Pegmatite-related Industrial Minerals

There has been minor production of beryl, mica and feldspar from the Mullalyup and Ferndale pegmatites in the South-West Forest region. The Ferndale pegmatite contains a large tonnage of clean microcline feldspar suitable for the ceramics industry (Townsend, 1994).

Vanadium

Vanadium-bearing titaniferous magnetite is present in a lateritised gabbro at Coates Siding. The measured and indicated resource for the primary deposit is 39 Mt at 0.51 % V_2O_5 and the indicated resource for the lateritised deposit is 1.5 Mt at 0.6 % V_2O_5. The deposit was mined in 1980 and 1981 before mining was suspended because of falling metal prices and difficulties with the processing plant.

Iron Ore

Total production of 19 000t of iron ore was recorded from lateritised BIF at Clackline between 1899 and 1907.

Iron-bearing laterite near Scott River was discovered in 1960. Development of the deposit, with an inferred resource of 32 Mt at 38 % Fe (acid-soluble iron), would be subeconomic by present Australian standards.

Graphite

Approximately 1000 t of graphite has been produced from Donnelly River. The deposit contains microcrystalline graphite which may be suitable in foundries, refractory bricks, conductive coatings, batteries, pencils or specialty paint (Townsend, 1994). Graphite has also been reported from Martigallup.

Kyanite

Total kyanite production from Ross's Swamp, Manjimup Brook and Donnelly River between 1938 and 1948 totalled 4300 t. Most of this material was eluvial and derived from kyanite schists of the Balingup Complex.

Silica Sand

Two deposits of silica sand with a total resource of 4 Mt have been identified in the Narrikup area near Albany.

Talc

Minor talc and soapstone production has been reported from deposits at Glen Lynn Siding and Meaneys Bridge.

Peat

Peat has been produced from Cowerup Swamp near Lake Muir since 1970; total recorded production is 24 000t. Production statistic for the year 1996 were not recorded as peat is no longer a mineral under the Mining Act. There is a demonstrated resource of 450 000 t of peat in Cowerup Swamp. The sedimentary rocks of the Bremer Basin and the Cretaceous sedimentary rocks west of the Darling Fault also host peat deposits.

Dimension stone

Sandstone from Donnybrook has been quarried for use as building stone since the early 1900s. A quartzite band extending from Jimperding Hill to Clackline is also quarried as a building and facing stone (‘Toodyay Stone’).

6 ASSESSMENT OF MINERALS/PETROLEUM POTENTIAL AND LAND ACCESS

Minerals

Mineral exploration is a long term and ongoing process. Even after mining commences, there is a continuum between orebody definition drilling and mineral exploration drilling aimed at discovery of additional resources. Exploration is extremely costly, is a commercially high-risk activity and areas are often explored many times. Each time the exploration process adds to the geological knowledge.
Because of incomplete geological knowledge, the discovery rate in Australia is roughly of the order of one mine for one thousand exploration programs. Thus areas are explored, often repeatedly, before a mineral deposit is found. Increased geological knowledge and other factors can result in discoveries of World class deposits both in highly prospective areas (eg Kanowna Belle in Yilgarn, WA; Century in the Mount Isa Inlier, Qld.) or in areas not previously known to be of very high potential (eg Olympic Dam, 300 metres below barren rocks of the Stuart Shelf, SA; heavy mineral sand deposits under shallow clay overburden at Horsham in Western Victoria). Other examples of new mineral fields being located include gold at Boddington in the 1980s (described above) and in the Drummond Basin (Queensland in 1980s), base metals in the Canning Basin (WA in 1980s) and nickel in the eastern Yilgarn (WA in 1960s). Thus continued access to land for regulated exploration, which is a transient process rather than a long-term land use, is an important issue for the minerals industry and for future mineral development.

The advent of Carbon-In-Pulp and Carbon-In-Leach gold extraction technologies in the 1970s provides examples of the way in which technological (and economic) change can affect exploration. These technologies dramatically changed the costs of gold recovery and also reduced the risks associated with exploration for gold-oxide ores by allowing gold to be mined profitably at much lower grades. This triggered intensive, Australia-wide exploration for large tonnage gold oxide deposits at considerably lower cut off grades than were previously considered economic (Blain, 1992). Carbon-In-Pulp and Carbon-In-Leach processing are also used for treatment of low-grade primary gold ores. Solvent extraction and electrowinning techniques have enabled the treatment of lower grade base metal and nickel deposits.

New geological models can also affect exploration. The discovery of the World- class Olympic Dam copper–uranium–gold deposit is an example. This deposit, which was discovered in 1975, is concealed 300 metres below the surface and was the first of its kind to be identified in Australia. The exploration program was based upon new ore deposit models developed by Western Mining Corporation geologists that postulated the existence of copper deposits in the region (Reeve et al., 1990). Within the South-West Forest region, the discovery of the Saddleback Greenstone Belt in an area which had previously been thought to have been underlain by granite, led to the discovery of the Boddington–Hedges laterite gold deposits using the analogy of the gold deposits in other greenstone belts in the Yilgarn. The discovery of a deposit often leads to the discovery of deposits nearby or in other areas that share similar geological characteristics.

Petroleum

In general, petroleum exploration is even more expensive than mineral exploration but the rewards are potentially much greater. Following the discovery of oil in Western Australia at Rough Range in 1953, extensive exploration resulted in the discovery of commercial quantities of oil at Barrow Island in 1964, natural gas at Dongara in 1966 and offshore gas fields at Scotts Reef, Rankin, North Rankin and Goodwyn in 1971. Subsequently many significant offshore oil and petroleum resources including Gorgon, Wanaea, Wandoo and Brecknock have been discovered. Western Australia is now Australia’s major petroleum producer.

Early phases of petroleum exploration typically involve airborne geophysical surveys and ground-based seismic surveys. Seismic surveys assist in determining if suitable structural traps are present and may require some clearing of vegetation along survey lines. Because test wells are expensive, few are drilled unless the prognosis is encouraging. The site of test wells is very limited in area (0.3–0.5 ha), and such wells involve minimal risk of damage to the environment. Even if oil or gas is discovered and production takes place the production site typically occupies only a small area (0.8–1.0 ha). Any activities likely to result in significant environmental disturbance are subject to review by the Environmental Protection Authority, WA.

Land access

No area can ever be classed as unprospective and no assessment of potential (ie, undiscovered) mineral resources can ever be classed as 'final'. New information, new concepts and better understanding of geological processes continually change the perceived prospectivity of areas and regions. New models are continually being developed and refined. Continued access to land is therefore a significant issue for the mining industry and for future mineral development.

Generally, exploration can be defined as the process of searching for and assessing mineral deposits. Although discovery and delineation are the primary reasons for exploration, lack of discovery from an exploration program does not imply that the effort yielded no benefit. Information gained from exploration will usually increase the understanding of a region's geology.

The cost and duration of exploration programs will vary from company to company and across commodities. Clark (1996) suggests that the development of a typical major mineral deposit (worldwide) involves a 5–20 year lead time. This estimate results from a typical 3–10 years exploration program prior to the mine development phase. The typical sequence of events that underlie a modern mineral exploration program is shown in below in Box 1.

It is important to note that the exploration process starts with assessments of very large regions and is then systematically narrowed down as the exploration target becomes better defined. The direct costs facing explorers increase as the target area becomes smaller and exploration methods more intense. The environmental impact associated with exploration also increases as the area being explored becomes smaller and the exploration methods used become more invasive (for example, drilling).

The initial phase of exploration using remote sensing from satellites involves no disturbance to the surface. The early stages of a surface exploration program involve activities such as mapping, geophysical measurements and geochemical sampling of stream sediments, soils and laterite. These activities are likely to have minimal effect upon the environment. Follow-up investigations that would require other techniques and that may have some localised and temporary effects may include (see ABARE, AGSO and BRS, 1993):

- rock chip sampling;
- collecting soil samples; and
- electrical, gravity, magnetic or seismic ground surveys.

If the results of this work were positive, additional follow-up work may include some drilling. However, it should be noted that not all exploration results in drilling.

In contrast to exploration, mining itself generally involves greater disturbance to the land surface in the immediate area of the mine and leaves potentially significantly changed landforms when mining is finished. Mining is generally seen as posing greater difficulties in terms of compatibility with other uses. Many potential environmental effects of mining activities can be eliminated or mitigated, though at a cost to the mining company. The major potential impact to the environment from mining in the South-West Forest region, is the risk of spreading Jarrah Dieback Disease. The experience from existing exploration and mining projects (eg. Alcoa's bauxite projects) is that this risk can be effectively eliminated by washing down all vehicles and

Box 1: Modern mineral exploration: the typical sequence of events

1. Global considerations
- Assessment of political stability
- Assessment of security of title
- Assessment of access and restrictions
- Assessment of financial climate, restrictions or inducements
- Determination of geoscientific framework and availability of information

2. Preliminary investigations
- Review regional geoscientific data (geology, geophysics, satellite imagery)
- Formulation of geological concepts and selection of prospective areas
- Examination of known mineralisation

3. Reconnaissance exploration
- Acquisition of exploration tenements
- Collection and assessment of geoscientific data over the tenement
- Examination of available regional geoscientific data
- Conducting of geoscientific surveys (indicating regional sampling and remote sensing surveys) required to augment available data
- Selection of target areas for more detailed exploration

4. Detailed exploration
- Detailed geoscientific surveys to detect and delineate anomalies
- Drilling of anomalies in search of significant mineralisation
- Delineation of mineral deposits by further drilling and other methods to determine configuration, approximate tonnage, grade and metallurgical characteristics
- Pre-feasibility studies
- Applying for mining tenements, if justified, at appropriate stage of program.

Source: ABARE, AGSO and BRS (1993).

machinery before moving from a dieback zone to a dieback-free area and by the careful planning of mine layout, development and rehabilitation with respect to the local topography, drainage and vegetation. Water pollution is another potential impact on the environment from mining. However, this can be controlled by using well-established techniques such as impoundment and evaporation of tailings, sedimentation, filtration and pH neutralisation. Dust and noise-control are also important in areas close to residences and some farming activities. Rehabilitation of minesites at the completion of operations can accommodate end land uses required by the land manager including restoring many of the features of the landscape that existed before mining. Normal aspects of rehabilitation include the re-establishment of vegetation and effective pollution control measures.

As discussed in Chapter 2 and in response to the Western Australian Government’s policy of multiple land use, standard conditions have been developed to cover exploration and mining in the different types of conservation reserve, proposed conservation reserves, State forests and other environmentally sensitive areas within Western Australia. In the case of mining proposals these conditions are modified to take into account the particular environmental issues applying for each project.

7 MINERAL POTENTIAL ASSESSMENT METHODOLOGY

The mineral potential of the study area has been assessed by determining the types of mineral deposits likely to be found within the geological framework known or believed to exist. The general methodology used was developed by the United States Geological Survey (USGS), and has been used successfully for mineral resource assessments of forest areas in North America and elsewhere in Australia (East Gippsland, Tasmania) for Comprehensive Regional Assessments. This approach identifies geological units (tracts) which could contain particular types of deposits. A summary of the qualitative assessment methodology is described in publications by Marsh, Kropschot and Dickinson (1984), Taylor and Steven (1983), and by Dewitt, Redden, Wilson and Buscher (1986).

An assessment of potential mineral resources of a region combines knowledge of its geology, geophysics, geochemistry, mineral deposits and occurrences with current theories of mineral deposit genesis and results of mineral exploration. The assessment process requires a study of available geoscientific data to determine the history of geological processes and environments. Geological environments that are judged to have characteristics known to be associated with specific types of mineral deposits are then identified. In particular, the assessment draws on regional and local characteristics of mineral deposit models to establish whether or not specific types of mineral deposits are likely to occur.

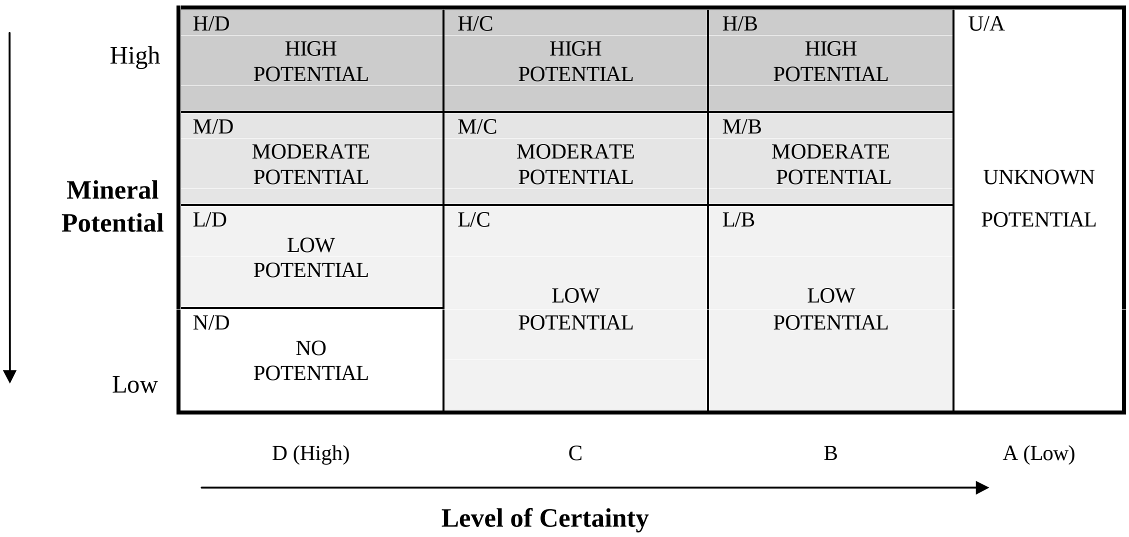
In the case of the South-West Forest region, anomalous values reported in company exploration reports were taken into account in addition to known resources and mineral occurrences. Anomalies were selected according to company criteria where the company had taken a large number of samples and carried out statistical analysis on them or, if only a few samples were taken, by comparing values with those from large surveys carried out by other companies. Anomalies were given mineral occurrence status when they reached certain predetermined levels (eg. for gold > 5m at > 1ppm Au, for copper > 5 m at >0.5 % Cu and for chromium > 0.2 m at > 5% Cr). All anomalies, mineral occurrences and known mineral resources were entered into a GIS database as discussed in Chapter 4. The resources, occurrences and anomalies were then superimposed on the geological maps to determine possible correlations with rock types or structure.

The mineral potential of an area, that is the likelihood of it having a particular type of mineral deposit, is assessed as high, moderate, low or unknown, based on professional judgments of geoscientists involved in the assessment. If there are insufficient data to classify the areas as having high, moderate or low potential, then the mineral resource potential is categorised as unknown. To reflect the differing amounts of information available, the assessments of mineral potential are also categorised according to levels of certainty, denoted by letters A–D in order of increasing certainty (Figure 1). That is, A denotes the lowest level of certainty and D the highest. The method is described in more detail in Appendix A.

A qualitative assessment of the potential resources 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 mineral resource. The term ‘mineral resource’ is here restricted to material, the extraction of which is judged to be potentially viable, either now or within the next 25 years.

Assessments similar to the procedure used in this report for the South-West Forest region are commonly used by companies to select areas for exploration. It is important to note, however, that the assessment of potential resources is subject to the amount and the quality of data available to the assessors. As geological knowledge of an area is never complete, it is not possible to have a ‘final’ assessment of potential mineral resources at any given time. The mineral resource potential of an area needs to be monitored and reassessed periodically to take account of new data, advances in geological understanding including new mineral discoveries. Advances in mineral exploration and mining technologies, and changes in mineral markets are other factors that may change the mineral resource potential of an area. Similarly the hydrocarbon potential may change with advancing technology, for example, the gas in the Whicher Range wells within the South-West Forest region was previously considered too deep to extract economically but technology developed by Penzoil in Texas may enable the gas to be extracted economically.

Figure 1: Relationship between levels of resource potential and levels of certainty



Geological areas (or ‘tracts’) in the South-West Forest region, judged to contain geological environments permissive of the formation of specific types of mineral deposits are delineated, and the mineral potential of these tracts was assessed (Figures 2 to 22).

8 POTENTIAL MINERAL AND HYDROCARBON RESOURCES

Using the techniques discussed in Chapter 7, tract maps were constructed for 21 deposit types (Figures 2–22). The mineral potential and weightings assigned to each of these tracts are summarised in Table 4. Four additional deposit types were tentatively identified, but a lack of geological knowledge precluded derivation of tract maps for them. The deposit types considered are briefly summarised below. Detailed information on each deposit type is given in Appendix B.

Lateritic-type bauxite (Fig. 2)

Large areas within the South-West Forest region have well defined lateritic bauxite resources. All areas with well-developed laterite within the region are considered have potential for bauxite.

Coal (Fig. 3)

Coal of Permian age is known to occur in the Collie, Wilga and Boyup Basins and on the Vasse Shelf. Coal seams have also been recorded in sediments of Jurassic age within the Perth Basin. Where these sediments are within 600m of the surface, they are considered to have potential for mineable coal deposits.

Laterite–saprolite gold (Fig. 4)

There is potential for laterite saprolite gold similar to that which occurs at Boddington–Hedges in locations where laterite overlies possible gold-bearing bedrock of Archaean or younger age.

Archaean/Precambrian gold (Fig. 5)

Archaean greenstone belts host most of the significant gold deposits in Western Australia, including the primary Boddington deposit within the South-West Forest region. For this reason all known greenstone belts in the region have a high potential for gold. There is also a moderate to high potential for gold within the metamorphic complexes. Areas where there is potential for hidden greenstone belts have been assessed as having moderate potential.

Rift-related epithermal gold deposits (Fig. 6)

There is potential for gold mineralisation related to major rift faults within the area, and particularly the one represented by the Darling Scarp. Donnybrook is an example of this type of mineralisation.

Placer gold (Fig. 7)

Some potential exists for discovery of placer gold derived from the older gold deposits.

Shoreline–fluviatile placer titanium (heavy mineral sands) (Fig. 8)

Known heavy mineral sand deposits (containing titanium zirconium and rare earths) are associated with modern and ancient shorelines and estuarine and fluviatile sedimentary rocks within the region. There is potential for other deposits in similar geological settings.

Rare-metal pegmatite (Fig. 9)

There is the potential for the discovery of other rare-metal (ie tin, tantalum and lithium) pegmatites similar to the Greenbushes type within the metamorphic complexes, especially in the vicinity of major shear zones.

Alluvial tin and tantalum (Fig. 10)

Within the region, there is potential for alluvial tin and tantalum deposits derived from rare-metal pegmatites.

Hydrocarbons (Fig. 11)

Three exploration wells in the Whicher Range indicate that gas is present in the Permian sedimentary rocks to depths of 4300m. The gas deposit is currently being reassessed by Penzoil to determine if the gas can be extracted economically using modern techniques. The Permian coal measures on the Vasse Shelf also have potential for coal-bed methane.

Synorogenic–synvolcanic nickel–copper–chromium–platinum group elements (Fig. 12)

Mafic and ultramafic rocks within the area have the potential to host deposits of nickel, copper, chromium and platinum group elements. Where altered, they also have the potential to host talc deposits.

Lateritic/saprolitic nickel (Fig. 13)

This type of deposit could be expected to develop over primary nickel deposits of the type described above where there has been deep weathering.

Vanadiferous and/or titaniferous magnetite (Fig. 14)

There is potential for vanadium and/or titanium-bearing magnetite deposits similar to the Coates deposit in the mafic and ultramafic rocks within the area. There is also potential for vanadium and/or titanium-bearing magnetite deposits in dolerite intrusions (dykes).

Silica sand and quartzite (Fig. 15)

There are known deposits of silica sand and quartzite within the region and there is the potential for more deposits.

Clay (Fig. 16)

Currently, high quality clays are produced from the weathered part of the Greenbushes pegmatite, but there is potential for high quality kaolin in areas where deep lateritic weathering of granite has taken place.

Pegmatite-related industrial minerals (Fig. 17)

There is potential for mica and glass-quality feldspar in pegmatites within the region.

Graphite (Fig. 18)

Graphitic schists within the metamorphic belts have potential to host graphite deposits.

Kyanite (Fig. 19)

Both massive and disseminated kyanite are known to occur in schists within the region and there is potential for further deposits.

Banded iron-formation (Fig. 20)

Banded iron-formation within the region has moderate potential to host an iron deposit of the Southdown type.

Volcanic hosted/associated massive sulphide deposits (Fig. 21)

Rock-types favourable for the presence of volcanic hosted massive sulphide deposits occur in the Saddleback Greenstone Belt and in the Biranup metamorphic complex.

Peat and/or lignite (Fig. 22)

There is potential for lignite in the lower energy lacustrine and fluviatile facies of the Cretaceous Leederville Formation. There is also potential for peat and lignite in the Tertiary sediments of the Bremer Basin and alluvial channel- fill sediments overlying the Precambrian basement.

Other commodities

The region has an untested potential for diamonds, rare-metals associated with carbonatites, and uranium associated with pegmatites or sandstone.

9 SUMMARY OF POTENTIAL MINERAL AND HYDROCARBON RESOURCES IN SOUTH WEST FOREST REGION

Mineral potential tracts were defined for 21 types of deposits (Figs 2–22, Table 4). These include:
- 13 metalliferous deposit types
- 5 industrial mineral deposit types
- coal, peat/lignite
- hydrocarbons.

Only the mineral deposit types judged to be most likely to constitute significant resources in the region have been assessed in detail. The assessments of all deposit types are described in detail in Appendix B.

Table 4: Summary of mineral and hydrocarbon resource potential as at February 1997

Deposit type	Ranking of deposit types (index)	Mineral potential	Standard potential score	Weighted potential score	Area of tract (sq km)	% of region covered by tract
Lateritic-type bauxite	8	High	18	144	14191	33.4
		Moderate	6	48	1887	4.4
		Low	1	8	8982	21.1
		Unknown			17369	40.9
Coal	6	High	18	108	1150	2.7
		Moderate–High	12	72	1328	3.1
		Moderate	6	36	997	2.3
		Low–Moderate	2	12	15467	36.4
		Low	1	6	1334	3.1
Laterite/saprolite gold	7	High	18	126	456	1.1
		Moderate–High	12	84	2596	6.1
		Moderate	6	42	10462	24.6
		Unknown			3620	8.5
Archaean-Precamb. Gold	9	High	18	162	597	1.4
		Moderate–High	12	108	6180	14.5
		Moderate	6	54	21234	49.9
		Unknown			9370	22.0
Epithermal gold	7	High	18	126	51	0.1
		Moderate–High	12	84	3955	9.3
		Moderate	6	42	1101	2.6
		Unknown			23465	55.2
Placer gold	4	Moderate–High	12	48	2124	5.0
		Moderate	6	24	6172	14.5
Shoreline–fluviatile placer titanium (heavy mineral sands)	7	High	18	126	2382	5.6
		Moderate–High	12	84	1051	2.5
		Moderate	6	42	1903	4.5
		Low–Moderate	2	14	2710	6.4
		Low	1	7	34473	81.1
Rare-metal pegmatite	5	High	18	90	1539	3.6
		Moderate	6	30	4897	11.5
Alluvial tin and tantalum	3	High	18	54	388	0.9
		Moderate	6	18	1253	3.0
Hydrocarbons	6	Moderate	6	36	4524	10.6
Synorogenic/ synvolcanic nickel–copper–elements	6	High	18	108	745	1.8
		Moderate	6	36	6551	15.4
		Low–Moderate	2	12	1744	4.1
		Low	1	6	18032	42.4
Lateritic/ saprolitic nickel	5	High	18	90	377	0.9
		Moderate	6	30	2871	6.8
		Low–Moderate	2	10	739	1.7
Vanadiferous and/or titaniferous magnetite	4	High	18	72	1501	3.5
		Moderate–High	12	48	214	0.5
		Moderate	6	24	5843	13.7
		Low–Moderate	2	8	1744	4.1
		Low	1	4	17766	41.8

Silica sand and quartzite	4	High	18	72	444	1.0
		Moderate–High	12	48	7995	18.8
Clay	3	High	18	54	1	0.0
		Moderate–High	12	36	14125	33.2
		Moderate	6	18	1890	4.5
Pegmatite-related industrial minerals	3	Moderate–High	12	36	3669	8.6
		Moderate	6	18	3710	8.7
Graphite	2	Moderate–High	12	24	496	1.2
Kyanite	2	Moderate–High	12	24	496	1.2
Banded iron-formation	4	Moderate	6	24	9	0.0
Volcanic massive sulphide	6	Moderate	6	36	336	0.8
Peat and/or lignite	1	Low–Moderate	2	2	12757	30.0
Some potential also for diamond-bearing kimberlites, rare-metal carbonatites, uranium-bearing pegmatites, sandstone hosted uranium deposits						

To facilitate land use decisions, all the mineral potential tracts were combined (overlain) to produce four types of summary maps of mineral potential (Maps 7, 8, 9 & 10).

Map 7 is a **composite of mineral potential** for the South-West Forest region and shows the highest level of mineral potential assessed (in February 1997) for any particular area in the region. Where tracts for different deposit types overlap, this area is assigned the highest potential level of all the overlapping tracts. In this approach, the tract having the highest mineral potential in any particular area obscures tracts of lower mineral potential.

The types of deposits with the most widespread tracts in the South-West Forest region are those types associated with laterite, ie lateritic bauxite (high), lateritic/saprolitic gold (moderate and above), clay (moderate to high); and also by Archaean/Precambrian gold, and placer gold (both moderate and above). The areas of high potential cover most of the Balingup Complex, Jimperding–Chittering Complex, and the lateritic areas of the Archaean granite/greenstone (Yilgarn Craton), the western and southern portions of the Perth Basin, and the eastern portion of the Leeuwin Complex.

It is important to note that Map 7 is a composite of mineral potential tracts for different types of mineral deposits that do not have equal economic values. For example a tract with moderate to high potential for Archaean/Precambrian gold may be considered to have a higher economic value than a tract with high potential for clay.

Map 8 shows the **cumulative mineral potential** for the South-West Forest region. In constructing this map, standard scores were allocated according to a subjective ranking of levels of mineral potential as follows: high potential (18), moderate – high (12), moderate (6), low – moderate (2), low (1), unknown (no score). In those areas where tracts overlap, the scores are added and this cumulative score is assigned to the overlapping areas. For example, where there is overlap of tracts with high potential for bauxite (score 18), moderate – high potential for lateritic/saprolitic gold (score 12) and moderate potential for lateritic nickel (score 6), then this area of overlap will have a cumulative score of 36. The cumulative mineral potential takes account of both the diversity of deposit types that may occur in each area as well as the level of mineral potential of each of these deposit types.

Map 8 shows that the areas with the highest scores for cumulative potential include the Balingup Complex, Jimperding–Chittering Complex, the Saddleback greenstone belt and the Collie Basin. A greater number of deposit types could occur in each of these areas. Other areas with a high cumulative potential score include lateritic areas developed on Archaean granite/greenstone (Yilgarn Craton), the western and southern parts of the Perth Basin, and areas of the Biranup Complex.

It should be understood that the areas with overlapping tracts (high cumulative scores) emphasise the diversity of mineral potential. These areas are not necessarily more prospective than a single tract of high potential, eg for bauxite deposits. The relative economic significance of the tracts for different types of mineral deposits, as perceived by mining companies, would be influenced by their perceptions of prospectivity, future market conditions, land access and other factors.

Map 9 shows the **weighted composite mineral potential** for the region. The weighted composite potential makes some allowance for the relative economic significance between different types of mineral deposits. In this approach, mineral deposits are indexed for their relative economic significance. For example, bauxite was given an index of 8 out of 10, whereas clay was given an index of only 3 out of 10. The indexes for the various deposit types are listed in Table 4. The weighted composite score is calculated by multiplying the deposit index by the standard mineral potential score. For example, heavy mineral sands tract (index of 8) with high potential (18) will have a weighted composite score of 144. Similarly a clay tract (score 3) with high potential (18) will have a weighted composite score of 54. Where there are overlapping tracts, with different weighted scores, the highest of these scores is assigned to the area of overlap.

The weighted composite map highlights the significance of extensive areas with potential for bauxite, laterite/saprolite gold, Archaean/Precambrian gold over the Balingup, Jimperding/Chittering Complexes, and the Yilgarn Craton. The map also highlights the tracts for heavy mineral sands and coal in the south-west part of the region over the Perth Basin and the Leeuwin Complex, and for epithermal gold along the east flank of the Darling Fault.

On Map 9, areas with weighted score classes of 108 to 162 cover about 48% of the South-west Forest region. This part of the region includes all of the areas (tracts) of high potential for the most significant types of mineral deposits (ie those with an index of 6 to 9 (Table 2)). The major bauxite mines, the Boddington and Hedges gold mines, the heavy mineral sand mines and the coal mines also occur within this part of the region. The most extensive high potential tracts are those for bauxite (weighted potential score of 144 for high potential, (Table 2)). Potential for other types of deposits in this part of the region are high and moderate to high potential for Archaean/Precambrian gold (score of 162 for high and 108 for moderate to high potential), high potential for lateritic gold (126), epithermal gold (126), heavy mineral sands (126), coal (108) and synorogenic/synvolcanic nickel-copper-chromium-platinum group element deposits (108).

The area covered by weighted composite score classes of 72 to 90 comprises 6% of the region. This class range includes tracts of high potential for important rare-metal pegmatite type deposits similar to the Greenbushes deposit (index of 5 and a weighted potential score of 90). It includes areas with moderate to high potential for other significant deposit types (indexes of 6 and 7) such as epithermal gold (84), heavy mineral sands (84) and coal (72). Potential for other deposit types include high potential for vanadiferous/titaniferous magnetite deposits (72) and silica sand (72).

The area with weighted mineral potential classes below a score of 72 covers about 45% of the region. It contains only moderate or moderate to high potential for various types of deposits. For example there is moderate to high potential for clay deposits (36) and moderate potential for Archaean/Precambrian gold (54). Tracts of high potential for some deposits of lesser significance (index of 3), such as alluvial tin and tantalum, are almost completely overlain by areas with higher weighted potential scores.

Within each tectonic region, there is potential for the following deposit types:

- Balingup Complex — for deposits of bauxite (maximum weighted score in this tectonic region for bauxite is 144; includes tracts of high and moderate-high potential), lateritic/saprolitic gold (126; h, m-h), rare-metal pegmatites (90; h, m-h), synorogenic/synvolcanic nickel–copper–chromium–platinum (108; h, m), Archaean-Precambrian gold (108; m-h), lateritic nickel (90; h, m-h), epithermal gold (84; m-h), silica sand and quartzite (72; h), vanadiferous/titaniferous magnetite (72; h, m-h), alluvial tin and tantalum (54; h, m), placer gold (48; m-h), pegmatite-related industrial minerals (36; m-h, m), clay (36; m-h), graphite (24; m-h) and kyanite (24; m-h);
- Jimperding - Chittering Complex — for deposits of bauxite (144; h, m-h), lateritic/saprolitic gold (126; h, m-h); Archaean-Precambrian gold (162; h, m-h), epithermal gold (126; h, m-h), synorogenic/synvolcanic nickel–copper– chromium–platinum (108; h, m), lateritic nickel (90; h, m), vanadiferous/ titaniferous magnetite (72; h, m), silica sand and quartzite (72; h), clay (36; m-h), placer gold (48; m-h), pegmatite-related industrial minerals (36; m-h, m), graphite (24; m-h) and kyanite (24; m-h);
- Archaean granite/greenstones of the Yilgarn Craton — for deposits of bauxite (144; h, m-h), lateritic/saprolitic gold (126; h, m-h), Archaean-Precambrian gold (162; h, m), epithermal gold (126; h, m), vanadiferous/titaniferous magnetite (72; h, m-h), clay (36; m-h), pegmatite-related industrial minerals (36; m-h, m);
- Biranup Complex — for deposits of bauxite (144; h, m-h), lateritic nickel (30; m), silica sand and quartzite (72; h), clay (36; m-h), placer gold (48; m-h), graphite (24; m-h), and kyanite (24; m-h);
- Nornalup Complex — for deposits of bauxite (144; h, m), clay (36; m-h, m), silica sand and quartzite (48; m-h), and pegmatite-related industrial minerals (36; m-h, m);
- Leeuwin Complex — for deposits of heavy mineral sands (126; h, m-h);
- Collie Basin — for deposits of coal (108; h), silica sand (72; h), clay (36; m-h) and bauxite (144; h, m);
- Perth Basin — for deposits of heavy mineral sands (126; h, m-h), coal (108; h, m-h), and silica sand (48; m-h).

The **weighted cumulative mineral potential** (Map 10) is similar to the weighted composite mineral potential in that the score for each tract is calculated by multiplying the deposit index by the mineral potential score. Where there is overlap of tracts, the scores of the overlapping tracts are summed and this total score is assigned to the overlap area. In Map 10, the relative importance of deposit types is taken into account before adding individual potential scores. Thus on a simple cumulative map, an area where a high potential tract of Precambrian gold overlaps a tract with moderate potential for bauxite deposits will have the same score (18+6=24) as an area where high potential tract for Precambrian gold overlaps with a tract of moderate potential for clay deposits (18+6=24). However, on a weighted cumulative map, the two areas would acquire different scores because of the different weights given to each of the deposit types. That is, for overlapping Precambrian gold tract (high potential) and bauxite (moderate potential) the score is (18x9) + (6x8) = 210; for the overlapping Precambrian gold tract (high potential) and clay tract (moderate potential) the score is (18x9) + (6x3) = 180. The distribution of known resources has been superimposed on the map to highlight areas where deposits have already been found and tested.

APPENDIX A: METHODOLOGY FOR ASSESSMENT OF POTENTIAL (UNDISCOVERED) MINERAL AND PETROLEUM RESOURCES

The mineral potential of the study areas has been assessed by determining the types of mineral deposits likely to be found under the geological conditions known or believed to exist there. The general methodology used and described below, was developed by the United States Geological Survey (USGS), and utilised successfully for mineral resource assessments of forest areas in North America and elsewhere. The qualitative methodology for the assessment of potential mineral resources is described by Marsh, Kropschot and Dickinson (1984), Taylor and Steven (1983), and by Dewitt, Redden, Wilson and Buscher (1986).

An assessment of the potential mineral resources of a region combines knowledge of the region's geology, geophysics, geochemistry, mineral deposits and occurrences with current theories of mineral deposit genesis and results of mineral exploration. The assessment process requires a study of available geoscientific data — on a regional or local scale as required — to determine the history of geological processes and environments. Geological environments that are judged to have characteristics known to be associated with specific types of mineral deposit are then identified. In particular the assessment draws on regional and local characteristics of mineral deposit models to establish whether or not specific types of mineral deposits are likely to occur.

The mineral deposit models used in this assessment are generally those published by Cox and Singer (1986). These mineral deposit models are the systematic arrangements of information describing the essential attributes (properties) of groups or classes of mineral deposits. The models used are empirical (descriptive), the various attributes being recognised as essential even though their relationships are unknown. Each model encapsulates the common features of a group of deposits, as these are known from deposits around the world, and is constructed (as far as possible) to be independent of site-specific attributes not common to the group. The value of these models lies in the ability to apply what is known about a group of significant mineral deposits to the known geological environment of the area being assessed.

The assessment takes into account all of the features of the deposit models and whether these features can be recognised in the geoscientific data available for the area being assessed. Local and regional-scale features provide evidence as to whether the geological environment is conducive to, or permissive of, the formation of a given deposit type.

There are probably at least 70 styles of mineral deposits of economic or potential economic significance in Australia. These have distinct features and have formed in different ways. It is not feasible to apply models for all of these deposit classes systematically in each study area. Only the deposit types judged to be most likely to constitute economically significant resources in each area have been assessed in any detail. Where necessary, new models have been proposed or variations on USGS deposit models (Cox and Singer, 1986) have been made to better fit regional circumstances.

Qualitatively assessed potential resources

A qualitative assessment of the potential resources of an area is an estimate of the likelihood of occurrence of mineral deposits that may be of sufficient size and grade to constitute a mineral 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. It cannot be classified according to the two dimensional (‘McKelvey’) diagram used for identified resources. For this reason the qualitatively assessed potential resources are shown in a separate box (Figure 1). 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 being assessed.
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.
The ranking of ***M–H*** is used for areas intermediate between ***H*** and ***M*** and ***L–M*** is used for areas intermediate between ***M*** and ***L***.

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 (Figure 1).

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

APPENDIX B: MINERAL/HYDROCARBON RESOURCE ASSESSMENT AND DEPOSIT MODELS

Bxt: LATERITIC TYPE BAUXITE DEPOSITS (MODEL 38B BY COX AND SINGER, 1986) (Figure 2)

Model Description

Description modified after Sam H. Patterson.

Approximate Synonym: Aluminium ore (Patterson, 1967).

Description**:** Weathered bauxitic residual material in subsoil formed on any rock or unconsolidated sediment containing aluminium; or material transported from above. Overlain by thin "A" horizon soil, underlain by saprolite (parent rock in intermediate stages of weathering).

General Reference: Hickman et al (1992), Schaap (1990), Patterson (1984), Somm (1975)

Geological Environment:

Rock Types: Weathered rock formed on granites, greenstones, aluminous silicate rocks, clays, unconsolidated sediments or same materials associated with karst limestones.

Textures: Pisolitic, massive, nodular, earthy.

Age Range: Mainly Cainozoic, two Cretaceous? deposits known.

Depositional Environment: Deeply weathered, well-drained plateaux in regions with warm to hot and wet climates with dense vegetation. Locally deposits in poorly drained areas low in iron due to its removal by organic complexing.

Tectonic Setting(s): Typically occurs on plateaux in tectonically stable areas.

Associated Deposit Types: Lateritic gold, lateritic nickel, lateritic iron.

Deposit Description:

Mineralogy: Mainly gibbsite and mixture of gibbsite and boehmite, also diaspore; gangue minerals haematite, goethite, anatase, locally quartz.

Texture/Structure: Pisolitic, massive, earthy, nodular.

Alteration: Aluminous rocks, clays or unconsolidated sediments are altered by weathering to bauxite.

Ore Controls: Thoroughly weathered rock, commonly erosional boundaries of old plateau remnants. Parent rock has inherent porosity/permeability and/or is well fractured; some deposits have been transported.

Weathering: Intensive weathering required to form bauxite. Bauxite continues to form at present in some deposits where tropical weathering conditions prevail.

Geochemical Signature: Al, Ga.

Examples:

Darling Range, Western Australia	Hickman et al (1992).
Weipa, Queensland	Schapp (1990), Evans (1975).
Gove, Northern Territory	Somm (1975).
Mitchell Plateau, Western Australia	Joklik et al (1975).

Known local deposits, occurrences and mineral prospects

Darling Range residual, lateritic bauxite is mainly underlain and derived from deeply weathered Precambrian granitic and gneissic rocks and to a lesser extent basic rocks. Deeply weathered aluminous metasedimentary rocks also provide some potential for bauxite formation. Warm temperature, high rainfall, moderate relief, good drainage and dense vegetation are important factors in bauxite formation. An optimum uplift rate of deeply weathered (kaolinised) rocks to form the central Darling Range caused a lowering of the water table to provide good drainage conducive to bauxite formation (Grubb 1966, in Hickman et al. 1992). Lower rainfall, subdued relief and/or lack of dense vegetation outside the main bauxite areas have inhibited bauxite formation where iron rich laterite (or ferricrete) predominates.

There are four bauxite mines in the Darling Range called Jarrahdale, Huntly (including the previous Del Park Mine), Willowdale and Mount Saddleback.

At Jarrahdale most of the bauxite is developed on Archaean rocks chiefly even-grained, porphyritic granite, with minor amounts on migmatite gneiss, dolerite and gabbro. Bauxite deposits are up to 20 metres thick (average 4 metres) and are best developed on hill slopes where optimum groundwater influx and drainage conditions conducive to bauxite formation occurred. Available alumina (Av.Al_2O_3) grades average 33% (but can be as high as 45%) in areas of granite/gneiss bedrock and 18% (15–20% range) in remaining material. Iron content of the former is 14% but averages 27% in the latter. Deleterious reactive silica (Re.SiO_2) averages 1.3% for the granitic material and 1.8% for the remaining material (Hickman et al. 1992).

The bauxite deposits at the Huntly (Del Park) mine are developed on similar bedrock types to those at Jarrahdale and, again, are best developed on hill slopes. Some of the thickest bauxite deposits of the Darling Range occur here and average 4 to 5 metres.

At Willowdale, most of the bauxite has developed over porphyritic granite but in the western part of the area, thick bauxite has developed over gneissic rocks of the Darling Scarp Zone.

In contrast, bauxite deposits at the Mount Saddleback mine have formed on mafic volcanic bedrock. Average bauxite ore thickness is 6 to 7 metres, locally exceeds 20 metres and is thickest on ridge slopes. Average Al_2O_3 is about 35%.

In addition to the above mines there are many known large, potentially economic, unmined deposits in the Darling Range (see Table 2, Chapter 5), some of which are constrained by other land uses. Most of these were formed on granite bedrock but others (eg. Manjimup and Wannamal) have developed over metasediments and gneisses in the metamorphic complexes.

Assessment Criteria

1. Distribution of Precambrian rocks which have been subjected to lateritic weathering.
2. Distribution of ferricrete (laterite) (Czrf on map), sand over ferricrete (laterite)(Czrs) and residual material which includes laterite (Czr).
3. Distribution of known bauxite deposits.

Assessment:

Tract Bxt1a/H/C–D

Delineation of the tract is based on the distribution of ferricrete (Czrf) east of the Darling Scarp and distribution of known deposits.

Potential for economic bauxite in this tract is considered high with a certainty level of C where laterite occurs and a certainty level of D where known deposits occur.

Tract Bxt1b/M/B

This tract is based on the distribution of sand overlying ferricrete (Czrs) and residual material including

laterite (Czr) to the east of the Darling Scarp.
There is a potential for bauxite deposits in laterite hidden beneath other residual material.
Potential for economic bauxite in this tract is considered moderate with a certainty level of B.

Tract Bxt1c/L/B–C

This tract includes the Pemberton Karri Forest area where very little laterite occurs. Potential for economic bauxite in this tract is considered low with a certainty level of C.

The tract also includes the area west of the Darling Fault. No bauxite deposits have been recorded in this area and the laterite is generally thin and poorly developed. Potential for bauxite is considered to be low with a certainty level of B.

Tract Bxt1e/N/D

This tract includes all mined out areas. It has no potential with a certainty level of D. It should however be noted that there may be ore-grade bauxite which has not yet been mined adjacent to this tract.

Tract Bxt1d/U/A

This tract comprises remaining areas east of the Darling Scarp. In this area, it is possible that lateritic bauxite is hidden beneath Recent alluvial deposits or that areas mapped as outcropping Archaean rocks may have unmapped pods of laterite overlying them. Potential for bauxite is unknown with a certainty level of A.

Economic Significance

Bauxite deposits are of great economic significance to WA as discussed in Chapter 5.

Coal1: COAL DEPOSITS (Figure 3)

Model Description

Coal-bearing sedimentary sequences

Approximate Synonyms:

Description: Coal measures

General References: Harrington et al (1989), Traves and King (1975), Doyle et al (1986)

Geological Environment

Rock types: Coal measures interbedded with various terrestrial and marine sedimentary sequences.

Age Range: Carboniferous to Tertiary

Depositional Environment: Peat swamps behind coastal barrier systems or within inland structural depressions; swamps and peat bogs associated with and marginal to alluvial fans and deltaic plains, fluvial flood plains, lakes and lagoons. Depositional environment must be free from frequent incursions of clastic sediments or oxygenated waters, thus environments are generally low energy, anoxic and occur in fresh – brackish waters.

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.

Associated deposit types: Oil Shale, peat, hydrocarbons.

Deposit Description

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

(After Doyle et al 1986)

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. Seam morphologies may be modified by 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 variable lithotypes and banding within seams.

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 and can influence the size and quality of the deposits.

Examples:

Gippsland Basin, Victoria	(Barton et al 1992).
Sydney Basin, New South Wales	(Brackel 1989).
Bowen Basin, Queensland	(O'Brien 1989).
Collie Basin, Western Australia	(Le Blanc Smith 1993).

Known Deposits and Mineral Prospects in South West WA

Major deposits of coal in the South-West Forest region are located in the Collie Basin where known resources of coal for the basin are 2,400 Mt (Le Blanc Smith 1993). To the south of the Collie Basin lie the much smaller Wilga (39 km^2) and Boyup (6 km^2) basins containing inferred resources of 264 Mt and 60 Mt respectively (Le Blanc Smith 1990). The tectonic setting of the basins is the same as that of the Collie Basin; that is they are remnants of a formerly more extensive Permian sequence preserved in fault bounded grabens.

The Sue Coal Measures of Early to Late Permian age is the coal-bearing unit of primary interest in southern part of the Perth Basin. Estimated resources of coal for the Vasse Shelf for seams over 1.3m thick and within 600m of the surface are 600Mt (Le Blanc Smith 1990). In the Bunbury Trough the Sue Coal Measures occur at depths of 2.7 km and deeper and as such are considered uneconomic.

Coal has also been reported from Jurassic sediments of the southern part of the Perth Basin in the Cockleshell Gully Formation.

Assessment Criteria

1. Phanerozoic Basins containing Permian and Jurassic sequences.
2. Areas considered to have potential for concealed Phanerozoic Basins.

Assessment:

Tract Coal1a/H/B–D

This tract includes the Collie Basin. Extensive mining operations, detailed drilling and gravity data all confirm the presence of coal in the Collie Coal Measures throughout the Collie Basin apart from marginal areas about 200m wide. This in addition with very large known resources indicates a high potential with a certainty level of D for this part of the tract.

Parts of the Wilga and Boyup basins are also included in this tract. Numerous drill hole intersections, the recognition of the Collie Coal Measures and close relationship of the sedimentary sequence in these basins to that of the Collie basin, and the definition of resources within the basins all indicate a high potential with a certainty level of D.

This tract also incorporates the Vasse Shelf as delineated by the Dunsborough Fault in the west and the Busselton and Alexander Bridge Faults in the east. It is based on the occurrence of the upper parts of the Permian Sue Coal Measures within 600m of the surface. The unit and accompanying coal seams have been identified in numerous drill holes in the tract. Given the information above the potential of this area is considered high with a certainty level D in the northern part and B in the southern part, which is related to various densities of drilling information.

Tract Coal1b/M–H/B

The Busselton Fault in the west and the Darradup Fault to the east define this tract. In this area the upper parts of the Lower Jurassic coal-bearing Cockleshell Gully Formation are recorded at depths which would make coal deposits within the formation economically significant. Coal seams have been detected in the Cockleshell Gully Formation in water bores (Lasky, 1993). Known significant coal seams from the same formation in the northern section of the Basin outside the South-West Forest region also indicate the potential for the sequence to host coal seams. For areas where the Cockleshell Gully Formation can be detected within 600m of surface the potential is considered moderate to high with a certainty level of B due to low density of drilling data.

Tract Coal1c/M/B

Between the Darling Fault and a sub-parallel regional fault, approximately 1 km to the west. A moderate potential within this zone due to possibility of unrecognised slivers of Permian Sue Coal Measures upfaulted to within 600m of surface. Certainty level of B due to limited data.

Tract Coal1d/L–M/B

This tract includes the southern part of the Archaean Terrain, defined by the presence of NW–SE regional faults which are considered instrumental to the preservation of the known Permian Basins. Potential in this area is for the presence of undiscovered Permian Basins similar to the Collie, Wilga and Boyup basins beneath the extensive Tertiary cover. The potential for the tract is considered low to moderate with a certainty level of B due to limited density of regional gravity and other exploration.

Tract Coal1e/L/B–C

This tract includes the remaining areas of the Perth Basin. In these areas the same Permian and Jurassic coal bearing units mentioned in the above tracts are known to occur below 600m depth. Beyond these depths the economic significance of the deposits becomes minor. The potential for deposits in this area is considered to be low with a certainty level B or C depending on density of data.

Two small basins north of Wilga also form part of the tract. It is likely that these two small basins have developed along the same lines as the Collie, Wilga and Boyup basins. Potential low due to limited size and depth. Certainty level is C.

Economic Significance

Collie Basin coals fall into the sub-bituminous to bituminous ranks. About 80% of coal currently produced from the basin is sold to the State Energy Commission for power generation. The remainder is utilised in a number of ways including private power generation, cement manufacture, brick making, mineral sands production and refining and other industrial applications. WA resources are discussed in Chapter 5.

Au1: LATERITE–SAPROLITE GOLD (Figure 4)

Model Description

Description of model by Gregory E. McKelvey (in Bliss, 1992).

Approximate Synonyms: Eluvial gold placers (Boyle, 1979), Au-bearing saprolite (Becker, 1985).

Description: Au disseminated in laterite and saprolite that developed under conditions of tropical weathering over and distal to a wide variety of bedrock types containing primary gold mineralisation.

General References: Boyle (1987); Monti (1987).

Geological Environment:

Rock Types: Host rocks include regolith; most are lateritic. Others enriched in aluminium (bauxite) (Boyle, 1979). Also, less frequently, deposits found in saprolites, as in the southern Appalachians (Becker, 1895).

Associated rocks: Greenstones with Au-bearing veins and disseminations. Bedrock may contain various lode deposits and mineralised occurrences typical of stable craton areas (see Associated Deposit Types). Iron-formation or itabirite (Brazil). Other gold-bearing terranes.

Age Range: Cainozoic; late Oligocene to early Miocene in Western Australia (Monti, 1987).

Depositional Environment: Stable craton, prolonged weathering. If like laterite-type bauxite, deposits should occur commonly along erosional boundaries of old plateau remnants (Patterson, 1986).

Tectonic Setting(s): Stable weathering zone commonly above greenstone belts and other gold-bearing rocks.

Associated Deposit Types: (suspected to be genetically related): Laterite-type bauxite, lateritic Ni, lateritic V, alluvial Au-PGE placers. All Au-bearing lodes may be found in the bedrock, including low-sulphide Au-quartz veins, Homestake Au, polymetallic replacement and vein deposits, Kuroko or Cyprus massive sulphides, porphyry Cu, and rarely lithified placers (Boyle, 1987).

Deposit Description:

Mineralogy: Mineralisation in saprolite may have a cover of mineralised or unmineralised in situ or transported laterite or a thin "A" horizon as at Boddington (Symons et al, 1988), which includes loose pisolites (maximum diameter of 2 cm) with gibbsite (45 percent), goethite (20 percent), haematite (20 percent), and maghemite (Monti, 1987).

Ore minerals: Finely divided Au, may be splendent, hackle, unworn, rough, and irregular in form. Nuggets are rare. No nuggets are found at Boddington but are identified at Edna May, Westonia, Western Australia (Monti, 1987). Au as flakes, wire, and specks in canga (see Texture/Structure and Zoning). Au is between I and 10 micron with an average of 3–5 micron at Boddington (Symons et al, 1988). Ag and other metal contents are usually higher than in alluvial Au placers (however, no Ag was detected in Au grains from Boddington (Monti, 1987) but small amounts of Cu (1.4 to 1.7 percent) and Fe (0.04 to 0.06 percent) were). Saprolitic Au is very rough, with masses of wire Au (Becker, 1895)

Gangue minerals: Fe, Al oxides and hydroxides, and Mn oxides. Disintegrated bedrock fragments, including iron formation and kaolinite (Boyle, 1979).

Texture/Structure and zoning: Blanket-like on flat terrains or fanlike on gentle slopes. Gold mineralisation is non-uniform and erratic throughout the ore zone (Boyle, 1979). Au mineralisation may be localised in the laterite or displaced at depth into the underlying saprolite; mineralisation in laterite is likely to have the same texture as that of laterite-type bauxite, which includes pisolitic, massive, nodular, and earthy (Patterson, 1986). Limonite-cemented fragments of iron formation called apanhoancango or canga in Brazil (Boyle, 1979). Au found in pisoliths at Edna May but not at Boddington (Monti, 1987).

Alteration: Iron oxide and clay mineralogy may indicate chemical enrichment.

Ore Controls: Presence of laterite is a precondition for this deposit type. Mature laterite. Bedrock sufficiently fractured and (or) faulted (or have other types of porosity) so that ground water is below weathered horizon. Bauxite and saprolite occurs in areas where geomorphology (commonly erosional boundaries of old plateau remnants) allows sufficient drainage, so that oxidation is both extensive and deep to promote extensive leaching. Mineralisation develops under conditions of strong chemical weathering and with mean annual temperatures greater than 10°C and annual rainfall between 90 and 500 cm). Deposition of gold at Boddington is possibly controlled by the position of the water table. Multiple mineralised horizons are products of fluctuations in the water table resulting from climatic variation and tectonic uplift (Monti, 1987).

Weathering: Main processes of Au concentration include residual enrichment of Au, chemical precipitation of Au, and a combination of both (Boyle, 1987).

Geochemical Signature: Au+As+Ag (Cu, Fe, Ni and Sn not directly related to mineralisation but indicate where the drainage crosses a greenstone belt), Beeson (1995).

Geophysical Signature: Unknown. May be used to identify bedrock features associated with protore. Electrical properties of deposits may prove to be a useful tool in identifying mineralisation. Shallow seismic may be useful in deposit-shape determination.

Other Exploration Guides: Vegetation may be useful either in identifying areas of poor fertility or in biogeochemical exploration; oxide mineralogy may change systematically from background to anomalous adjacent to and over the deposits.

Examples:

Boddington	Western Australia.
Mt. Gibson	Western Australia.
Edna May	Western Australia .
Akaiwing	Guyana.
Arakaka	Guyana.
Luinpkin and White Counties,	Georgia.

Known deposits and mineral occurrences in the region

The Boddington deposit and its northern extension, Hedges, is one of the largest gold deposits in Western Australia. This lateritic gold deposit has developed over and proximal to primary gold–copper mineralisation in felsic to intermediate volcanics and felsic intrusions of the Saddleback Greenstone Belt. At Boddington, three subhorizontal mineralised zones separated by barren or weakly mineralised clay have been recognised: a continuous upper level averaging 5m thick but up to 20 m thick that occurs mainly in the ferruginous zone, a second discontinuous level of similar thickness that occurs in the clay zone and a third discontinuous zone that is less than 5 m that occurs in saprolite at the base of the clay zone (Monti, 1987). At this deposit, gold is homogeneously distributed in the laterite but erratic when in saprolite (Symons et al, 1988).

Assessment criteria

1. Presence of ferricrete (laterite) (Czrf on map), sand over ferricrete(laterite) (Czrs) and residual material which includes laterite (Czr).
2. Distribution of greenstone belts and metamorphic complexes.
3. Distribution of known primary and lateritic gold occurrences.
4. Presence of geochemical anomalies.

5. Distribution of major fault zones that would control the distribution of primary gold mineralisation.

Assessment:

Tract Au1a/H/B–C

This tract covers mapped ferricrete (laterite)(Czrf) over known greenstone belts (Saddleback and Morangup). It includes the Boddington–Hedges deposit and is assessed as having high potential with a certainty level of C.

This tract also includes areas mapped as sand over ferricrete (Czrs) and residual material including ferricrete (Czr) over known greenstone belts. These areas are assessed as having a high potential but because the laterite is largely covered, they are given a certainty rating of B.

Tract Au1b/M–H/B–C

This tract includes all areas of ferricrete (laterite) over the Jimperding–Chittering and Balingup Complexes. There are known primary gold occurrences and areas of gold anomalism within this tract. The tract is considered to have moderate to high potential with a certainty level of C.

This tract also includes areas mapped as sand over ferricrete (Czrs) and residual material including ferricrete (Czr) over the Jimperding–Chittering and Balingup Complexes, but because the laterite is largely covered, in these areas they are given a certainty rating of B.

Tract Au1c/M/B

This tract includes all areas of ferricrete (Czrf)(laterite), areas mapped as sand over ferricrete (Czrs) and residual material including ferricrete (Czr) over the remaining area of Archaean to the East of the Darling Fault (except for the Collie Basin) and over the paragneiss of the Biranup Complex where there is a possibility of gold mineralisation related to major faults. This tract is considered to have a moderate potential with a certainty level of B.

Tract Au1d/U/A

This tract includes all areas of ferricrete (Czrf)(laterite), areas mapped as sand over ferricrete (Czrs) and residual material including ferricrete (Czr) over the remainder of the Biranup Complex and Nornalup Complex. This tract has an unknown potential with a certainty level of A.

Economic significance:

Grade and tonnage information for only nine deposits of this type is available (Bliss, 1992). The data indicates that 90% of these deposits contain at least 0.81 million tonnes of ore, 50% at least 3.9 million tonnes and 10% at least 19 million tonnes. Lateritic deposits have gold of high fineness and 90% of them have at least 0.64 g/t gold, 50% at least 1.4 g/t and 10% at least 3.2 g/t gold. For resource data on the Boddington–Hedges deposit see Chapter 5.

Au2: ARCHAEAN-PRECAMBRIAN GOLD (Figure 5)

Model Description

Description of the model after Byron R. Berger in Cox and Singer (1986)

Approximate Synonyms: Volcanogenic gold, iron-formation hosted Au, Archaean lode gold, Quartz-carbonate vein gold.

Description: Gold in cross-cutting quartz veins and lodes, and stratabound to stratiform gold deposits in Precambrian greenstone belts and metamorphic complexes.

Geologic Environment:

Rock types: Regionally metamorphosed mafic and felsic metavolcanic rocks, komatiites, and volcaniclastic sedimentary rocks, banded iron-formation, schists and paragneisses, intrusive mafic and ultramafic rocks and felsic to intermediate plutonic rocks

Age range: Mainly Archaean (includes metamorphic complexes which have been reworked in the Proterozoic).

Depositional environment: Controversial: hydrothermal activity related to faulting, metamorphism or intrusive rocks or submarine hot-spring activity related to volcanism.

Tectonic setting(s): Archaean greenstone belts and metamorphic complexes (including metamorphic complexes which have been reworked in the Proterozoic). In greenstone belts mineralisation is commonly near a regional division or "break" between predominantly metavolcanic and metasedimentary rocks; greenschist facies metamorphism is an important factor in gold transportation and deposition. Granite–greenstone belts are interpreted to be formed in convergent plate margin settings with local marginal basin and volcanic arc conditions.

Associated deposit types: Kuroko massive sulphide deposits, Algoma Fe, low-sulphide gold–quartz veins.

Deposit Description:

Mineralogy: Native gold + pyrite ± pyrrhotite ± arsenopyrite ± magnetite ± sphalerite ± chalcopyrite. May contain minor tetrahedrite + scheelite + wolframite + molybdenite ± fluorite ± stibnite. ± realgar. Some volcanogenic deposits show zoning from proximal pyrrhotite ± magnetite to distal arsenopyrite.

Texture/Structure: Mineralised shear zones or narrow thinly laminated beds, veins, or lenses overlying stringers or stockworks of quartz veins.

Alteration: Host rocks contain quartz ± sericite ± siderite and (or) ankerite ± tourmaline ± chlorite ± magnetite in mafic volcanic terranes. Chromium mica and chlorite particularly around veins and stockworks. Banded oxide-facies iron-formation replaced by pyrite or pyrrhotite.

Ore controls: Controversial: many deposits are structurally controlled, others may be synsedimentary or synvolcanic with varying degrees of remobilization. Host rock competence or the chemical composition of the host rock may play a role in the localisation of the gold deposit.

Weathering: Auriferous laterite may form over these deposits.

Geochemical signature: Au ± As ± Ag ± Sb ± Fe ± B (± platinum-group metals in mafic volcanic terranes)± Te ± Bi ± Hg, and minor Cu–Pb–Zn–Mo.

Examples:

Big Bell, Western Australia	(Handley and Cary, 1990).
Golden Mile, Western Australia	(Clout et al, 1990).
Sons of Gwalia, Western Australia	(Kalnejais, 1990).
Wiluna, Western Australia	(McGoldrick, 1990).
Boddington, Western Australia	(Symonds et al, 1990).
Granny Smith, Western Australia	(Hall and Holyland, 1990).
Westonia, Western Australia	(Drummond and Beilby, 1990).
Nevoria, Western Australia	(Cullen et al, 1990).
Homestake, USA	(Rye and Rye, 1974).

Passagem, Brazil (Fleisher and Routhier, 1973).
Dome Mine, Canada (Fryer et al, 1979).
Agnico Eagle, Canada (Barnett et al, 1982).
Vubachikwe, Zimbabwe (Fripp, 1976).

Known deposits and mineral prospects in the region

The region hosts several gold occurrences and deposits of this type. Boddington gold is the best known example where primary mineralisation is located within altered felsic and intermediate volcanic rocks and intrusions within the Saddleback greenstone belt (Roth et al, 1990). According to Roth et al (1990), the presence of typical alteration (potassic, phyllic, locally argillic, propylitic and silicification), a possible close link with intrusive bodies, and high-salinity fluid inclusions indicate a close similarity with Phanerozoic porphyry gold systems. However, recent dating of rocks in the area coupled with structural and timing relationships suggest that the mineralisation and alteration haloes overprint the regional metamorphic assemblage and fabric, which means that the mineralisation is not related to the intrusives and occurred late in the tectonic evolution of the Saddleback greenstone (Allibone et al, 1996). Phyllic and sericitic alteration, which Roth et al (1990) interpreted to be indicative of porphyry systems are suggested to be the result of regional metamorphism (Allibone et al, 1996). Allibone et al (1996) interpreted mineralisation to be similar in timing to many other structurally late gold deposits in the Yilgarn Craton such as Mt. Magnet, Mt Charlotte and Wiluna.

Other occurrences of gold assigned to this model are hosted in the Jimperding–Chittering, Balingup, and Biranup metamorphic complexes. In these complexes, mineralisation is associated with paragneiss, schist, amphibolite and banded iron formation. This model also includes gold mineralisation in Proterozoic rocks that may be of Archaean age but which was remobilised during Proterozoic deformation, magmatism and metamorphism. The Redmond and Kendenup occurrences in the Nornalup Complex may be of this type.

Assessment criteria:

1. Distribution of greenstone belts and metamorphic complexes.
2. Presence of major faults.
3. Presence of known occurrences of primary and lateritic gold.
4. Presence of geochemical anomalies.

Assessment:

Tract Au2a/H/C

The tract includes the Saddleback and Morangup Greenstone belts. The tract contains a major occurrence of primary and lateritic gold mineralisation: the Boddington–Hedges deposit that is one of the largest gold deposits in Western Australia. The known association of gold with greenstone belts elsewhere in the Yilgarn and the known occurrence of a major gold deposit in the area indicates that the tract has a high potential for Archaean gold deposits with a certainty level of C.

Tract Au2b/M–H/C

This tract includes the Archaean Jimperding–Chittering and Balingup metamorphic complexes. Within the Jimperding–Chittering Complex, the Wundowie and Jimperding gold workings are associated with Banded Iron Formation. There are several old gold workings in the Balingup Complex including Mine Hill and Majenup in which the mineralisation is probably of Archaean age. In the Mine Hill occurrence, gold, molybdenite and chalcopyrite are present in a shear zone and stockwork of quartz veins in metasedimentary rocks or felsic volcanic rocks. At Majenup, gold is present in a massive quartz vein ; the country rocks are paragneiss, micaceous schist and talc schist. At the Yanmah prospect, a drill hole intersected gold mineralisation with associated high arsenic values at the contact between a light coloured and a dark coloured schist. The tract also includes a small area that covers outcrop of amphibolite in the Nornalup Complex. It hosts the old Redmond gold workings.

The tract is considered to have moderate to high potential with a certainty level of C.

Tract Au2c/M/B

This tract consists of the remaining Archaean to the east of the Darling Fault. It excludes the Collie Basin. This tract contains a number of northwest trending faults. These faults were active in the Phanerozoic but are inferred to have been lines of weakness from Archaean times. The Saddleback Greenstone Belt is controlled by two of these faults and it is possible that there are some as yet discovered slivers of greenstone belt along these faults. The faults may also have acted as conduits for auriferous fluids.

This tract also includes paragneiss, schist and metasedimentary rocks of the Biranup Complex. This area has the potential to host Archaean deposits that were metamorphosed and deformed in the Proterozoic. There are no known deposits in this tract within the South-West Forest region but the Kendenup deposit located just outside the eastern margin of the South-West Forest region, is associated with gneiss, granofels and amphibolite of the Biranup Complex. Some gold anomalies have also been reported from this area.

The potential of this tract is assessed as moderate with a certainty level of B.

Tract Au2d/U/A

This tract consists of the remainder of the Biranup Complex and Nornalup Complex. It consists predominantly of granite, migmatite and orthogneiss but there could be other rock types hidden beneath the extensive Tertiary sedimentary and regolith cover. The area is assessed as having an unknown potential with a certainty level of A.

Economic Significance

Grade and tonnage data on 116 deposits of this type (Cox and Singer, 1986) shows that 10% of them contain at least 0.093 million tonnes of ore, 50% at least 0.94 million tonnes and 10% at least 12 million tonnes. In general these deposits have more gold than silver. The ores in 90% of these deposits contain at least 4.4 g/t gold, 50% at least 9.2 g/t gold, and 10% at least 19 g/t gold and 3.3 g/t silver. The primary resource at Boddington is very large: 215 Mt (See Chapter 5).

Au3: RIFT-RELATED EPITHERMAL GOLD DEPOSITS (Figure 6)

Model Description:

Description of model by Lee Hassan.

Approximate Synonym: Hot spring gold deposits related to rifting

Description: gold ± base metal sulphides in quartz carbonate veins, stockworks, breccias and silicified shear zones.

General References: Pirajno and Surtees (1993), Fulp and Woodward (1990), Morant (1988)

Geological Environment:

Rock types: Could be any type of rock. Known deposits occur in clastic sedimentary rocks, mafic lavas and Precambrian gneisses and greenstones.

Age range: Carboniferous to Recent

Depositional environment: hot spring activity due to elevated geothermal gradient associated with rifting. There may be cooling igneous bodies at depth in some cases but, in general, the deposits show no obvious association with igneous rocks. There may be older gold-bearing source rocks at depth.

Tectonic Setting(s): Along and adjacent to major rift zones.

Associated deposit types: Rift-related hot spring massive sulphide deposits, hot spring gold deposits

Deposit Description:

Mineralogy: Gold ± electrum ± pyrite ± arsenopyrite ± basemetal sulphides ± tellurides. Gangue minerals include quartz, chalcedony ± carbonate ± barite ± fluorite ± alunite ± kaolinite ± iron oxides ± turquoise

Texture/structure: veins banded, drussy or with bladed textures, stockworks, breccias (often recemented by silica), dense cherty silica, spongy silica.

Alteration: silicification, propylitic and argillic alteration; alteration minerals include quartz, kaolinite, illite, smectite, sericite, pyrite, alunite and haematite.

Ore controls: Through-going fracture systems and breccia zones.

Weathering: Precambrian host rocks may be kaolinised or lateritised, sulphides in the ore zone may be oxidised and leached.

Geochemical signature: Au ± Ag ± As ± Ba ± F ± Cu ± Pb ± Zn.

Geophysical signature: gravity, radiometric and magnetic anomalies associated with rift zone.

Examples:

Donnybrook, Western Australia	(Morant, 1988, Ward, 1986).
Limpopo Region, South Africa	(Pirajno and Surtees, 1993).
Hell Canyon, USA	(Fulp and Woodward, 1990).

Known deposits and occurrences in the region

There are a number of gold-bearing silicified shear zones, breccia zones, quartz stringers and quartz veins in close proximity to the Darling Fault south of Donnybrook. The Darling Fault is a major rift zone (Veevers and Hansen, 1981). Gold has been worked from the Donnybrook Sandstone, mudstone and fluvio–glacial sandstones of Early Permian age (Backhouse and Wilson, 1988) and from the underlying Archaean schists, gneisses and amphibolites of the Balingup Complex. The mineralisation has a number of distinctive epithermal features including platy textures with silica replacing original carbonate and/or sulphate minerals, breccias which have been recemented by silica, multiple fine quartz veining/stockworking and pyritic silica and chert breccias (Morant, 1988). Alteration includes silicification, propylitic and argillic alteration (Ward, 1986). Alunite is associated with the highest-grade mineralisation and pyrite and haematite are locally associated with silicification in the sandstones. Mineralisation was previously thought to be Cretaceous in age and related to the 135 Ma Bunbury Basalt. However, pebbles of mineralised Donnybrook Sandstone have been found in palaeovalleys beneath the Bunbury Basalt indicating that mineralisation preceded the Bunbury Basalt. Furthermore, the Bunbury Basalt and Leederville Formation that unconformably overlie the Donnybrook Sandstone, show no sign of hydrothermal alteration whereas the Donnybrook Sandstone is pervasively silicified. For these reasons, Morant (1988) concluded that the mineralisation was of Permian age but may have been a prelude to basaltic volcanism. Chalmers (pers comm) suggested that a mantle plume generated by major rifting and the Gondwana breakup was responsible for the epithermal fluids.

Several small gold occurrences in the Leeuwin Complex (eg. Petterd and Cross Reef and Boodgidup Brook) also have epithermal textures and have been interpreted as rift related epithermal deposits (Ian Chalmers, pers comm).

Assessment Criteria

1. Presence of favourable structures (ie rift zones).
2. Presence of silicification, propylitic and argillic alteration.
3. Presence of mineralisation displaying typical epithermal features.

Assessment Tract: Au3a/H/C

This tract covers the extent of the Donnybrook Sandstone and includes the known Donnybrook epithermal deposits. The tract is assessed as having high potential with a certainty level of C.

Assessment Tract: Au3b/M–H/C

This tract covers the remaining area within 10 km of the Darling Fault on the eastern side of the fault. Base metal and barite mineralisation has been reported from Mundijong, Armadale and Serpentine just to the west of the South-West Forest region and occurrences of quartz veins with epithermal features have been reported north and south of the Donnybrook deposits. The tract is assessed as having moderate to high potential with a certainty level of C.

Assessment Tract: Au3c/M/B

This tract covers the Leeuwin Block where there are a number of old workings on quartz veins that have been interpreted as epithermal (Chalmers, pers comm). The tract is assessed as having moderate potential with a certainty level of B.

Assessment Tract: Au3d/U/A

This tract covers the remaining Precambrian rocks south of the Saddleback Greenstone Belt where there are a number of major northwest trending faults and also a major tectonic boundary between the Yilgarn Craton and the Albany–Fraser Orogen. This tract has an unknown potential (certainty level of A) for epithermal gold mineralisation.

Economic Significance

To date, only a few deposits of this type have been reported and they are relatively small producers of gold. However, as the model is new and there has been very little exploration for this type of mineralisation, significant deposits could be discovered in the future.

Au4: PLACER GOLD (MODEL 39A OF COX AND SINGER, 1986) (Figure 7)

Model Description

Modified after Warren E. Yeend.

Approximate Synonym: Placer gold.

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

General References: Boyle (1979), Wells (1973), Lindgren (1911).

Geological Environment:

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

Textures: Coarse clastic.

Age range: Generally Cainozoic but may be of any age.

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

Tectonic setting(s): 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: Alluvial tin and tantalum, black sands (magnetite, ilmenite, chromite); Platinum group elements, yellow sands (zircon, monazite). Au placers commonly derived from various Au vein-type deposits but also other gold deposits, eg. porphyry copper–gold, gold skarn, massive sulphide deposits and replacement deposits.

Deposit Description:

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

Texture/Structure: Usually flattened with rounded edges, also flaky or flour gold (extremely fine grained); rarely angular and irregular ("crystalline"), very rarely equidimensional nuggets.

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

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

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

Examples:

Sierra Nevada, USA	(Lindgren, 1911; Yeend, 1974)
Victoria	(Knight, 1975)

Known deposits and occurrences in the area

Placer gold deposits derived from epithermal gold veins have been worked at Donnybrook. Alluvials derived from Archaean quartz veins in the Balingup Complex have been worked at Waterfall Gully.

Assessment Criteria

1. Presence of gold-bearing source rocks or areas assessed to have potential for primary gold mineralisation.
2. Distribution of Permian, Cretaceous, Tertiary and Quaternary alluvial, colluvial, eluvial, fluvio–glacial and lacustrine deposits.
3. Distribution of placer gold prospects and deposits.

Assessment

Tract: Au4a/M–H/B

This tract includes all Permian, Cretaceous, Tertiary and Quaternary alluvial, colluvial, eluvial, fluvio–glacial and lacustrine deposits over areas considered to have high or moderate to high potential for primary gold mineralisation. It includes known deposits of placer gold at Donnybrook and Waterfall Gully as well as anomalous gold results from stream sediment surveys. The tract is assessed as having moderate to high potential for placer gold with a certainty level of B.

Tract: Au4b/M/B

This tract includes all Permian, Cretaceous, Tertiary and Quaternary alluvial, colluvial, eluvial, fluvio–glacial and lacustrine deposits over areas considered to have moderate potential for primary gold mineralisation. The tract includes several northwest trending faults that may have acted as conduits for auriferous fluids and along which there may be remnants of greenstone belts. It is considered that the potential for placer gold being derived from such deposits is moderate with a certainty level of B.

Economic significance:

According to grade/tonnage models for placer gold deposits, 90% of deposits contain at least 0.022 million tonnes of ore, 50% at least 1.1 million tonnes and 10% at least 50 million tonnes. In these types of deposits, 90% contain at least 0.084 g/t Au, 50% at least 0.2 g/t Au and 10% at 0.48 g/t Au (Cox and Singer, 1986).

HMS1: DESCRIPTIVE MODEL OF SHORELINE/FLUVIATILE PLACER TITANIUM (HEAVY MINERAL SANDS) (MODEL 39C OF COX & SINGER, 1986) (Figure 8)

Model Description

Description of the model modified after Eric R. Force:

Description: Ilmenite and other heavy minerals concentrated by beach and fluviatile processes and enriched by weathering.

General References: Force (1976), Baxter (1977), Harrrison(1990).

Geological Environment:

Rock Types: Well-sorted medium- to fine-grained sand in dune, beach, inlet, estuarine and fluviatile deposits commonly overlying shallow marine deposits.

Age Range: Commonly Miocene to Holocene, but may be any age; Cretaceous to Recent in the South-West Forest region.

Depositional Environment: Stable coastal or fluviatile region receiving sediment from deeply weathered metamorphic terranes or older sedimentary rocks.

Tectonic Setting(s): Margin of craton. Crustal stability during deposition and preservation of deposits.

Deposit Description:

Mineralogy: Altered (low Fe) ilmenite ± rutile ± zircon ± leucoxene ± monazite (in some cases garnet concentrations may be high and of economic significance eg Port Gregory). Low levels of magnetite, pyroxene, amphibole, sillimanite, tourmaline and/or garnet. Quartz greatly exceeds feldspar.

Texture/Structure: Elongate "shoestring" ore bodies parallel to coastal dunes and beaches or disseminated in estuarine/lacustrine deposits.

Ore Controls: High-grade metamorphic or older sedimentary rock source; stable coastline or estuarine/fluviatile environment with efficient sorting and winnowing; weathering of beach deposits.

Weathering: Leaching of Fe from ilmenite and destruction of labile heavy minerals results in residual enrichment of deposits.

Geochemical and Geophysical Signatures: High Ti, Zr, REE, Th and U. Gamma radiometric anomalies resulting from monazite content. Induced-polarisation anomalies from ilmenite. Weak magnetic anomalies from ilmenite.

***Examples**:*

Capel Shoreline	Western Australia.
Eneabba Shoreline	Western Australia.
Waroona Shoreline	Western Australia.
Scott River	Western Australia.
Yoganup Shoreline	Western Australia.
Beenup	Western Australia.

Known deposits and mineral prospects in the region

The most significant deposit in the area is the Beenup deposit. This is a large, low-grade, heavy mineral sand deposit associated with estuarine and fluviatile sedimentary rocks in the Cretaceous Leederville Formation and overlying Tertiary sediments on the Scott Coastal Plain (BHP Environmental Review and Management Plan). Some of the deposits of the Yoganup, Waroona and Happy Valley Strandlines fall within the boundaries of the South West Forest region. These paleo-strandlines onlap the Darling Fault and lie at the base of the Whicher Scarp on the Swan Coastal Plain. On the Scott Coastal Plain, there are deposits and occurrences along the Warren or Scott Shoreline, the Donnelly Shoreline, the Milyeaanup Shoreline and the Quindalup Shoreline.

Assessment criteria

1. Late Tertiary and Quaternary shallow marine sands, that have reworked Permian to Cretaceous sediments or material eroded from them.
2. Coastal sands subjected to marine transgression/regression and periodic uplift.
3. Recent or fossil dune sands.
4. Cretaceous fluviatile and estuarine sediments.
5. Residual deposits over Precambrian Rocks.
6. Alluvial channels developed over Precambrian rocks.
7. Distribution of known deposits, occurrences and anomalies.

Assessment:

Tract HMS1a/H/C–D

This tract includes the Yoganup, Waroona and Happy Valley Strandlines with known deposits onlapping the Darling Fault and lying at the base of the Whicher Scarp which are assessed as having high potential with a certainty level of C to D.

This tract also includes an area of known deposits and anomalies in the estuarine and fluviatile facies of the Cretaceous Leederville Formation deposits and anomalies on the Quaternary to Recent Scott Coastal Plain and residual deposits including the Mt. Duckworth deposit on the Leeuwin Block. These areas are assessed as having a high potential with a certainty level of C.

Tract HMS1b/M–H/B–C

This tract includes a buffer zone to the east of Tract HMS1a overlapping the Darling Fault and Whicher Scarp with known occurrences and also the West Coastal dune sands along the western margin of Leeuwin Block with small known deposits. There are also some residual deposits within this tract. The tract is assessed as having moderate to high potential with a certainty level of B to C.

Tract HMS1c/M/C

This tract includes the South Coast Quaternary to Recent dune sands and the north western edge of the South-West Forest region where the Darling Fault scarp is subdued and overlain by Quaternary alluvium (this marks the start of the Gingin shoreline which is outside of the study area). The tract is assessed as having a moderate potential with a certainty level of C.

Tract HMS1d/L–M/B

This tract includes the remaining Cretaceous Leederville Formation that has sedimentary rocks formed in a lacustrine environment with lower concentrations of HMS and increasing presence of thin seams of peat or lignite. The potential of this tract is assessed as low to moderate with a certainty level of B.

Tract HMS1e/L /B–C

This tract includes the Archaean east of the Darling Fault that has minor residual and Tertiary to Recent alluvial occurrences. The potential of this area is assessed as low with a certainty level of B. This tract also includes the Central Leeuwin Block between Tract HMS1b and Tract HMS1a where extensive drilling has indicated that there is a low potential with a certainty level of C.

Economic Significance: Western Australia is a major producer of heavy mineral sands as discussed in Chapter 5

RMPeg1: RARE-METAL PEGMATITE (Figure 9)

Model Description

Description of model by Subhash Jaireth and Lee Hassan.

Description: Zoned and/or simple pegmatites with tin, tantalum, niobium, lithium, beryl and REE mineralisation.

General References: Sinclair (1995), Cerny (1993), Bettenay et al (1985), Partington et al (1995).

Geological Environment:

Rock types: Pegmatites are simple, layered or zoned. Zoned pegmatites are frequently composed of blocky microcline, albite and quartz zones. Pegmatites intrude sedimentary, metasedimentary and metavolcanic rocks. In many cases there is a genetic and spatial relation with granites.

Textures: Rare relict igneous textures in pegmatites. Most pegmatites are recrystallised.

Age Range: Variable, from Archaean to Tertiary.

Depositional Environment: Rare element pegmatites of the LCT (Lithium, Caesium and Tantalum rich) and NYF (Niobium, Yttrium and Fluorine rich) types of Cerny (1993) occur in less deeply eroded low pressure (2–4 Kb) metamorphic terranes, generally of cordierite–amphibolite facies. They are typically late orogenic to anorogenic and are commonly peripheral to larger granitic plutons. Most of these rare element pegmatites are distributed in zonal patterns around intrusions with the most enriched in rare elements and volatiles located farthest from the intrusion. Rare element pegmatites of the magmatic disseminated class of Bettenay et al (1985) occur in medium pressure (4–5.5 kb), upper amphibolite Barrovian type metamorphic terrains along major shear zones; they are syntectonic and synmetamorphic and have no demonstrated relationship with specialised granites although there may be some spatial relationship with non-specialised granites.

Tectonic Setting (s): Archaean cratons and Phanerozoic orogenic belts. Some Archaean pegmatites are typically localised along deep fault systems that in many areas coincided with major metamorphic and tectonic boundaries.

Associated deposit types: Other types of pegmatite, tin and tungsten greisens and veins, rare metal deposits associated with peraluminous to subalkaline granites. Residual and alluvial cassiterite and tantalite concentrations and kaolin/halloysite.

Deposit Description:

Mineralogy: Quartz, microcline, perthite, albite, muscovite, zinnwaldite, tourmaline, apatite, zircon, garnet, rutile, cassiterite, spodumene, beryl, tantalite, stibiotantalite, microlite, tapiolite, wodginite, holtite. REE-bearing pegmatites (NYF type) contain davidite, samarskite, monazite, brannerite, fergusonite, euxinite–polycrase, allanite, florencite.

Texture/Structure: Many unmineralised pegmatites are unzoned but rare element pegmatites show complex zoning. Typical zoning in zoned pegmatites of LCT and NYF types (from margin to the centre): border zone (aplitic texture); wall zone (coarse-grained and contains mainly quartz, feldspar, and muscovite); intermediate zone (contains economically important minerals such as sheet mica, beryl, spodumene amblygonite, lepidolite, columbite–tantalite and cassiterite. Some crystals may be metres or even tens of meters in dimension); core (massive or euhedral quartz). Reverse zoning may be present in magmatic disseminated type pegmatites. Pegmatites frequently have xenoliths of country rocks. In REE-bearing pegmatites of the NYF type the REE minerals and phosphate nodules occur between the quartz core and the intermediate feldspar-rich zone.

Alteration: Alteration zones around pegmatite bodies are usually up to a few meters thick but may be over 150 m in magmatic disseminated rare earth pegmatites and contain biotite, holmquistite (lithium–glaucophane), sphene, garnet, tourmaline, epidote, scapolite and arsenopyrite.

Ore controls: Many pegmatite bodies are controlled by shear zones and may be synmetamorphic and synkinematic. Potassium zone contains traces of tin, tantalum, niobium and lithium. Tin, tantalum and niobium mineralisation is generally concentrated in the albite zone as disseminations and locally in quartz and- and greisen-rich marginal zone. Lithium mineralisation may form irregular zones and bands throughout the pegmatite body or be concentrated in a separate zone. Tin and tantalum may be in discrete bodies or be disseminated throughout the albite zone.

Weathering: Weathering can be up to a few tens of meters. Pegmatites weather into a mass of kaolinitic clay with residual pegmatitic minerals such as quartz and muscovite. The weathered mass bears low-grade tin and tantalum mineralisation.

Geochemical signature: A broad geochemical halo of alkali elements in the country rock. Primary dispersion haloes in host rocks of Li, Rb, Cs, Be, B, As and Sb. Secondary dispersion haloes in overburden along with light and heavy minerals in stream sediments.

Geophysical signature: radiometric survey may be useful for identifying parent granite and/or associated pegmatites that are enriched in U and Th.

Examples:

LCT type: Tanco pegmatite, Canada (Sinclair, 1995), Bikita field, Zimbabwe (Cerny, 1993).
NYF type: Shatford Lake, Canada (Cerny, 1993).
Magmatic disseminated type: Greenbushes, Western Australia (Bettenay et al., 1995).

Known deposits and occurrences in the region

The Greenbushes pegmatite is one of the largest lithium and tantalum deposits in the world. It consists of one main pegmatite and several smaller pegmatites that have intruded the Archaean Balingup Complex over a strike length of 7 km along the regional Donnybrook–Bridgetown shear zone. The main pegmatite is approximately 3.3 km long and up to 250 m wide and has been drilled to a vertical depth of 500 m with no indication of a decrease in thickness (Hatcher and Clynick, 1990). The main pegmatite occurs at or close to the contact between mafic /ultramafic rocks and laminated metasedimentary rocks (granofels). The pegmatite has sharply bounded Li-rich, K-rich and Na-rich zones. Unlike other zoned pegmatites in which the Li occurs in the central part of the pegmatite, the Na-zone is centrally disposed and the Li zone forms a carapace to the pegmatite. Sn–Ta mineralisation is disseminated throughout the Na-rich zone. Major element and trace element geochemistry (with the exception of Ti) of the pegmatites is essentially similar to that reported for other rare-element pegmatites (Partington, 1995). Similarly, the fractionation indices are also similar to those reported for other rare-element pegmatites (Partington, 1995). Blockley (1980) noted that granites belonging to the Darling Range–Wheat Belt Granite outcropped 10 km north of Greenbushes to the east of a major lineament. He reported that the petrography and chemistry had no characteristics of typical tin granites. There are also a number of smaller granitoids aligned parallel to the Donnybrook–Bridgetown shear zone (Partington et al., 1995). Recent age dating of pegmatites and granitoids in the area suggests that the intrusion of pegmatites occurred at least 85 to 50 m.y. after the intrusion of granitoids known to exist in the vicinity of the pegmatites and a regional gravity survey discounts the possibility of a body of granitoid large enough to be parental to these pegmatites (Partington et al, 1995). This provides the basis for Partington et al (1995) to conclude that the rare-element pegmatites do not have any parental granitoid. Unlike most other rare metal pegmatites, intrusion and crystallisation of the Greenbushes pegmatite was synchronous with deformation and the pegmatite formed under medium–to high temperature and medium–pressure metamorphic conditions.

The most important control on the intrusion of the pegmatites is attributed to the Donnybrook–Bridgetown shear zone. Detailed studies by Bettenay et al (1995) suggest that the Greenbushes pegmatite formed directly by partial melting of Li-rich source rock. Bettenay et al (1995) proposed the term 'magmatic disseminated' for this type of rare metal pegmatite.

A small swarm of Sn–Ta bearing pegmatites at Smithfield, approximately 30 km south of Greenbushes, close to the same regional shear zone is probably also of the magmatic disseminated type.

A small pegmatite at Mt Dale containing minor rare-earth minerals, manganocolumbite and beryl is possibly an NYF type pegmatite. It probably occurs within granite but has not been studied in detail.

Assessment Criteria

1. Distribution of metamorphic complexes
2. Presence of major faults
3. Presence of known primary and alluvial tin and tantalum deposits and occurrences
4. Presence of geochemical anomalies of Sn, Ta, Li, Nb, Sb and As.

Assessment:

Tract RMPeg1a/H/C

The tract is delineated based on the criteria that all significant rare-element pegmatites in the area are regionally controlled by major faults and shear zones. The Greenbushes pegmatite and Smithfield pegmatites are spatially associated with the Donnybrook–Bridgetown shear zone and most tin, tantalum and lithium anomalies occur close to fault zones within the metamorphic complexes. A 3 km zone around major faults (Darling Fault, Donnybrook–Bridgetown shear zone, Donnybrook–Nanup shear zone) within the Balingup Complex defines the tract. Thus the presence of metamorphic complexes of amphibolite facies metamorphism, of major structures and of known mineral occurrences indicates that the tract has a high potential with a certainty level of C.

Tract RMPeg1b/M/C

The tract includes the remainder of the Balingup Complex and the Jimperding–Chittering Complex where some anomalous values of tin, tantalum and lithium have been reported. It also includes the Mt Dale pegmatite occurrence. The mineral potential of this tract is assessed to be moderate with a certainty level of C

Economic Significance

Rare-element pegmatites are one of the major sources of rare metals such as Cs, Nb, Ta. The Tanco pegmatite in Canada contains the largest known concentration of Cs bearing mineral pollucite. It was also the largest tantalum producer in the 1970s (Sinclair, 1995). These pegmatites are also major producers of lithium. The tin–spodumene belt in North Carolina has measured and indicated reserves of 26 million tonnes of ore with 1.5% Li_2O (Sinclair, 1995). Greenbushes is the largest pegmatite producer of Ta and Li mineralisation the world. For resource data on the Greenbushes pegmatite see Chapter 5.

RE1: ALLUVIAL TIN and TANTALUM (MODIFIED AFTER MODEL 39E OF COX AND SINGER, 1986) (Figure 10)

Model Description

Description of the model after Bruce L. Reed and Victor M. Levson (British Columbia).

Description: Cassiterite, Columbite–tantalite and associated heavy minerals in silt– to cobble–size nuggets.

Approximate Synonyms: fluvial, alluvial, colluvial, aeolian and glacial placers. Surficial placers.

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

Geological Environment:

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

Textures: Fine to very coarse clastic.

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

Depositional Environment: Surficial fluvial placer concentrations occur mainly in large, high order, stream channels (allochthonous deposits) and along bedrock in high energy, steep gradient, low sinuosity, single channel streams (autochthonous deposits). Concentrations occur along erosional surfaces at the base of the channel sequences. 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). Alluvial fan, fan-delta and delta deposits are distinct from fluvial placers as they occur in relatively unconfined depositional settings and typically are dominated by massive or graded sands and gravels, locally with interbedded diamicton. Colluvial placers generally develop from residual deposits associated with primary lode sources by sorting associated with downslope migration of heavy minerals. Fluvio–glacial and glacial placers are mainly restricted to areas where ice or meltwater has eroded pre-existing placer deposits. Cassiterite, ilmenite, zircon and rutile are lighter heavy minerals that are distributed in a broader variety of depositional settings. Stream placers may occur as offshore placers where they occupy submerged valleys or strandlines.

Tectonic Setting(s): Fine-grained, allochthonous, placers occur mainly in stable tectonic settings (shield or platform environments and intermontane plateaus) where reworking of clastic material has proceeded for long periods of time. Coarse autochthonous, placer deposits occur mainly in Cainozoic and Mesozoic accretionary orogenic belts and volcanic arcs, commonly along major structural faults. Accreted terranes or stable cratonic foldbelts that contain highly evolved granitoid plutons or their extrusive equivalents constitute favourable environments.

Associated Deposit Types: Alluvial gravels may contain by-product ilmenite, zircon, monazite, and, where derived from cassiterite-bearing pegmatites, columbite–tantalite. Economic placers are generally within a few (<8) kilometres of the primary sources. Any type of cassiterite-bearing tin deposit may be a source. The size and grade of the exposed source frequently has little relation to that of the adjacent alluvial deposit.

Deposit Description:

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

Texture/Structure: Cassiterite becomes progressively coarser as the source is approached; euhedral crystals indicate close proximity to primary source. Where a marine shoreline intersects or transgresses a stream valley containing alluvial cassiterite the shoreline placers normally have a large length-to-width ratio. Placer minerals associated with colluvial placer deposits are generally coarser grained and more angular.

Ore Controls: In fluvial settings, placer concentrations occur at channel irregularities, in bedrock depressions and below natural riffles created by fractures, joints, cleavage, faults, foliation or bedding planes that dip steeply and are oriented perpendicular or oblique to stream flow. Coarse grained placer concentrations occur as lag concentrations where there is a high likelihood of sediment reworking or flow separation such as at the base of channel scours, around gravel bars, boulders or other bedrock irregularities, at channel confluences, in the lee of islands and downstream of sharp meanders. Basal gravels over bedrock typically contain the highest placer concentrations. Fine-grained placer concentrations occur where channel gradients abruptly decrease or stream velocities lessen, such as at sites of channel divergence and along point bar margins. The richest placers lie virtually over the primary source. Streams that flow parallel to the margin of tin-bearing granite are particularly favourable for placer tin accumulation. Colluvial placers are best-developed on steeper slopes, generally over a weathered surface and near primary lode sources. Fluvio–glacial concentrations occur mainly along erosional unconformities within otherwise aggradational sequences.

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

Geophysical Signature: Ground penetrating radar is especially useful for delineating the geometry, structure and thickness of deposits with low clay contents particularly fluvial terrace placers. Shallow seismic, electromagnetic, induced polarisation, gravity, resistivity and magnetometer surveys are locally useful. Geophysical logging of drill holes with apparent conductivity, naturally occurring gamma radiation and magnetic susceptibility tools can supplement stratigraphic data.

Examples:

Southeast Asian tin fields	(Hosking, 1974); (Newell, 1971). (Simatupang et al, 1974). (Westerveld, 1937).
Rio Huanuni and Ocuri, Bolivia	

Known deposits and mineral prospects in the region

Alluvial tin deposits at Greenbushes occur both in Recent alluvium and in the Greenbushes Formation (formerly known as "Old Alluvium") in close proximity to the primary pegmatite (Blockley, 1980). The age of the Greenbushes Formation is uncertain; it has been correlated with the Nakina Formation which is now regarded as being Cretaceous (Backhouse, 1989). The tin-bearing Greenbushes Formation consists of interbedded sandstone and conglomerate. The conglomerate contains quartz, quartzite and more rarely, pegmatite clasts ranging from pebble to boulder size in a matrix of white clayey sand containing tourmaline and cassiterite. Small workings at Willow Springs are also in the Greenbushes Formation. The source of the tin and tantalum at Willow Springs is not certain because no pegmatites have yet been located in the vicinity. Recent alluvial tin deposits are associated with small pegmatites at Smithfield and Native Dog Gully.

Assessment Criteria

1. Distribution of metamorphic complexes.
2. Distribution of Permian, Cretaceous, Tertiary and Quaternary alluvial, colluvial, eluvial, fluvio–glacial and lacustrine deposits.
3. Presence of major faults.
4. Distribution of alluvial tin deposits and geochemical anomalies of Sn, Ta, Li, Nb, Sb and As in stream sediment samples.

Assessment:

Tract: RE1a/H/C

This tract includes all Permian, Cretaceous, Tertiary and Quaternary alluvial, colluvial, eluvial, fluvio–glacial and lacustrine deposits over areas considered to have high potential for primary rare element pegmatite mineralisation (ie. over areas adjacent to major faults within the Balingup Metamorphic Complex). This tract includes the Greenbushes, Willow Springs, Smithfield and Native Dog Gully alluvial deposits and many anomalous stream sediment values. The tract is assessed as having a high potential with a certainty level of C.

Tract RE1b/M/B

This tract includes all Permian, Cretaceous, Tertiary and Quaternary alluvial, colluvial, eluvial, fluvio–glacial and lacustrine deposits over areas considered to have moderate potential for primary rare element pegmatite mineralisation (ie. over remaining areas of the Balingup Complex and the Jimperding/Chittering Metamorphic Complex). The tract includes some anomalous stream sediment values. The tract is assessed as having a moderate potential with a certainty level of B.

Hydrocarb: HYDROCARBONS (Figure 11)

Assessment

Tract: Hydrocarb/M/B

The onshore southern Perth Basin is a deep elongate north-trending trough that covers an area of approximately 50 000 km^2 between the Leeuwin Complex to the west and the Yilgarn Craton to the east. The contacts with those areas are major faults — the Dunsborough and Darling Faults, in the west and east respectively. On the western margin of the basin between the Dunsborough and Busselton Faults is the structurally shallow Vasse Shelf whereas to the east is the deep Bunbury Trough. The basin contains up to 9000 m of Permian to Quaternary sediments but only the pre-Cretaceous is of sufficient thickness to be of interest for petroleum. The prospectivity of the area is limited by the absence of thick shales that could form a regional seal and source, rocks similar to the northern Perth Basin. Nevertheless, the presence of thin shales associated with coal seams in the Sue Coal Measures suggests that there is at least a moderate potential for the generation of gas at that level. The rarity of shale above the Permian suggests little other potential exists in the area.

To date most of the approximately 3000 km of seismic data that has been recorded in the area is from the western half of the Bunbury Trough where the top of the Permian is at depths of up to 4750 m, and where most of the 10 exploration wells in the area have been drilled. The presence of moderate gas shows within the Permian at depths up to 4300 m in the three Whicher Range wells confirms that the area has generated hydrocarbons. These shows are currently being reassessed by Penzoil using modern stimulation techniques.

In the eastern half of the Bunbury Trough there are relatively few seismic lines but, even though the top of the Permian is likely to exceed 6000 m depth in places, this does not preclude the possibility of deep traps in that area. Although the risk of decreasing permeability and porosity could make drilling for such a deep target expensive, the presence of hydrocarbons is known to preserve reservoir quality at depth and the high pressures of any deep gas can make the economics of such plays attractive.

On the Vasse Shelf the Permian lies at depths between 50 and 2500 m and is known to contain substantial coal deposits. Although there have not been any recorded shows of methane from coal exploration drilling such bores are typically shallow and are unlikely to have been drilled on valid traps. The potential for gas including coal-bed methane, therefore, is also rated as moderate in this area.

Economic significance: Petroleum production represents 30% of Western Australia’s value of production for minerals and energy. Any gas produced from the South-West Forest would lower power costs for industry.

NiCuPGE1: SYNOROGENIC–SYNVOLCANIC NICKEL–COPPER–CHROMIUM–PLATINUM GROUP ELEMENTS (MODEL 7A OF COX AND SINGER, 1986) (Figure 12)

Model Description

Description of the model modified after Norman J Page.

Approximate Synonyms: Ni–Cu–Cr–PGE in mafic rocks; Stratabound sulphide-bearing Ni–Cu; gabbroid associated Ni–Cu–Cr–PGE.

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

General References: Hoatson et al (1992), Ross and Travis (1981), Marston et al (1981), Hoatson and Glaser (1989).

Geological Environment:

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

Textures: Phase and cryptic layering sometimes present, rocks 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(s): Mobile belts; metamorphic complexes, greenstone belts.

Associated Deposit Types: Komatiitic Ni–Cu, dunitic Ni–Cu (adcumulate komatiite), lateritic Ni–Co

Deposit Description

Mineralogy: ± Pyrrhotite ± pentlandite ± chalcopyrite ± pyrite ± Ti-magnetite ± chromite ± PGE's, ± graphite; with possible by product Co.

Texture/Structure: Disseminated sulphides in stratabound layers up to 3m thick; commonly deformed and metamorphosed so primary textures and mineralogy may be modified. Chromite can occur in cumulous layers or lenses.

Alteration: Alteration (serpentinization, etc.) can be present in this deposit type.

Ore Control: Sulphides may be near the basal contacts of the intrusion but are generally associated more with gabbroic dominated rather than basal ultramafic cumulates. Sulphides may be disseminated through the intrusion and chromite is generally concentrated in the basal cumulates.

Weathering: May be recessive if altered and 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	(Thornett, 1981).
Radio Hill, Mount Sholl, Western Australia	(Hoatson et al, 1992).
Rana, Norway	(Boyd and Mathiesen, 1979).
Moxie pluton, USA	(Thompson and Naldrett, 1984).

Cuni deposits (Five mile), Tasmania	(Blissett, A,H,. 1962).
Zeehan, Tasmania	(Horvath, J., 1957).

Known deposits and mineral prospects in the South-West Forest Region

In the south of the region occurrences of Cr and Ni are known at Yornup South, Cr at Yornup Northeast and Ni at Palgarup. Best intersections at Palgarup were 0.83% Ni while at Yornup South drill intersections of generally less than 0.3% Ni have been recorded. The best Cr intersections were 5m at 5.3% Cr at Yornup South and 2m at 7.4% Cr at Yornup Northeast. The ultramafic–mafic complex at Yornup consists of olivine gabbronorite and harzburgite, lherzolite and dunite which have been extensively serpentinized.

On the northwestern edge of the region significant Ni, Cu and PGE mineralisation has been recorded from an ultramafic–mafic complex near New Norcia. Values of > 2 ppm Pt and Pd have been recorded as well as grades of up to 1.5% Ni and 2.4% Cu. The mafic–ultramafic complex consists of olivine gabbronorite and serpentinite after peridotite and pyroxenite.

Assessment Criteria

1. Existence and extent of mafic – ultramafic bodies (metamorphosed to varying degrees).
2. Known Cu–Ni–Cr–PGE mineral occurrences.
3. Known Cu–Ni–Cr–PGE geochemical anomalies.

Assessment:

Tract: NiCuPGE1a/H/C

This tract is characterised by the presence of abundant mafic–ultramafic bodies within the Balingup and Jimperding–Chittering Complexes: it contains chromite and nickel occurrences at Yornup and Palgarup, and PGE anomalies at Yornup in the south of the South-West Forest region (Balingup Complex). The New Norcia and Yarrawindah PGE occurrences lie just outside the northern margin of the South-West Forest region within the Jimperding–Chittering Complex.

For the two most intensively studied ultramafic/mafic bodies of the Western Gneiss Terrain (WGT), New Norcia and Yornup, different conclusions have been reached as to their genetic origin. Harrison (1986) concluded that these bodies and several others like them are the remnants of large layered igneous complexes and have tholeiitic affinities. Cornelius et al (1987) on the other hand surmised that the Yornup and New Norcia bodies were originally komatiitic-like sills derived from high degrees of partial melting.

It is likely that some of these bodies are dunitic intrusives with komatiitic affinities that have developed cumulate textures and are partially differentiated. Other ultramafic–mafic rocks in the region may have more tholeiitic compositions (eg. Coates gabbro) due to lesser degrees of partial melting. At the scale of the current study it is impossible to distinguish between the different types of mafic and ultramafic bodies.

Komatiite related deposits in the greenstone belts of Western Australia range up to several percent Ni and about 4 ppm combined PGE. Their primary importance is as nickel deposits; in some cases PGE and Cu are produced as by-products. It should be noted that most komatiites are extrusive rocks, whereas the mafic–ultramafic rocks identified in the WGT are not. It is thought that the sediment underlying komatiitic flows may well have been important in the mineralisation process.

Large layered igneous complexes have potential for large stratiform chromite and PGM deposits in thin horizons at particular stratigraphic levels in fractionated mafic–ultramafic sequences. Given the current distribution of mafic–ultramafic rocks and amphibolitic rocks in the WGT and the history of deformation and metamorphism in the area it is difficult to know how large the original mafic–ultramafic bodies were.

Numerous Cu, Ni, PGE and Cr anomalies and prospects in an area around the Yornup and surrounding bodies of mafic–ultramafic composition and intersections from the New Norcia body in the north east of the South-West Forest region indicate that conditions required for Ni–Cu–PGE and chromite mineralisation have been present to some degree.

Given the above information the tract is considered to have high potential with a certainty level of C.

Tract: NiCuPGE1b/M/B

This tract includes the remainder of the Balingup and Jimperding–Chittering Complexes, the Saddleback Greenstone Belt and also an envelope around two large east-west trending dykes. There are scattered mafic/ultramafic intrusions and amphibolites which could be metamorphosed equivalents of these intrusions throughout the metamorphic complexes. Anomalous values for Cr, Cu and Ni have been recorded in the metamorphic complexes. A stream sediment concentrate reputed to have come from Nannup South was found to contain abundant platinum and osmium by the Government Chemistry Laboratory but doubt has been expressed as to the origin of this sample (Saint-Smith, 1912). The large east-west trending dykes have the potential to host a nickel/PGE deposit similar to Jimberlana. This tract has been assessed as having moderate potential with a certainty level of B.

Tract: NiCuPGE1c/L–M/B

This tract includes the paragneisses of the Biranup Complex which contain mafic intrusions that have been reworked in the Proterozoic. The tract is assessed as having low to moderate potential with a certainty level of B.

Tract NiCuPGE1d/L/B

This tract is defined by the remainder of the Archaean terrain in the South-West Forest region. Due to the wide areal extent of regolith development over most of the Yilgarn block it is probable that some ultramafic–mafic bodies remain hidden. The location of some geochemical anomalies apparently at some distance from outcropping mafic–ultramafic sequences attests to the possibility of deposits being obscured by regolith cover. Given the above information the potential for deposits in the terrain is low with a certainty level of B.

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 0.35 wt% Ni and 0.13 wt% Cu, 50% contain at least 0.77% wt% Ni and 0.47% Cu and 10% at least 1.6 wt% Ni and 1.3 wt% Cu (Cox and 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 0.71 wt% Ni and 0.13% Cu, 50% at least 1.5 wt% Ni and 0.094 wt% Cu, and 10% at least 3.4 wt% Ni and 0.28 wt% Cu (Cox and Singer, 1986).

Ni: LATERITIC /SAPROLITIC NICKEL (Figure 13)

Model Description

Description of model modified after Donald A. Singer, in Cox and Singer, 1986

Description: Nickel-rich, in situ lateritic weathering products developed from dunites and peridotites. Ni-rich iron oxides and Ni silicates.

General References: Evans et al (1979), Elias et al. (1981).

Geological Environment

Rock Types: Ultramafic rocks, particularly peridotite, dunite, and serpentinized peridotite.

Age Range: Precambrian to Tertiary source rocks, typically Cainozoic weathering.

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

Tectonic Setting(s): Mobile belts, metamorphic complexes, greenstone belts, convergent margins where ophiolites have been emplaced. Uplift is required to expose ultramafic rocks to weathering.

Associated Deposit Types: Synorogenic–synvolcanic nickel–copper–chromium–platinum group elements, komatiitic Ni–Cu, dunitic Ni–Cu, podiform chromite, PGE placers, serpentine-hosted asbestos.

Deposit Description

Mineralogy: Garnierite, Ni-rich antigorite, Ni and Co analogues of todorokite and chalcophanite, cryptomelane, nontronite, chromite, magnetite, poorly defined hydrous silicates, quartz, and goethite. Goethite commonly contains much Ni.

Texture/Structure: Red–brown pisolitic soils, silica-rich boxworks.

Alteration: Zoned - from top: (1) red, yellow and brown limonitic soils: (2) saprolites - continuous transition from soft saprolite below limonite zone, hard saprolite and saprolitized peridotite, to fresh peridotite. Boxworks of chalcedony and garnierite occurs near bedrock-weathered rock.

Ore Controls: Upper limonite zone containing 0.5-2 percent Ni in iron-oxides; lower saprolite and boxwork zone typically contains 2–4 percent Ni in hydrous silicates. The oxide and silicate ores are end members and most mineralisation contains some of both. Jointing of the ultramafic rock influences the susceptibility to weathering.

Weathering: The profile from red–brown pisolitic soil down to saprolite represents the products of chemically weathered ultramafic rocks.

Geochemical Signature: Enriched in Ni, Co, Cr; depleted in MgO relative to fresh peridotite (less than 40 percent MgO).

Examples:

Poro, New Caledonia	(Troly et al, 1979).
Cerro Matoso, Columbia	(Gomez et al, 1979).
Nickel Mountain, USA	(Chance et al, 1969).
Greenvale, Queensland	(Burger, 1979).
Siberia, Western Australia	(Elias et. al, 1981).

Known deposits and mineral prospects in the South-West Forest region:

Secondary enrichment of Ni has been recorded from several drill holes around the Yornup and Palgarup prospects. The best grades at Yornup were 2% Ni over 6.7m while at Palgarup the best intersections in laterite were 0.8% Ni.

Laterite is extensively developed across the Yilgarn block of Western Australia and covers a significant proportion of the South-West Forest regions area. Ancient lateritic soil profiles in the Yilgarn block 75–100m deep are not uncommon. Lateritic saprolitic Ni deposits known from the Yilgarn block (outside the South-West Forest regions area) include Murrin Murrin, Bulong, Cawse and Siberia. Most of these deposits are developed in saprolite rather than laterite (Elias et al., 1981).

Assessment Criteria

1. Distribution of ultramafic rocks as recorded by Ni–Cu–Cr–PGE tracts.
2. Co-existence of laterite with Ni–Cu–Cr–PGE tracts.
3. Known secondary Ni mineral occurrences.
4. Known Ni–Cu–Cr–PGE geochemical anomalies.

Note: The following tract assessments are in part based on the same tracts as the Ni–Cu–Cr–PGE assessment because the possible host rocks for these deposits are the possible source rocks for lateritic Ni deposits.

Assessment:

Tract: Ni1a/H/B

This tract includes laterite which overlies areas in the Balingup and Chittering Complexes where ultramafic bodies are abundant. This tract includes the Yornup and Palgarup secondary Ni occurrences, as well as several Ni, Cr and PGE geochemical anomalies. Given the numerous ultramafic bodies in the area and the known occurrences of lateritic Ni mineralisation the tract is considered to have a high potential with a certainty level of B.

Tract: Ni1b/M/B

This tract is present where laterite overlies the remainder of the Balingup and Jimperding–Chittering Complexes, the Saddleback Group and two large dykes in the South-West Forest region. The tract is considered to have a moderate potential with a certainty level of B.

Tract: Ni1c/L–M/ B

This tract includes areas where laterite has developed over paragneisses of the Biranup Complex that contains mafic intrusions that have been reworked in the Proterozoic. The tract is assessed as having low to moderate potential with a certainty level of B.

VTi: VANADIFEROUS/TITANIFEROUS MAGNETITE (Figure 14)

Model Description

Description of the model modified after Eric R. Force in Cox & Singer (1986).

Description

Vanadiferous and/or titaniferous magnetite deposits hosted in gabbro and leucogabbro (formerly termed gabbro–anorthosite) and dominantly ilmenite deposits hosted in anorthosite

Geological Environment

Rock Types: Titaniferous magnetite - mafic layered and massive intrusives. The host intrusives are typically differentiated and include gabbro, leucogabbro, diorite, diabase, gabbro–diorite, and quartz monzonite. Ilmenite type - anorthositic rocks. Some deposits in gabbros.

Age Range: The vanadiferous and titaniferous deposits can be any age from Archaean to Cainozoic. Most ilmenite type deposits are between 900 and 1,500 m.y. in age.

Depositional Environment: Lower crust, intrusion under hot, dry conditions.

Tectonic Setting(s): Not well known.

Associated Deposit Types: Ni–Cu/Chromite/PGE, Lateritic vanadium.

Deposit description:

Mineralogy:

(1)Vanadiferous and/or titaniferous magnetite.
(2) Ilmenite ± rutile ± apatite, in anorthosite.

Texture/Structure: Massive lenses, dykes, sills, and irregular bodies; or stratiform, layered, concordant or irregular bodies:
Vanadiferous/titaniferous magnetite- The layered deposits generally form concordant, laterally continuous magnetite-rich layers. Deposits in massive intrusions usually consist of disseminations.
Ilmenite type- Discordant dykes, sills, and stock like masses. Some form layered concentrations of Fe-Ti oxides within anorthosite or gabbro, concordant to layering in the host and to the internal fabric of late stage intrusions.

Alteration: None related to ore.

Ore Controls:
(1) Immiscible Ti, V, P liquid in ferrodioritic magma, forming both cumulate-like bodies and fracture fillings.
(2) High-temperature metasomatism between Ti-Fe oxides-rich country rock, and anorthosite, coupled with unknown processes in anorthosite magma. Especially concentrated in swarms of anorthosite sills.

Weathering: Residual enrichment may occur in weathered zone. Upgrading of vanadiferous magnetite occurs where deposits are lateritised.

Geochemical and Geophysical Signature: High Ti, P, V and Zr. Magnetic anomalies.

Examples

(1) Roseland, USA	(Herz and Force, 1984).
Sanford Lake, USA	(Gross, S. O., 1968).
Laramie Range, USA	(Eberle and Atkinson, 1983).
Coates, Western Australia	(Baxter, 1978).
(2) Roseland, USA	(Herz and Force, 1984).
Pluma Hidalgo, Mexico	(Paulson, 1964).

Known Deposits and Mineral Prospects in Western Australia South-West Forest region area

The Coates vanadium deposit occurs in a layered gabbro. The gabbro consists essentially of three layers: leucogabbro on the footwall, a magnetite gabbro in the centre and a gabbro in the hanging wall. The magnetite gabbro contains 20 to 40 % magnetite and ilmenite which is concentrated in lenticular layers. The ilmenite:magnetite ratio varies considerably but is generally about 4:1. The vanadium is concentrated in the magnetite but small amounts occur in the ilmenite. The magnetite gabbro contains between 0.3 and 0.7 per cent V_2O_5. The gabbro has been subjected to intense weathering and lateritisation. Both the kaolinised gabbro and the laterite contain vanadium resources with the laterite containing the highest grades (0.88 per cent V_2O_5) (Baxter, 1978). Recent aeromagnetic interpretation suggests that Coates is part of a very extensive north-northwest trending dyke (Chalmers, pers comm).

The Tallanalla vanadium occurrence is related to a poorly exposed gabbro containing magnetite bands.

Five small deposits of oxidised vanadium-bearing, titaniferous magnetite (martite and goethite) in laterite occur within 30 km of Katanning (outside the South-West Forest region). Primary mineralisation in gabbro has been located in a small prospecting shaft at Mine Hill, 25 km northwest of Katanning (Townsend, 1994).

Other layered intrusions are present within the metamorphic complexes but on the scale of the mapping undertaken, it is not possible to differentiate those which are tholeiitic and hence which may contain vanadium and ilmenite concentrations, and those which are komatiitic and hence are more prospective for Cu/Ni/Cr/PGE metals (see model for these elements).

Assessment criteria

1. Large doleritic or gabbroic dykes and layered mafic intrusives.
2. Layers of magnetite and ilmenite in gabbro and anorthosite.
3. Magnetic anomalies
4. V, Cr and Ti geochemical anomalies

Assessment:

Tract: VTi1a/H/C

This tract includes a large NNW trending intrusion inferred from aeromagnetic data which contains the Coates vanadium deposit and J64 vanadium deposit. It also includes an area in the eastern part of the Balingup Complex that contains layered mafic/ultramafic intrusions associated with the Yornup Northeast and Yornup South Cr deposits. This tract is assessed as having high potential with a certainty level of C.

Tract: VTi1b/M–H/B

This tract includes the Tallanalla vanadium deposit and a number of dolerite dyke intrusions. This tract is assessed as having moderate to high potential with a certainty level of B.

Tract: VTi1c/M/B

This tract includes:
1. the remainder of the Jimperding/Chittering and Balingup metamorphic complexes which contain scattered layered mafic intrusions.
2. several large east-north east trending dolerite intrusions in the central part of the region (northeast of Collie). These were emplaced along a major east-northeast trending lineament and form the western extremity of the Binneringee Dyke (one of the longest dykes in the world at 585m) Wilde and Walker,1982).

Overall, the tract is assessed as having moderate potential with a certainty level of B.

Tract: VTi1d/L–M/B

This tract includes the paragneisses of the Biranup Complex, which contain mafic intrusions that have been reworked in the Proterozoic. The tract is assessed as having low to moderate potential with a certainty level of B.

Tract: VTi1e/L/B

This tract includes the remainder of the Archaean granite–greenstone terrain which includes a number of dolerite dykes. The tract is assessed as having low potential with a certainty level of B.

Economic Significance

The primary deposit at Coates has demonstrated in situ resources of 39 Mt ore averaging 0.51% V_2O_5 and the lateritised deposit which overlies the primary deposit, has indicated resources of 1.5 Mt ore averaging 0.6% V_2O_5.

At the Windimurra deposit west-southwest of Mt Magnet(outside the South-West Forest region), vanadium is associated with titaniferous magnetite in Archaean gabbroic sills. Precious Metals Australia Ltd reported indicated resources of 44 Mt of oxidised ore averaging 0.56% V_2O_5. The deposit has been subjected to deep lateritic weathering and as a result, the ore is friable and could be easily mined.

Silica: SILICA SAND AND QUARTZITE (Figure 15)

Model description

Description of the model by Aden McKay .

Description: 1. Glass sands, sandstone, aeolian sands, quartzite, chert

General References: Zdunczyk & Linkous 1994; Fetherstone & Brown 1990; Townsend 1994.

Geological Environment:

Rock Types: Unconsolidated sand, sandstone, quartz arenite, quartzite, chert.

Age Range: High quality sands (suitable for glass manufacture) range from Cambrian to Quaternary. Most deposits mined (including WA deposits) are Tertiary and Quaternary. High quality quartzite suitable for silicon production may be any age. In the South-West Forest region, these are Archaean to Proterozoic

Depositional Environment: Wide range in depositional environments including continental shelf, near-shore alluvial fans and aeolian.

Tectonic Setting(s): Various, usually cratonic or continental shelf.

Deposit description:

Mineralogy: Silica sands used for manufacture of glass and quartzite used for manufacture of silicon metal must contain >99% SiO_2 with only very minor amounts of other minerals such as clays and heavy minerals. Sands used for other industrial purposes may be lower quality and contain higher percentages of other minerals.

Texture/Structure: Subangular to well-rounded grain texture, usually well-sorted sands. Quartzites have recrystallised grain texture cemented by silica.

Alteration:

Ore Controls: Silica sands which are mined for industrial uses must conform to the chemical and physical specifications (grain size, grain size distribution, clay content) set by the customers. Quartzite used for manufacture of silicon metal must have >99% SiO_2. Foundary sands must exceed 98% SiO_2 (Zdunczyk & Linkous, 1984). Those deposits of industrial sands which are economic to mine are usually located near to the markets, eg. large cities. Transport costs and beneficiation costs determine which deposits are economic to mine.

Weathering: The highest quality sands are those that have been upgraded by repeated cycles of erosion, winnowing and redeposition (often including aeolian redeposition). Also, high quality silica sands can be produced by leaching of impurities from sands by groundwater.

Examples:

Known Deposits and Mineral Prospects in South-West Forest Region

The Collie and Collie Road South silica sand deposits, located 10 km south-southeast of Collie, are mined for construction sand.

Metaquartzites within the Jimperding–Chittering Complex are quarried at the Clackline deposit, located 18 km southwest of Northam, for use as building and facing stone.

Very high quality silica sands are present within well-sorted Pleistocene sands along the south coast, and the Scott coastal plain. Westralian Sands Limited located a number of silica sand deposits suitable for glass manufacture within a 40 km radius of Albany. Washed sands from these deposits contain greater than 99%

SiO_2. They include two deposits of silica sand in the Narrikup area which have a total resource of 4 million tonnes.

Gwalia Consolidated has demonstrated resources of 20 mt and inferred resources of 100 mt of high-grade silica sand at Kemerton just to the west of the region.

High purity quartzite used for silicon metal manufacture is quarried at Coomberdale near Moora, 160 km N of Perth (and 65 km N of the CRA boundary).

Assessment criteria

1. Pleistocene sands of the Scott coastal plain.
2. Aeolian sands and south coast dune system.
3. Permian sands in the Collie and equivalent basins.
4. Precambrian metaquartzites and quartz veins (in the Balingup, Jimperding–Chittering and Biranup Complexes.
5. Sands derived (reworked) from Precambrian quartzite.

Assessment:

Tract: Silica1a/H/C

This tract includes:
1. Permian sands in the Collie and equivalent sedimentary basins.
2. Precambrian metaquartzites and quartz veins (in the Balingup, Jimperding–Chittering, and Biranup Complexes), and sands derived from these metaquartzites.

This tract includes the Collie, Collie Road South and Clackline silica sand deposits and is assessed as having high potential with a certainty level of C.

Tract: Silica1b/M–H/B

This tract includes:
1. Pleistocene sands of the Scott coastal plain, and
2. Aeolian sands and silica sands of the south coast dune system.

This tract includes the Narrikup deposits and is assessed as having moderate to high potential with a certainty level of B.

Economic Significance

Approximately half of the silica sand mined worldwide is used in the manufacture of glass. Other important uses for silica sands include foundry sands, ground silica, blasting sand and filtration sand. High purity quartzite and silica gravel (>99.5% SiO_2) are used for manufacture of silicon metal and ferrosilicon.

High-purity quartzite is quarried at the rate of 80 000 tonnes per year at Coomberdale near Moora, 160 km N of Perth. It is hauled 350 km by road to a silicon metal plant at Kemerton, 20 km N of Bunbury. The Kemerton plant produces about 28 000 tonnes of chemical-grade silicon metal per year.

Kao: CLAY (KAOLIN, BENTONITE, HORMITES, COMMON CLAY) (Figure 16)

Model Description

Description of the model after D Hora (1992).

Synonyms: Primary kaolin, secondary kaolin.

General References: Murray (1994); Elzea and Murray (1994); Heivilin and Murray (1994); Pickering and Murray (1994).

Geological environment:

Rock types: Kaolinised feldspathic rocks, eg. granites to diorites with their volcanic equivalents. Secondary alluvial kaolinitic clays.

Age range: Upper Cretaceous to Eocene.

Tectonic setting: Plateaus in tectonically stable areas. Down-faulted sedimentary basins.

Depositional environment:
Kaolin: 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. 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.

Bentonite: Residual. Alteration of volcanic ash or tuff. Sometimes hydrothermal alteration of volcanic rocks. Most commonly due to alteration of volcanic ash by sea water. In some instances it is also formed in contact with alkaline lake water and groundwater.

Hormites: Alteration of volcanic detritus, diagenetic alteration of montmorillonite and direct crystallisation.
Common clays: These clays are formed in many rock types and include glacial clay, soils, alluvium, loess, shale weathered and fresh schist, slate, and argillite.

Associated deposit types: Fireclay, bentonite, coal, ceramic and cement "shales".

Deposit Description:

Mineralogy: Kaolin, 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.

Examples:

Kaolin: Cornwell, U.K., China, Greenbushes and Ockley, W.A.
Bentonite: Lang Bay, Sumas Mountain, British Columbia, Canada; Germany, Czechoslovakia. Georgia-Soht Carolina districts in the USA host important clay deposits of all types.

Known deposits and occurrences in the region

At Greenbushes intense deep weathering during the Tertiary has produced kaolinisation of the pegmatite and the host rocks to a depth of 60 m. Parts of the pallid zone overlying a spodumene-rich section of the pegmatite have been mined for high-grade halloysite and kaolin suitable for high-quality ceramics. The Ockley deposit (to the east of the South-West Forest region) is a large resource of high quality kaolin formed by deep weathering of granitoid rocks during the Tertiary. Deposits of this type probably extend into the

South-West Forest region.

Refractory or fireclay occurs about 5 km west of Clackline. It is developed to 15 metres depth on schist of the Jimperding Gneiss Complex and blended with residual clay from overlying weathered dolerite.

Bentonitic clays have been reported from Collie and Mumballup and deposits of brick making and cement clays have been worked in the Perth Metropolitan region.

Assessment criteria*:*

1. Tertiary deep weathering profiles formed on granitoids, pegmatites, dolerites, schists or argillaceous sedimentary rocks (claystone, siltstone, shale, slate).
2. Areas mapped as ferricrete (Czrf), sand over ferricrete(Czrs) and residual material including laterite (Czr).

Assessment:

Tract Kao1a/H/D

The tract includes the known high grade kaolin/halloysite deposit associated with deeply weathered pegmatite at Greenbushes. Mineral potential of the tract is assessed to be high with a certainty level of D.

Tract Kao1b/M–H/B

The tract includes areas mapped as ferricrete (Czrf). The rocks in the tract have undergone intense weathering and pallid zones in the area may have localised high-quality kaolin clays. Mineral potential of the tract for Ockley-type high-grade kaolin is assessed to be moderate to high with a certainty level of B.

Tract Kaol1c/M/B

The tract includes areas mapped as residual deposits (Czr) and sand over ferricrete (Czrs). Mineral potential of the tract for Ockley-type high-grade kaolin is assessed to be moderate with a certainty level of B.

Economic significance

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.

Peg1: PEGMATITE-RELATED INDUSTRIAL MINERALS (Figure 17)

Model Description

Description of model by Lee Hassan and Subhash Jaireth.

Approximate Synonym: Mica pegmatite.

Description: Zoned and/or simple pegmatites containing feldspar and/or mica.

General References: Ginsberg (1984), Bates, 1960, Sinclair (1995), Cerny (1993).

Geological Environment:

Rock types: Pegmatites are simple, layered or zoned. Zoned pegmatites are frequently composed of blocky microcline, albite and quartz zones. Pegmatites intrude sedimentary, metasedimentary and metavolcanic rocks. In many cases there is a genetic and spatial relation with granites.

Textures: Rare relict igneous textures in pegmatites. Most pegmatites are recrystallised.

Age Range: Variable: from Archaean to Tertiary.

Depositional Environment: Abyssal pegmatites are formed in (upper amphibolite to) low – to high– pressure granulite facies. They represent segregations of anatectic migmatite. Muscovite pegmatites formed in high–pressure, amphibolite environments; they generally have no obvious relationship with granites. Miarolitic pegmatites formed in a low pressure, shallow to subvolcanic environment; they are generally interior to, or marginal to granites (Ginsberg, 1984; and Cerny, 1993).

Tectonic Setting (s): Archaean cratons and Phanerozoic orogenic belts. Some Archaean pegmatites are typically localised along deep fault systems that in many areas coincided with major metamorphic and tectonic boundaries. Often pegmatitic belts are formed during tectonic reactivation of shields and platforms.

Associated deposit types: Rare element pegmatites, tin and tungsten greisens and veins, rare metal deposits associated with peraluminous to subalkaline granites. Residual and alluvial cassiterite and tantalite concentrations and kaolin/halloysite.

Deposit Description:

Mineralogy: Quartz, microcline, perthite, albite, muscovite, phlogophite, ± zinnwaldite, ± tourmaline, ± apatite, ± zircon, ± garnet, ± rutile; may contain minor cassiterite, spodumene, beryl, tantalite, or rare earth elements (if these are substantial they are classed as rare element pegmatites).

Texture/Structure: May be simple or zoned. Generally coarse-grained; in some pegmatites crystals are metres or even tens of meters in length. Pegmatites frequently have xenoliths of country rocks.

Alteration: Alteration zones around pegmatite bodies are usually up to a few meters thick and contain biotite and possibly sphene, garnet, tourmaline and arsenopyrite.

Ore controls: Many pegmatite bodies are controlled by shear zones and may be synmetamorphic and synkinematic.

Weathering: Weathering up to few tens of meters. Pegmatites weather into a mass of kaolinitic clay with residual pegmatitic minerals such as quartz and muscovite.

Geochemical signature: A broad geochemical halo of alkali elements in the country rock.

Geophysical signature: radiometric survey may be useful for identifying parent granite and/or associated pegmatites that are enriched in U and Th.

Examples:

Spruce Pine District, North Carolina, USA	Bates (1960).
Bihar District, India	Bates (1960).
Minas Gerais, Brazil	Bates (1960).

Known deposits and occurrences in the region

The Ferndale pegmatite intrudes amphibolite and gneiss of the Balingup Metamorphic Complex. It has been dated at 690 Ma (Partington et al. ,1986). The pegmatite is zoned with a quartz–K-feldspar–muscovite zone and a quartz–muscovite–K-feldspar zone. The pegmatite is poorly differentiated and microclines from the pegmatite are low in Li. About 10.9 t of beryl has been produced and the pegmatite contains a large tonnage of clean microcline feldspar suitable for the ceramics industry (Townsend, 1994).

Mica has been produced from several pegmatites intruding mica schist and granitic gneiss in the vicinity of Mullalyup. Beryl, feldspar and vermiculite are also associated with the pegmatites (Townsend,1994).

Some mica has been produced from a pegmatite at Clackline for use as a refractory material in the smelting of the Coates vanadium ore.

Assessment Criteria

1. Presence of granites.
2. Presence of metamorphic complexes.
3. Presence of pegmatites.
4. Presence of pegmatites with mica or feldspar of industrial quality.

Assessment

Tract: Peg1a/M–H/C

This tract includes known pegmatite occurrences including Ferndale, Mullalyup and Clackline. The tract is assessed as having a moderate to high potential with a certainty level of C.

Tract: Peg1b/M/B

This tract covers the remaining granitic and metamorphic terranes where there is a moderate potential for pegmatites with a certainty level of B.

Economic Significance

In general feldspar and mica are relatively low value commodities but the value of mica increases significantly with sheet size and quality. Distance from market, material price, purity and market-demand play an important role in determining the economic significance of any deposit.

Graph1: GRAPHITE (Figure 18)

Model Description

Description of model by Lee Hassan.

Description

Graphite flakes disseminated in schists, gneisses or marbles, bedded graphite formed by metamorphism of coal beds; veins of almost pure graphite infilling fractures in various rock types; and metasomatic or hydrothermal graphite deposits in marble.

General References: Bates (1960), Cameron (1960).

Geological Environment:

Rock types: schist, gneiss, marble, sandstone, metamorphosed coal measures; vein graphite can be in any rock-type.

Age range: variable; most flake graphite deposits are Precambrian whilst most bedded graphite deposits are Permian to Cretaceous.

Depositional environment: metasedimentary belts, contact metamorphic zones and thermally or dynamically metamorphosed coal measures.

Tectonic setting(s): highly deformed metasedimentary belts, thermally or dynamically deformed coal measures, contact metamorphic zones, fault and fracture zones.

Associated deposit types: kyanite deposits, vermiculite deposits, coal deposits, corundum deposits.

Deposit Description:

Mineralogy: Graphite ± quartz ± mica ± feldspar ± clay ± carbonate ± garnet ±corundum ± tourmaline ± magnetite

Texture/Structure: graphite generally occurs as minute scales or flakes, as bladed or foliated masses or as earthy cryptocrystalline lumps. The host rocks of flake graphite are generally schistose or gneissic.

Alteration: Although the host rock is frequently altered to clay, quartz and mica, the graphite remains unaltered.

Ore controls: Disseminated flake deposits are controlled by regional metamorphism, folding and faulting of carbonaceous shale or limestone; bedded deposits are controlled by thermal or dynamic metamorphism of coal measures; vein and contact metasomatic or hydrothermal deposits are controlled by contact metamorphism of limestone or carbonate bearing rocks.

Geochemical signature: presence of graphite flakes in weathered rock.

Geophysical signature: resistivity and self potential anomalies may be used in prospecting.

Examples:

Disseminated graphite flake deposits: Madagascar (Bates,1960, Cameron, 1960), Senja Island, Norway (Cameron, 1960), Munglinup, Western Australia.
Bedded graphite: Sonora, Mexico (Bates, 1960), Southern Korea (Cameron, 1960)
Vein deposits: Sri Lanka (Bates,1960, Cameron, 1960)
Contact metasomatic or hydrothermal deposits in marble: Black Donald Mine, Ontario, Canada (Cameron, 1960).

Known deposits and mineral prospects in the region

There has been minor production of microcrystalline graphite from the Donnelly River Graphite deposit within graphitic schists of the Balingup Metamorphic Belt (Townsend, 1994). Graphite occurrences have also been reported from the Biranup Complex at Martigallup and the Furniss occurrence within the region and from Kendenup just to the east of the region. Gwalia Consolidated Ltd has investigated a graphite resource of 1.4 Mt at Munglinup to the east of the region.

Assessment:

Tract: Graph1/M–H/C

This tract includes areas mapped as schist within the Balingup, Jimperding– Chittering and Biranup Complexes. It includes all the known graphite deposits and occurrences within the South-West Forest region.

Kya1: KYANITE-FAMILY MINERALS (Figure 19)

Model Description

Description of model after Simandl et al (1995).

***Approximate Synonyms**:* Sillimanite-group minerals; Kyanite-group minerals; Andalusite-group minerals, anhydrous aluminous silicates.

***Description**:* Kyanite, sillimanite or andalusite concentrations in metamorphic rocks or eluvial or alluvial deposits derived from metamorphic rocks.

Geological Environment:

Rock types: Kyanite and/or sillimanite-bearing gneiss and schist, quartzite, marble, biotite and garnet paragneiss, mica schist, hornblende schist, orthogneiss, clinopyroxenite, amphibolite, pegmatite and a variety of other intrusive rocks.
Andalusite-bearing aluminous phyllite, slate, schist and hornfels/muscovite schist, pyrophyllite.

Age range: Variable; from Archaean onwards.

Depositional environment: Metasedimentary belts, metasedimentary roof pendants and contact metamorphic zones containing units derived from high-alumina protoliths (high-alumina shales, paleo-regolith, paleo-placers or alteration zones).

Tectonic setting(s): Mainly in highly deformed metasedimentary belts; andalusite and sillimanite are also known from contact-metamorphic environments.

Associated deposit types: graphite deposits, vermiculite deposits, sapphire deposits.

Deposit Description:

Mineralogy: Kyanite or sillimanite: quartz, biotite, ± muscovite, ± garnet, ± feldspar, ± staurolite, ± corundum, ± graphite, ± sulphides, ± oxides ± amphiboles ± cordierite ± rutile.
Andalusite: feldspar, sericite, ± clay, ± garnet, ± dumortierite, ± corundum, ± pyrophyllite, ± graphite, ± magnetite, ± quartz.

Texture/Structure: Kyanite and/or sillimanite deposits are stratabound and stratiform; high grade lenses, pockets and discordant planar or irregular features may be present. Andalusite deposits similar to above or as irregular or ring-shaped bodies surrounding intrusions. Kyanite and sillimanite-bearing rocks; porphyroblastic, lepidoblastic, schistose and gneissic; size of porphyroblasts may increase near the contact with intrusive. Abundant solid inclusions within aluminium silicates. Andalusite-bearing rocks may be massive.

Alteration: Pyrophyllite, muscovite and sericite are common alteration products of kyanite. Andalusite alters to muscovite. In general intense weathering facilitates separation of aluminium silicates from gangue minerals.

Ore controls: Palaeostratigraphy, chemical composition of the protolith and degree of metamorphism. High-grade zones within the mineralised units are commonly located in crests of folds and shear zones that were open to fluids at the time of crystallisation of anhydrous, aluminous silicates. Eluvial deposits are controlled by weathering processes. May be concentrated with other heavy minerals along palaeoshorelines.

Geochemical signature: Presence of kyanite, sillimanite or andalusite in panned concentrate.

Geophysical Signature: EM, radiometric methods may be used as indirect tools if marker horizons or igneous intrusions have distinctive signatures.

Examples:

Willis Mountain kyanite, USA (Harben and Bates, 1990).
Sillimanite-corundum deposits, South Africa (Caroll and Mathews, 1983).

Hillsboro andalusite deposit, USA (Bennett and Castle, 1983).

Known deposits and mineral prospects in the region:

Primary kyanite has been mined from kyanite schist at Manjimup Brook and eluvial nodules and boulders of kyanite have been mined at Manjimup Brook, Donnelly River and Ross's Swamp associated with schists in the Balingup Complex (Lord, 1950). Large quantities of kyanite at Wattle Flat and of sillimanite at Goyamin Pool occur in schists of the Jimperding–Chittering Complex but would require crushing and special beneficiation to be utilised (Wilde and Low, 1978).

Assessment criteria:

1. Presence of Archaean schist or Archaean schist which was deformed in the Proterozoic.
2. Presence of known kyanite and sillimanite deposits or occurrences.

Assessment:

Tract: Kya1/M–H/C

This tract includes areas mapped as schist within the Balingup, Jimperding– Chittering and Biranup Complexes. It includes all the known kyanite and sillimanite deposits and occurrences within the South-West Forest region.

Fe: BANDED IRON FORMATION (Figure 20)

Model Description:

After William F. Cannon.

Approximate Synonym: Taconite, metataconite.

Description: Banded iron-rich chemical sedimentary rock; generally of great lateral extent, typically layered on centimetre scale with siliceous (chert) beds interlayered with iron-rich beds.

General References: Gross (1996), Harmsworth et al (1990), Morris (1985), James and Sims (1973), James (1954).

Geological Environment:

Rock Types: Commonly interlayered with quartzite, shale, dolomite.

Textures: Iron-formations and host rocks commonly contain sedimentary textures typical of shallow-water deposition in tectonically stable regions.

Age Range: Mostly Early Proterozoic. Less commonly Archaean or Middle and Late Proterozoic.

Depositional Environment: Stable, shallow-water marine environment, commonly on stable continental shelf or intracratonic basin.

Tectonic Setting(s): Now commonly preserved in forelands of Proterozoic orogenic belts.

Associated Deposit Types: Sedimentary manganese deposits may occur stratigraphically near or be interbedded with iron-formations.

Deposit Description:

Mineralogy: Hematite, magnetite, martite, goethite, limonite, siderite, fine-grained quartz.

Texture/Structure: Nearly always banded at centimetre scale; very fine grained where not metamorphosed.

Alteration: None related to ore deposition. Commonly metamorphosed to varying degrees or weathered and enriched by supergene processes.

Ore Controls: No primary controls of local importance. Supergene ores may be localised by irregularities in present or palaeo-erosion surface and/or presence of a structural feature such as a fault or fold.

Weathering: Supergene and surface residual alteration of original iron mineral to Fe-hydroxides and hematite. Silica partly to totally leached. End product of weathering is high-grade supergene ore.

Geophysical Signature: Magnetic anomalies.

Examples:

Mt Whaleback, Western Australia	Harmsworth et al (1990).
Mount Tom Price, Western Australia	Harmsworth et al (1990).
Paraburdoo, Western Australia	Harmsworth et al (1990).
Mt Wright mine, Quebec, Canada	Gross (1996).
Mesabi Range, Minnesota, USA	James (1983).

Known deposits and mineral prospects in the South-West Forest region

Thin banded iron formation occurs within metasediments of the Balingup, Chittering–Jimperding and Biranup Complexes. Iron ore was produced from lateritised BIF at Clackline between 1899 and 1907. Quartz-magnetite-hypersthene BIF bands east of Northam, just north of the region, have been drilled and tested for magnetite but there has been no production from these (Wilde and Low, 1978).
Minor laterite iron deposits occur at Wundowie (NE of Perth) and Greenbushes (NW of Bridgetown). Laterite iron was discovered in 1960 at Scott River but its low grade (38% iron) renders it uneconomic (Townsend, 1993).

To the east of the South-West Forest region, the Southdown deposit in metamorphosed banded iron formation of the Biranup Complex about 80 km northeast of Albany is a significant deposit (Townsend, 1994)

Assessment Criteria

1. Presence of banded iron formation
2. Structure favouring supergene enrichment

Assessment:

Tract: Fe1a/M/B

This tract includes the Clackline BIF deposit and all known BIF within the South-West Forest region. It is assessed as having moderate potential with a certainty level of B.

Economic Significance

Although there has been only minor production of iron ore from the South-West Forest region, the Southdown deposit in the Albany–Fraser Orogen to the east of the South-West Forest region has an indicated resource of 75.8 Mt at 27% Fe (Townsend, 1994).

South-West Forest region

Grade/tonnage model for deposits of this type (Cox and Singer, 1986) indicates that 90% of deposits contain more than 11 million tonnes of ore, 50% more than 170 million tonnes and 10% contain more that 2,400 million tonnes. Ninety percent of these deposits contain at least 30% iron, 50% of them contain at least 53%

iron and 10% of them contain at least 66% iron.

Australia was the world's third largest iron ore producer in 1996 with 91% of that production coming from the Pilbara region of Western Australia.

BM1: VOLCANIC MASSIVE SULPHIDE BASE METAL DEPOSITS (Figure 21)

Model Description

Description of the model after Donald A. Singer (1986); Franklin (1995).

Approximate Synonym: Noranda type, volcanogenic massive sulphide, felsic to intermediate volcanic type.

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

General References: Ishihara (1974), Franklin et al (1981), Hutchinson et al (1982), Ohmoto and Skinner (1983), Large (1992); Franklin (1995).

Geological Environment:

Rock types:

Copper–zinc deposits: mafic and felsic volcanics. The felsic rocks higher in the volcanic piles, formed at depths greater than 500m. Volcanic sequences have prominent subvolcanic intrusions near their bases. Deposits are overlain by both clastic and chemical sedimentary strata. Deposits in sequences of volcanic and sedimentary rocks contain pelites (principally organic-rich mudstone or shale) with mafic and felsic (minor) volcanics.

Zinc–lead–copper deposits: calc-alkaline felsic ash-flow tuffs, rhyolites, felsic epiclastics, and basalts near the base. In deposits within volcanic–sedimentary sequences, felsic volcanics predominate near the ore horizon.

Textures: Flows (often pillowed, amygdaloidal, scoriaceous), tuffs, pyroclastics, breccias, bedded sediment, and in some cases felsic domes.

Age range: Archaean through Cainozoic.

Depositional environment: Hot springs related to marine volcanism, probably with anoxic marine conditions.

Tectonic setting(s): Archaean and Proterozoic greenstone belts. Phanerozoic mid-ocean spreading ridges and seamounts. Phanerozoic Island arcs and arc-related basins. Locally in submarine calderas during periods of extension following island-arc construction, may be temporally related to caldera resurgence.

Associated deposit types: Volcanogenic manganese, Algoma iron. Epithermal quartz-adularia veins as in kuroko deposits in Japan.

Deposit Description:

Mineralogy: In Copper–zinc deposits: Massive sulphide zone is underlain by a stockwork stringer zone. Massive sulphides zone is made up mainly of pyrite, with sphalerite, chalcopyrite and galena forming about 10%. Metamorphosed deposits contain abundant pyrrhotite. Deposits formed in deep water (Noranda type) contain only sphalerite and chalcopyrite as principal ore minerals and those formed in shallow conditions also contain recoverable galena. Barite occurs in some of the oldest deposits (pre –3.0 Ga) in Australia and South Africa. It is less common in other Archaean and Proterozoic terranes but common in most Phanerozoic deposits. Locally magnetite can constitute up to one-third of a deposit. Common gangue minerals are quartz, with chlorite, sericite and aluminosilicate minerals (or their metamorphic equivalents).

Gahnite is a common accessory mineral in deposits that have attained amphibolite grade of metamorphism. The stringer zone is made up of chalcopyrite, pyrite, pyrrhotite, sphalerite and magnetite. Locally bornite and/or selenium and tellurium minerals.

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

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

Alteration: In Copper–zinc deposits: Two distinct morphological types of alteration: Pipes and semiconformable. Alteration pipes in deep-water Precambrian deposits have chloritic core and sericitic rim. Some deposits contain talc, magnetite and phlogopite. In shallow water deposits alteration pipes are silicified, sericitised, with minor chloritisation. In Phanerozoic deposits alteration pipes have similar alteration. Locally deposits are characterised by talc-rich zones surrounded by silica–pyrite alteration. Metamorphism of Magnesium-rich zones results in anthophyllite and cordierite. Alteration in the semiconformable zone is laterally quite extensive and is located several hundred metres below massive sulphide ores. The semiconformable zones consists of metal depleted quartz–epidote± actinolite. In some deposits the zone is in the form of alkali-depleted carbonated rocks.

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

Ore controls: Ore is generally toward the more felsic top of volcanic or volcanic–sedimentary sequence and in some cases near centre of felsic volcanism. It may be locally brecciated or have a felsic dome nearby. Pyritic siliceous rock (exhalite) may mark horizon at which deposits occur. Proximity to deposits may be indicated by sulphide clasts in volcanic breccias. Some deposits may be gravity-transported and deposited in palaeo depressions in the seafloor. In Japan, best deposits have mudstone in the hanging wall.

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

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

Geophysical signature: EM anomalies, magnetic anomalies

Examples:

Golden Grove, Western Australia	(Frater,1983).
Benambra, Victoria	(Allen and Barr, 1990).
Mt. Lyell, Tasmania	(Hills, 1990).
Rosebery, Tasmania	(Lees et al, 1990).
Furutobe, Japan	Hideo Kuroda (1983).
Brittania, Canada	(Payne et al, 1980).
Buchans, Canada	(Swanson et al, 1981).

Assessment Criteria

1. Distribution of submarine volcanic–sedimentary sequence.
2. Distribution of known base metal occurrences.

Assessment:

Tract: BM1/M/B

This tract includes the felsic volcanic and pyroclastic rocks of the Wells Formation and the metasedimentary rocks of the Hotham Formation within the Saddleback Greenstone Belt. Anomalous copper values are associated with these formations. The tract also includes Archaean felsic schists of the Balingup Metamorphic Belt surrounding the old Mine Hill workings where quartz veins containing molybdenite and chalcopyrite are present. Morant (1988) suggested that the felsic schists might represent metamorphosed felsic volcanics.

Economic Significance

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

Peat: PEAT/LIGNITE DEPOSITS (Figure 22)

Model Description

Peat-bearing sedimentary sequences.

Approximate Synonyms:

Description: Peat.

General References: Doyle et al (1986).

Geological Environment

Rock types: Peat interbedded with various terrestrial and marine sedimentary sequences.

Age Range: Cretaceous? 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; lagoonal. Depositional environment must be free from frequent incursions of clastic sediments or oxygenated waters, thus environments are generally low energy, anoxic and occur in fresh – brackish waters.

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

Associated deposit types Coal

Deposit Description

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

Peat - Moisture content 75–80%, dry weight: 50–60% Carbon

Brown Coal - Moisture content 50–70%, dry weight: 60–75% Carbon

(After Doyle et al 1986)

Dominant components of peat are macerals and ash. Macerals are the organically derived components of coal. Texture/structure: Generally undeformed and in laterally continuous seams
Ore Controls: Limits of sedimentary basins and palaeo-valleys.

Examples:

Gippsland Basin, Victoria (Barton et al 1992)
Cowerup Swamp, Western Australia (Knight 1980)

Known Deposits and Mineral Prospects in South West WA

Lignite (brown coal) has been found in drillholes in the Cretaceous Leederville formation of the Perth Basin. The lignite is restricted to the lower energy fluviatile/lacustrine facies of this formation. These deposits are high in ash, tend to be very localised in extent and are usually less than one metre in thickness.

Intersections of brown coal have been observed from patches of Late Eocene sediments which overlie the irregular Precambrian basement in the south of the South-West Forest region. These occurrences include Flybrook and Coalmine Beach near Walpole where a 2.7m thick sequence of lignite and greyish sandstone has been recognised. Significant brown coal has also been identified in Tertiary sequences of the Bremer Basin, which partly lies within the southeastern edge of the region. At Cranbrook, just outside the region in the western section of the Bremer Basin, lignite has been recorded within the Plantagenet Group with a maximum thickness of 10m - indicated resources of 100 Mt have been estimated (Elms et al., 1995).

Peat has been extracted from Cowerup Swamp (Lake Muir) where deposits vary in thickness from 1 to 4m. In 1978 demonstrated resources for the Cowerup Swamp were 450 000 dry tonnes of peat (Knight, 1980).

Assessment Criteria

1. Presence of sedimentary basins containing Cretaceous or later sedimentary sequences.
2. Presence of Leederville Formation within the Perth Basin, presence of Plantagenet Group in the Bremmer Basin.
3. Tertiary alluvial, channel-fill sediments on Archaean and Proterozoic units.

Assessment:

Tract: Peat1/L–M/B

This tract is defined by the outline of the southern portion of the Perth Basin within the South-West Forest region as delineated by the Dunsborough Fault in the west and the Darling Fault in the east. It also includes the Bremer Basin in the south east portion of the South-West Forest region and the Tertiary shallow marine and alluvial channel-fill sediments overlying Precambrian basement.

Within the Cretaceous Leederville formation of the Perth Basin coal of very low rank is known to occur within the lower energy lacustrine and fluviatile facies. The various occurrences of lignite and peat in the Bremer Basin and Tertiary sediments overlying Precambrian basement indicate that conditions for the formation of lignite and peat bearing sequences were favourable over a considerable portion of the South-West Forest region during some parts of the Tertiary. The tract is considered to have a low to moderate potential with a certainty level of B.

DIAMOND BEARING KIMBERLITES

The South-West Forest region lies along the south-western margin of the Yilgarn Craton), which is prospective for hard rock (kimberlite or lamproite intrusive rock “pipes”) and alluvial diamond deposits.

Past diamond exploration focussed on the Kimberley region to the north after the discovery of the Ellendale and Argyle diamond deposits. Exploration has now also moved southward into the Pilbara and Yilgarn regions (Smith et al 1990).

Indicator minerals led to the discovery of the Bitter Sweet 1 pipe (no diamonds) and the recovery of a micro-diamond from the Bulljah pipe in the Nabberu Basin on the north-eastern edge of the Yilgarn Craton (region) in the mid 1980's.
North-east of Carnarvon, monchiquite rock diatremes and sills, with trace diamond, intrude Permian and Cretaceous sedimentary rocks of the Carnarvon Basin. Similar sedimentary rocks extend southward into the Perth Basin, which abuts the western margin of the Yilgarn Craton and the South-West Forest regions CRA. Monchiquite rock intrusives and lamproites (host rock of the Argyle and Ellendale diamond deposits) could occur in the Perth Basin and may also lie offshore.

Stockdale Exploration traced diamond indicator minerals to two micaceous alkalic ultrabasic dykes in the Fraser Range, 100 km to the east of Norseman, while exploring the Albany–Fraser Mobile Zone along eastern and southern margins of the Yilgarn Craton in the late 1970's but no diamonds were found. The western end of the Albany–Fraser Mobile Zone lies in the southern portion of the South-West Forest region.

Recent exploration (by Stockdale Prospecting from 1991 to 1995) in the central Yilgarn Craton, well to the east and northeast of the South-West Forest region, located a kimberlite body and two diamonds in drilling at Lake Raeside, 80km west of Leonora. After further work three kimberlite pipes were interpreted (Western Diamond Corp 1997), but small-scale bulk sampling of these bodies yielded no diamonds. A number of companies are exploring in the Leonora – Menzies area where a major NW-SE structural trend possibly related to kimberlite intrusions occurs (Carnegie Minerals 1997, Conquest Mining 1997).

Numerous magnetic anomalies identified near Merredin, to the NE of the region, are to be explored for diamonds in conjunction with loam and laterite geochemical sampling along road reserves (Astro Mining 1997). The Barra Barra prospect, to the north of the region, is in the early stages of investigation for diamonds (Bloodhound Gold 1997).

Although the more complex structure of the eastern portion of the Yilgarn Craton (including deep? crustal faults/lineaments) appears more favourable for the formation of diamondiferous intrusive pipes, the western portion (including the South-West Forest region) also contains regional faults/lineaments which may be prospective. The western end of the Albany–Fraser Mobile Zone lies in the southern portion of the South-West Forest region and has some potential for diamond deposits.

RARE METAL CARBONATITES

Carbonatite rock intrusions are essentially made up of carbonate minerals derived from mantle and deep crustal igneous processes and are major sources of niobium, phosphorus and rare earth elements. Carbonatites may also contain appreciable tantalum and copper.

Intrusion of molten carbonatite bodies is controlled by regional, deep-seated rock fractures associated with uplifted or domed areas, large-scale rift structures, arch structures and other major faults/lineaments which penetrate deep into the continental crust. Carbonatite favourable structures usually occur within stable craton areas but some are associated with orogenic zones (Lottermoser 1994). In Western Australia carbonatite intrusives have been discovered at Cummins Range (Kimberley region), Mundine Well (Pilbara region), Yangibana (NE of Carnarvon), Mt Weld (east of Leonora) and Ponton Creek (east of Kalgoorlie).

The Mt Weld carbonatite is located in the Laverton Tectonic Zone, which is bound by major tectonic boundaries/faults (Duncan & Willett 1990), and the Cummins Range carbonatite occurs where two major fault/structural systems meet at the southern apex of the Kimberley region (Andrew 1990). Both these bodies exhibit pronounced geophysical magnetic anomalies which led to their discovery. Mt Weld contains 15.4 mt at 11.2% rare-earth oxides as well as significant resources of niobium, tantalum and phosphorus.

Although the more complex structure of the eastern portion of the Yilgarn Craton (including ?deep crustal faults/lineaments) appears more favourable for the formation of carbonatite intrusives, the western portion (including the South-West Forest region) also contains regional faults/lineaments which may be prospective. The western end of the Albany–Fraser Mobile Zone lies in the southern portion of the South-West Forest region and has some potential for carbonatite intrusives.

URANIUM-BEARING PEGMATITES

There is some potential for uranium-bearing pegmatite deposits in the Balingup, Biranup and Nornalup Complexes but to date none have been reported.

APPENDIX C: MINERALS METADATA SHEETS

DIGITAL GEOLOGICAL MAPS

Organisation: Geological Survey of Western Australia

Abstract: This index displays the geology of the South-West Forest area of Western Australia in four layers with textual information on rock units including rock types, their age, deformation and metamorphism.

Contents:

Citation Information
Dataset Description
Spatial Domain (including Attribute List)
Dataset Currency and Status
Dataset Storage and Format
Dataset Quality

Citation Information

Data Set Title: South-West Forest Digital Geological Maps
Data Set Short Title:
Custodian: Geological Survey of Western Australia
Publication Date: September 1997
Acknowledgments:
References:

Dataset Description

Abstract: This index displays the geology of the South-West region of Western Australia in four layers with textual information on rock units including rock types, their age, deformation and metamorphism. The four layers are: Precambrian, Permian, Mesozoic–Early Tertiary, and Regolith. Separate layers contain dolerite and pegmatite dykes, veins, faults and lineaments.
Search Words: geology, geological maps
Location Description: South-West Forest area, Western Australia

Spatial Domain

Bounding Co-ordinates: 114.0, -35.25, 118.0, -31.0
Bounding Polygon:
Attribute List: see attached list

Data Currency and Status

Beginning Date: 1960
Ending Date: 1996
Progress: In progress
Maintenance and Update Frequency: Irregular
Metadata Reviewed:

Dataset Storage and Format

Stored Data Format: Digital — dbf, dxf
Output Data Format: Digital — ASCII, ArcInfo
Native Data Format: Digital — points, lines, polygons, text
Access Constraints: Data are Crown Copyright

Dataset Quality

Lineage Summary: All positional data were culled from hard copy maps of various scales, including published Geological Survey of Western Australia 1:250,000 geological maps and unpublished geological maps in statutory company reports, typically at scales ranging from 1:5 000 to 1:50 000.
Scale: 1:250 000
Resolution: 100m
Cell Size:
Positional Accuracy: ± 250m.
Attribute Accuracy: Were culled from Geological Survey reports and geoscience journal articles.
Logical Consistency: The accuracy of the geological boundaries is dependent upon the methods used to differentiate geological units on the ground. In some areas, the original geological mapping was not as detailed as in other areas, and individual geological units have been combined into a larger, more generalized unit.
Completeness: The dataset contains spatial data and selected attribute data relating to geological units covering the entire South-West Forest area.
Additional Information: The dataset is current as at 1/12/96.
Attribute List: See attached listing

Attribute List

AGE_SORT: Unique index for each geological unit.
CODE: Unique map letter code assigned to each unit.
SYMBOL: Suggested symbol colour look-up reference.
SHORT_DESC: Summary of rock types in unit
LONG_DESC: Geological legend statement for rock unit.
AGE1: Geological period(s) the unit belongs to.
AGE_MA: Age of unit in millions of years (if determined).
GEOL_UNIT: Formal name of geological unit.
METAMORP: Description of deformation of metamorphism affecting the unit.

MINERAL EXPLORATION ACTIVITY INDEX

Organization: Geological Survey of Western Australia

Abstract: This index is a subset of the WAMEX bibliographic database of statutory mineral exploration reports submitted by mineral tenement holders in Western Australia.

Contents:

Citation Information
Dataset Description
Spatial Domain (including Attribute List)
Dataset Currency and Status
Dataset Storage and Format
Dataset Quality

Citation Information

Data Set Title: South-West Forest Mineral Exploration Activity Index
Data Set Short Title:
Custodian: Geological Survey of Western Australia
Publication Date: September 1997
Acknowledgements:
References:

Dataset Description

Abstract: This dataset contains records relating to the South-West Forest region of Western Australia within the WAMEX bibliographic database of statutory mineral exploration reports submitted by mineral tenement holders. The Mineral Exploration Activity Index contains spatial and textual information defining the location of mineral exploration activity in Western Australia. Compilation of the index began in 1995 and contains information on type of mineral exploration activity, metres of exploration drilling, commodity sought, a brief description of activity, and a link to the statutory report containing original data.
Search Words: minerals, mineral exploration, geology
Location Description: South-West Forest area, Western Australia

Spatial Domain

Bounding Co-ordinates: 114.0, -35.25, 118.0, -31.0
Bounding Polygon:
Attribute List: see attached list

Data Currency and Status

Beginning Date: 1962
Ending Date: 1996
Progress: In progress
Maintenance and Update Frequency: Irregular
Metadata Reviewed:

Dataset Storage and Format

Stored Data Format: Digital — dbf, dxf
Output Data Format: Digital — ASCII, ArcInfo
Native Data Format: Digital — polygons, lines, points, text
Access Constraints: Data are Crown Copyright

Dataset Quality

Lineage Summary: All positional data were culled from hard copy maps of various scales submitted by mineral exploration companies.
Scale: 1:100 000
Resolution: 100m
Cell Size:
Positional Accuracy: ± 100m.
Attribute Accuracy: Information culled from statutory reports submitted by mineral exploration licence holders.
Logical Consistency: Areas, lines and points relating to mineral exploration activity indicated on maps at various scales submitted by exploration licence holders were transfered onto 1:50 000 maps and then digitized.
Completeness: The dataset contains spatial data and selected attribute data relating to all reported mineral exploration activities in the South-West Forest area. Some attribute data from company reports confidential under WA State law were deleted from the dataset. All points, lines and polygons were visually checked. Attribute data were checked on an audit basis.
Additional Information: The dataset is current as at 1/12/96.
Attribute List: See attached listing

Attribute List

ACTIVITYID: Unique identifier of individual mineral exploration activities.
WAMEX A NUMBER: Pointer to unique code in WAMEX bibliographic database for the report containing information summarized in ACTIVITYID record.
ACTPOLY: Number of polygons containing information corresonding to ACTIVITYID. May be null.
ACTLINE: Number of lines corresponding to information in ACTIVITYID. May be null.
ACTPOINT: Number of points corresponding to information in ACTIVITYID. May be null.
ACTIVITY: Letter code describing type of mineral exploration activity.

ACTIVITY	DESCRIPTION
ACH	Airborne geochemistry
AEM	Airborne electromagnetic surveys
AGRA	Airborne gravity surveys
AMAG	Airborne magnetic surveys
ARAD	Airborne radiometric surveys
DIAM	Diamond drilling
EM	Electromagnetic surveys (includes TEM, Sirotem, etc.)
GEOL	Geological mapping
GEOP	Other geophysical surveys (includes IP, resistivity, etc.)
GRAV	Gravity surveys
HYDR	Groundwater surveys
LSAT	Landsat TM data
MAG	Magnetic surveys
NGRD	Non gridded geochemical surveys (includes chip, channel, dump and
RAB	RAB drilling (includes other shallow geochemical drilling such as auger)
RAD	Radiometric surveys (includes downhole logging)
RC	RC drilling
REGO	Regolith surveys (includes laterite, pisolite, ironstone, etc.)
RES	Resistivity
ROT	Rotary drilling - predominantly percussion drilling
SEIS	Seismic surveys
SOIL	Soil surveys
SSED	Stream sediment surveys

DRILL M: Total number of metres drilled if ACTIVITY code refers to drilling.
ACTIVITYTYPE: Text description of activity. Is null if CONFIDENTIAL = Y (see below). Anomalous elements are indicated by “#”.
COMMODITY: Letter code for commodity explored for. Is null if CONFIDENTIAL = Y (see below).

REPORT SUMMARY: Abstract of report referred to in WAMEX A NUMBER. Is null if CONFIDENTIAL = Y (see below).
CONFIDENTIAL: Y or N corresponding to whether report referred to in WAMEX A NUMBER is confidential or not. Report is confidential if tenement is current.

MINERAL EXPLORATION ANOMALY INDEX

Organization: Geological Survey of Western Australia

Abstract: This index is related to the Mineral Exploration Activity Index by use of ACTIVITYID as a common field. Information for the index was obtained from statutory exploration reports submitted by mineral tenement holders. The Mineral Exploration Anomaly Index contains information for polygons, lines and points defining the location of anomalies identified during mineral exploration activity in the South-West Forest area of Western Australia

Contents:

Citation Information
Dataset Description
Spatial Domain (including Attribute List)
Dataset Currency and Status
Dataset Storage and Format
Dataset Quality

Citation Information

Data Set Title: South-West Forest Mineral Exploration Anomaly Index
Data Set Short Title:
Custodian: Geological Survey of Western Australia
Publication Date: September 1997
Acknowledgments:
References:

Dataset Description

Abstract: This index was created for the Comprehensive, Regional Assessment of mineral resources for the South-West Forest area of Western Australia. The index is related to the Mineral Exploration Activity Index by use of ACTIVITYID as a common field. Information for the index was obtained from statutory exploration reports submitted by mineral tenement holders. The Mineral Exploration Anomaly Index contains information for polygons, lines and points defining the location of anomalies identified during mineral exploration activity. Textual and numeric information on type of anomaly, anomalous elements and their abundance are contained in the index, together with the unique reference code to the report in the WAMEX bibliographic database of statutory mineral exploration reports that contained the raw data.
Search Words: minerals, mineral exploration, geology, geophysics, geochemistry
Location Description: South-West Forest area of Western Australia

Spatial Domain

Bounding Co-ordinates: 114.0, -35.25, 118.0, -31.0
Bounding Polygon:
Attribute List: see attached list

Data Currency and Status

Beginning Date: 1962
Ending Date: 1996
Progress: In progress
Maintenance and Update Frequency: Irregular
Metadata Reviewed:

Dataset Storage and Format

Stored Data Format: Digital — dbf, dxf
Output Data Format: Digital — ASCII, ArcInfo
Native Data Format: Digital — polygons, lines, points, text
Access Constraints: Data are Crown Copyright

Dataset Quality

Lineage Summary: All positional data were culled from hard copy maps of various scales submitted by mineral exploration companies.
Scale: 1:100 000
Resolution: 100m
Cell Size:
Positional Accuracy: ± 100m.
Attribute Accuracy: Information culled from statutory reports submitted by mineral exploration licence holders.
Logical Consistency: Areas, lines and points relating to mineral exploration anomalies indicated on maps at various scales submitted by exploration licence holders were transferred onto 1:50 000 maps and then digitized.
Completeness: The dataset contains spatial data and selected attribute data relating to all reported mineral exploration anomalies in the South-West Forest area of Western Australia. Some attribute data from company reports confidential under WA State law were deleted from the dataset. All points, lines and polygons were visually checked. Attribute data were checked on an audit basis.
Additional Information: The dataset is current as at 1/12/96.
Attribute List: See attached listing

Attribute List

ANOMALID: Unique identifier of individual mineral exploration anomalies.

Anomaly selection

Anomaly thresholds for elements were selected from company data where large regional surveys of the area gave statistically derived thresholds for soils, stream, laterite and hard rock. These thresholds were used for other reports where no statistical analyses were carried out.

Bauxite

All bauxite information has been collated using company reports and GSWA Report 33 (1992) and hence the only bauxite anomalies delineated in the Anomaly Index are those outside of the special Agreement Act tenements.

Anomalies were defined on the basis of >20% available alumina.

Heavy Mineral Sands

As the occurrence of heavy mineral sands is widespread throughout the South-West Forest area, a strict cutoff was applied in the selection of anomalies. If the anomalies were areally extensive they were included as WAMIN sites.

Anomalies (downhole) were selected on the basis of >5m averaging >2% heavy mineral (HM. N.B. Anomalies were not selected in areas with defined resources or where they coincided with a mineral occurrence(WAMIN) site. In situ iImenite anomalies (>2% ilmenite) should be ranked much higher than >2% HM anomalies where the valuable heavy mineral (VHM) content has not been determined and may be low.

Coal

Any coal or peat layers intersected in drill holes were selected as anomalies.

ACTIVITYID: Unique identifier of individual mineral exploration activities in the Mineral Exploration Activity Index.
ACTPOLY: Number of polygons containing information corresponding to ACTIVITYID. May be null.
ACTLINE: Number of lines corresponding to information in ACTIVITYID. May be null.
ACTPOINT: Number of points corresponding to information in ACTIVITYID. May be null.
WAMEX A NUMBER: Pointer to unique code in WAMEX bibliographic database for the report containing information summarized in ACTIVITYID record.
ACTIVITY: Letter code describing type of mineral exploration activity used to define the anomaly.

ACTIVITY	DESCRIPTION
ACH	Airborne geochemistry
AEM	Airborne electromagnetic surveys
AGRA	Airborne gravity surveys
AMAG	Airborne magnetic surveys
ARAD	Airborne radiometric surveys
DIAM	Diamond drilling
EM	Electromagnetic surveys (includes TEM, Sirotem, etc.)
GEOL	Geological mapping
GEOP	Other geophysical surveys (includes IP, resistivity, etc.)
GRAV	Gravity surveys
HYDR	Groundwater surveys
LSAT	Landsat TM data
MAG	Magnetic surveys
NGRD	Non gridded geochemical surveys (includes chip, channel, dump and
RAB	RAB drilling (includes other shallow geochemical drilling such as auger)
RAD	Radiometric surveys (includes downhole logging)
RC	RC drilling
REGO	Regolith surveys (includes laterite, pisolite, ironstone, etc.)
RES	Resistivity
ROT	Rotary drilling - predominantly percussion drilling
SEIS	Seismic surveys
SOIL	Soil surveys
SSED	Stream sediment surveys

ELEMENT: anomalous element(s) Is null if CONFIDENTIAL = Y (see below).
BACKGROUND: Abundance of element outside of anomalous area. Is null if CONFIDENTIAL = Y (see below).
RANGE: Maximum or range in abundance of anomalous element(s). Is null if CONFIDENTIAL = Y (see below).
UNITS: Units of measurement of abundance. Is null if CONFIDENTIAL = Y (see below).
COMMENTS: Text description of anomaly. Is null if CONFIDENTIAL = Y (see below).
CONFIDENTIAL: Y or N corresponding to whether report referred to in WAMEX A NUMBER is confidential or not. Report is confidential if tenement is current.
ENTEREDBY: Unique identifier of individual who inputted data.

MINERAL OCCURRENCE DATABASE (WAMIN)

Organization: Geological Survey of Western Australia

Abstract: This database is a subset of the WAMIN database that contains geoscience attribute information on mineral occurrences in Western Australia.

Contents:

Citation Information
Dataset Description
Spatial Domain (including Attribute List)
Dataset Currency and Status
Dataset Storage and Format
Dataset Quality

Citation Information

Data Set Title: South-West Forest Mineral Occurrence Database
Data Set Short Title:
Custodian: Geological Survey of Western Australia
Publication Date: September 1997
Acknowledgments:
References:

Dataset Description

Abstract: : This dataset consists of records relating to the RFA area contained in WAMIN, the mineral occurrence database for Western Australia. The database comprises textual and numeric information on location of occurrence, location accuracy, commodities, order of magnitude resource tonnage and estimated grade, mineralization classification, mineralogy of ore and gangue mineralogy, details of host rocks, and seminal references on the deposit.
Search Words: minerals, geology
Location Description: South-West Forest area, Western Australia

Spatial Domain

Bounding Co-ordinates: 114.0, -35.25, 118.0, -31.0
Bounding Polygon:
Attribute List: see attached list

Data Currency and Status

Beginning Date: 1900
Ending Date: 1996
Progress: In progress
Maintenance and Update Frequency: Irregular
Metadata Reviewed:

Dataset Storage and Format

Stored Data Format: Digital — dbf
Output Data Format: Digital — ASCII, ArcInfo
Native Data Format: Digital — points, text
Access Constraints: Data are Crown Copyright

Dataset Quality

Lineage Summary: All positional data were culled from hard copy maps of various scales submitted by mineral exploration companies and from other reports on mineral deposits. Other attributes were culled from reports provided by mineral exploration companies or from authoritative text references.
Scale: 1:50 000
Resolution: 50m
Cell Size:
Positional Accuracy: ± 100m unless otherwise indicated.
Attribute Accuracy: Information culled from maps and reports, supplemented by field inspection in rare cases.
Logical Consistency: Points relating to mineral occurrences indicated on maps at various scales were transferred onto 1:50 000 maps for determination of latitude and longitude. For some occurrences, locations were taken from existing reports. For mineral occurrences with a large surface expression, the point location represents the centroid.
Completeness: The dataset contains spatial data and selected attribute data relating to all reported mineral occurrences in the South-West Forest area. Some attribute data from company reports confidential under WA State law were deleted from the dataset. Some occurrences were field verified. Attribute data were checked on an audit basis.
Additional Information: The dataset is current as at 1/12/96.
Attribute List: See attached listing

Attribute List

There are four tables in the database provided as part of the South-West Forest area Comprehensive Regional Assessment.

Table: MIN_DEP

This is the primary table

DEPOSNO: Unique identifier of individual mineral occurrences
DEPNAME: Best-known name for the occurrence
DLAT: Latitude in decimal degrees of centroid of occurrence
DLONG: Longitude in decimal degrees of centroid of occurrence
ACCURACY: Possible error in metres of location
GEOPROV: Geological Province containing the occurrence

GEOPROVNO	PROVNAME
3	Albany-Fraser Orogen
15	Bremer Basin
69	Perth Basin
93	Yilgarn Craton
121	Western Gneiss Terrane
491	Collie Basin

EXPOSED: Whether deposit is exposed (Y) or not (N) or unknown (null)
LENGTH: Observed maximum horizontal dimension in metres of deposit
WIDTH: Observed horizontal dimension in metres of deposit measured perpendicular to LENGTH
DEPTH: Average thickness of deposit in metres measured in a vertical plane
MINEDEX: Unique SITE or PROJECT code for same deposit in MINEDEX database
WAMEX/WAPEX: Unique code in WAMEX or WAPEX bibliographic databases for major report(s) containing information on the occurrence
OTHERREF: Reference to major non-statutory literature references to the occurrence
ENTEREDBY: Unique number assigned to individual who entered the data on the occurrence

Table: MINCOMMOD

DEPOSNO: Unique identifier of individual mineral occurrences
COMMODITY: Commodities that are or could be obtained from the occurrence

COMMODITY	COMMODNAME
Ag	Silver
Au	Gold
Ba	Barium
Be	Beryllium
Bx	Bauxite
Clay	Clay
Co	Cobalt
Coal	Coal
Cr	Chromium
Fe	Iron
Fel	Feldspar
Grap	Graphite
HM	Heavy minerals
Ilm	Ilmenite
Kaol	Kaolin
Kyan	Kyanite
Li	Lithium
Lst	Limestone
Mica	Mica
Mo	Molybdenum
Mona	Monazite
Ni	Nickel
Pb	Lead
PGE	Platinum Group Elements
Rut	Rutile
Sil	Silica
Sn	Tin
Sst	Sandstone/Quartzite
Ta	Tantalum
Talc	Talc
V	Vanadium
Xeno	Xenotime
Zn	Zinc
Zrcn	Zircon

MAINGROUP: Classification of commodities associated with occurrence into a geochemical or commercial grouping of commodities.

MAIN GROUP	COMMODGROUP
Fe	Iron
Mn	Ferro-alloy
Cr Ti V	Ferro-alloy
Ni Co	Ferro-alloy
Sn Ta Li	Other alloys
W Mo	Other alloys
Nb Zr REE	Other alloys
Cu Pb Zn Ag (Ba F)	Base metal
Al	Alumina
Au	Precious metal
PGE	Precious metal
U	Energy
Coal	Energy
Diamond	Precious stone
Semi-precious stones	Precious stone
Industrial minerals	Undivided
Construction materials	Undivided

COMMODGROUP: Higher order commercially-based classification of MAINGROUP (see above)
RESOURCES: order of magnitude tonnage (millions of tonnes) of deposit (not necessarily equal to JORC tonnage as used in “Identified Mineral Resource” or “Reserves”).
GRADE: approximate average grade of occurrence (not necessarily equal to JORC grade as used in “Identified Mineral Resource” or “Reserves”)
UNIT: units of grade
CONFIDENTIAL: whether source of information was a confidential statutory report (Y) or not (N). If Y, RESOURCES, GRADE and UNIT fields are null.

Table: MINATTRIBS

Attributes of the mineral occurrence

DEPOSNO: Unique identifier of individual mineral occurrences
STYLEGROUP: Broad classification of occurrence according to style of mineralization

STYLEGROUP	SUBTYPE
Orthomagmatic - basic and ultrabasic	Undivided
Pegmatitic	Undivided
Residual and supergene	Undivided
Sedimentary	Placer and beach
Sedimentary	Undivided
Strata-bound	Undivided
Stratiform sedimentary and volcanic	Sedimentary-hosted sulphide
Stratiform sedimentary and volcanic	Volcanic oxide
Vein and hydrothermal	Disseminated
Vein and hydrothermal	Undivided

SUBTYPE: subdivision of STYLEGROUP applicable to occurrence
ATTRIB: Letter code for an extendable attribute of the occurrence

ATTRIB	ATTRIBNAME
AGE	Age methods
ALT	Alteration
CLA	Classification
CON	Ore controls
EXP	Expression
GMIN	Gangue mineral
MIS	Mineralisation style
MIT	Mineralisation texture
MMG	Metamorphic grade
OMIN	Ore mineral
OPS	Operating status
REH	Relation to host
SHA	Shape
SMO	Structural modifier
VST	Vein style

VALUEID: Descriptor for extendable attribute (ATTRIB)
ALT (*Alteration types)*

ATTRIBID	ATTRIBNAME	VALUEID	VALUENAME
ALT	Alteration	AB	albitic
ALT		AR	argillic
ALT		CA	carbonate
ALT		CL	chloritic
ALT		GR	greisen
ALT		HM	hematitic
ALT		OTH	other
ALT		PO	potassic
ALT		PR	propylitic
ALT		PY	pyritic
ALT		SE	sericitic
ALT		SP	serpentinisation

ALT		SI	silicification
ALT		SK	skarn
ALT		UN	unknown
ALT		ZE	zeolitic

CLA (modified USGS Deposit Model Classification)

ATTRIBID	VALUEID	VALUENAME
CLA	A-C	MAFIC AND ULTRAMAFIC INTRUSIONS
CLA		
CLA	A	Tectonically stable stratiform
CLA	A1	Stratiform deposits
CLA	A1a	Basal zone
CLA	1	Stillwater Ni-Cu
CLA	A1b	Intermediate zone
CLA	2A	Bushveld chromitite
CLA	2B	Merensky Reef PGE
CLA	A1c	Upper Zone
CLA	3	Bushveld Fe-Ti-V
CLA	A2	Pipe-like deposits
CLA	4a	Cu-Ni pipes
CLA	4b	PGE pipes
CLA		
CLA	B	Tectonically unstable
CLA	B1	Intrusions same age as volcanic rocks
CLA	B1a	Rift environment
CLA	5A	Duluth Cu-Ni-PGE
CLA	5B	Noril'sk Cu-Ni-PGE
CLA	B1b	Greenstone belt
CLA	6A	Komatiitic Ni-Cu
CLA	6B	Dunitic Ni-Cu
CLA	B2	Intrusions emplaced during orogenesis
CLA	B2a	Synorogenic in volcanic terrane
CLA	7A	Synorogenic-synvolcanic Ni-Cu
CLA	B2b	Synorogenic in non-volcanic terrane
CLA	7B	Anorthosite Ti
CLA	B2c	Ophiolites
CLA	8A	Podiform chromite
CLA	8B	Major podiform chromite
CLA	38A	Lateritic Ni
CLA	39A	Placer Au-PGE
CLA		Serpentine
CLA	8C	Limassol Forest Co-Ni
CLA	8D	Serpentine-hosted asbestos
CLA	27C	Silica-carbonate Hg
CLA	36A	Low-sulphide Au-quartz veins
CLA	B2d	Cross-cutting intrusions
CLA	9	Alaskan PGE
CLA	39B	Placer PGE-Au
CLA		
CLA	C	Alkaline intrusions in stable areas
CLA	10	Carbonatite
CLA	11	Alkaline complexes
CLA	12	Diamond pipes
CLA		
CLA		
CLA	D-E	FELSIC INTRUSIONS
CLA		
CLA	D	Phanerocrystalline
CLA	D1	Pegmatitic
CLA	13a	Be-Li pegmatites
CLA	13b	Sn-Nb-Ta pegmatites
CLA	13c	Greenbushes type
CLA	D2	Granitic intrusions
CLA	D2a	Calcareous wallrocks

CLA	14A	W skarn
CLA	14B	Sn skarn
CLA	14C	Replacement Sn
CLA	D2b	Other wallrocks
CLA	15A	W veins
CLA	15B	Sn veins
CLA	15C	Sn greisen
CLA	36A	Low-sulphide Au-quartz veins
CLA	36B	Homestake Au
CLA	D3	Anorthosite intrusions
CLA	7B	Anorthosite Ti
CLA		
CLA	E	Porphyroaphanitic
CLA	E1	High silica granites and rhyolites
CLA	16	Climax Mo
CLA	26B	Fluorspar deposits
CLA	E2	Other felsics
CLA	17	Porphyry Cu
CLA	E2a	Calcareous wallrocks, deposit near contact
CLA	18A	Porphyry Cu, skarn related
CLA	18B	Cu skarn
CLA	18C	Zn-Pb skarn
CLA	18D	Fe skarn
CLA	18E	Carbonate-hosted asbestos
CLA	E2b	Calcareous wallrocks, deposit far from contact
CLA	19A	Polymetallic replacement
CLA	19B	Replacement Mn
CLA	26A	Carbonate-hosted Au
CLA	E3	Wallrocks coeval
CLA	E3a	Granitic in felsic
CLA	20A	Porphyry Sn
CLA	20B	Sn-polymetallic veins
CLA	E3b	Calcalkaline
CLA	20C	Porphyry Cu-Au
CLA	25G	Epithermal Mn
CLA	E4	Wall rocks older
CLA	E4a	Deposits in intrusions
CLA	21A	Porphyry Cu-Mo
CLA	21B	Porphyry Mo, low F
CLA	21C	Porphyry W
CLA	E4b	Deposits in wallrocks
CLA	22A	Volcanic-hosted Cu-As-Sb
CLA	22B	Au-Ag-Te veins
CLA	22C	Polymetallic veins
CLA	25E	Epithermal quartz-alunite Au
CLA	36A	Low-sulphide Au-quartz veins
CLA		
CLA		
CLA	F-G	EXTRUSIVE ROCKS
CLA		
CLA	F	Mafic
CLA	F1	Continental
CLA	23	Basaltic Cu
CLA	30B	Sediment-hosted Cu
CLA	F2	Marine
CLA	24A	Cyprus massive sulphide
CLA	24B	Besshi massive sulphide
CLA	24C	Volcanogenic Mn
CLA	24D	Blackbird Co-Cu
CLA	6A	Komatiitic Ni-Cu
CLA		
CLA	G	Felsic-mafic
CLA	G1	Subaerial
CLA	G1a	Deposits within volcanics
CLA	25A	Hot spring Au-Ag
CLA	25B	Creede epithermal veins

CLA	25C	Comstock epithermal veins
CLA	25D	Sado epithermal veins
CLA	25E	Epithermal quartz-alunite Au
CLA	25F	Volcanogenic U
CLA	25G	Epithermal Mn
CLA	25H	Rhyolite-hosted Sn
CLA	25I	Volcanic-hosted magnetite
CLA	25J	Epithermal veins
CLA	G1b	Deposits in calcareous rocks
CLA	26A	Carbonate-hosted Au
CLA	26B	Fluorspar deposits
CLA	G1c	Deposits in sedimentary rocks
CLA	27A	Hot spring Hg
CLA	27B	Almaden Hg
CLA	27C	Silica-carbonate Hg
CLA	27D	Simple Sb
CLA	G2	Marine
CLA	28A	Kuroko massive sulphide
CLA	28B	Algoma Fe
CLA	24C	Volcanogenic Mn
CLA	25F	Volcanogenic U
CLA	36A	Low-sulphide Au-quartz veins
CLA	36B	Homestake Au
CLA		
CLA		
CLA	H-J	SEDIMENTARY ROCKS
CLA		
CLA	H	Clastic
CLA	H1	Conglomerate and breccia
CLA	29A	Quartz pebble conglomerate Au-U
CLA	29B	Olympic Dam Cu-U-Au
CLA	30C	Sandstone U
CLA	23	Basaltic Cu
CLA	H2	Sandstone
CLA	30A	Sandstone-hosted Pb-Zn
CLA	30B	Sediment-hosted Cu
CLA	30C	Sandstone U
CLA	23	Basaltic Cu
CLA	32C	Kipushi Cu-Pb-Zn
CLA	37A	Unconformity U-Au
CLA	H3	Shale-siltstone
CLA	31A	Sedimentary exhalative Zn-Pb
CLA	31B	Bedded barite
CLA	31C	Emerald veins
CLA	23	Basaltic Cu
CLA	26A	Carbonate-hosted Au
CLA	30B	Sediment-hosted Cu
CLA		
CLA	I	Carbonate
CLA	I1	Not associated with igneous rocks
CLA	32A	Southeast Missouri Pb-Zn
CLA	32B	Appalachian Zn
CLA	32C	Kipushi Cu-Pb-Zn
CLA	14C	Replacement Sn
CLA	31A	Sedimentary exhalative Zn-Pb
CLA	38C	Bauxite, karst type
CLA	I2	Igneous heat source present
CLA	19A	Polymetallic replacement
CLA	19B	Replacement Mn
CLA	26A	Carbonate-hosted Au
CLA	26B	Fluorspar deposits
CLA		
CLA	J	Chemical
CLA	J1	Oceanic
CLA	33A	Mn nodules
CLA	33B	Mn crusts

CLA	J2	Shelf (BIF)
CLA	34A	Superior Fe (BIF)
CLA	34B	Sedimentary Mn
CLA	34C	Phosphate, upwelling type
CLA	34D	Phosphate, warm-current type
CLA	J3	Restricted basin
CLA	35A	Marine evaporite
CLA	35B	Playa evaporite
CLA	31A	Sedimentary exhalative Zn-Pb
CLA	34B	Sedimentary Mn
CLA		
CLA		
CLA	K-L	REGIONALLY METAMORPHOSED ROCKS
CLA		
CLA	K	Eugeosynclinal
CLA	36A	Low-sulphide Au-quartz veins
CLA	36B	Homestake Au
CLA	36C	Archaean lode Au
CLA	8D	Serpentine-hosted asbestos
CLA	37B	Gold on flat faults
CLA		
CLA	L	Sedimentary rocks
CLA	37A	Unconformity U-Au
CLA	37B	Gold on flat faults
CLA		
CLA		
CLA	M-N	SURFICIAL AND UNCONFORMITY-RELATED
CLA		
CLA	M	Residual
CLA	38A	Lateritic Ni
CLA	38B	Bauxite, laterite type
CLA	38C	Bauxite, karst type
CLA	38D	Lateritic Au
CLA	38E	Lateritic Fe
CLA	38F	Lateritic V
CLA	37A	Unconformity U-Au
CLA		
CLA	N	Depositional
CLA	39A	Placer Au-PGE
CLA	39B	Placer PGE-Au
CLA	39C	Shoreline placer Ti
CLA	39D	Diamond placers
CLA	39E	Stream placer Sn
CLA	39F	Fluviatile placer Ti
CLA	29A	Quartz pebble conglomerate Au-U
CLA		
CLA		
CLA	FM	FUEL MINERALS
CLA		
CLA	40A	Coal, bituminous
CLA	40B	Coal, sub-bituminous
CLA	40C	Coal, lignite
CLA	40D	Petroleum
CLA		
CLA		
CLA	IND	HIGH VALUE INDUSTRIAL MINERALS
CLA		
CLA	41A	Graphite
CLA	41B	Magnesite
CLA	41C	High grade kaolin
CLA	41D	Kyanite
CLA	41E	Talc
CLA	41F	Barite
CLA		
CLA	FRD	FAULT-RELATED DEPOSITS
CLA		

CLA	42A	Epithermal gold deposits (Donnybrook)
CLA	42B	Polymetallic veins (Mundijong)

CON (Ore controls)

ATTRIBID	ATTRIBNAME	VALUEID	VALUENAME
CON	Ore controls	GC	geochemical
CON		MAG	magmatic
CON		MEC	mechanical
CON		MET	metamorphic
CON		STA	stratigraphic
CON		STU	structural
CON		UN	unknown

EXP (Exploration expression)

ATTRIBID	ATTRIBNAME	VALUEID	VALUENAME
EXP	Expression	CON	concealed
EXP		GC	geochemical
EXP		GP	geophysical
EXP		GO	gossan
EXP		IN	intersection
EXP		OUT	outcrop
EXP		UN	unknown

MIS (Mineralization style)

ATTRIBID	ATTRIBNAME	VALUEID	VALUENAME
MIT	Mineralisation texture	BX	brecciated
MIT		CU	cumulus
MIT		DI	disseminated
MIT		IC	intercumulus
MIT		LA	laminated (or banded)
MIT		MA	massive
MIT		NO	nodular
MIT		PI	pisolitic
MIT		UN	unknown
MIT		ZO	zoned

MIT (Mineralization texture)

ATTRIBID	ATTRIBNAME	VALUEID	VALUENAME
MIS	Mineralisation style	AL	alluvial
MIS		BE	bed
MIS		BR	breccia
MIS		EV	evaporitic
MIS		MAG	magmatic
MIS		MB	multiple bed
MIS		MV	multiple vein
MIS		RPL	replacement
MIS		RE	residual
MIS		SZ	shear zone
MIS		SV	single vein
MIS		SK	skarn
MIS		ST	stockwork
MIS		SUP	supergene
MIS		SUR	surficial
MIS		UN	unknown

MMG (Metamorphic grade)

ATTRIBID	ATTRIBNAME	VALUEID	VALUENAME
MMG	Metamorphic grade	ZE	zeolite
MMG		PP	prehnite-pumpellyite
MMG		BL	blueschist
MMG		GS	greenschist
MMG		AM	amphibolite
MMG		EC	eclogite
MMG		GR	granulite
MMG		KC	K-feldspar-cordierite hornfels
MMG		HB	hornblende hornfels
MMG		AE	albite-epidote hornfels

OPS (Operating status)

ATTRIBID	ATTRIBNAME	VALUEID	VALUENAME
OPS	Operating status	AM	abandoned mine
OPS		D	mineral deposit
OPS		O	occurrence
OPS		OM	operating mine
OPS		P	prospect

REH (Relation to host)

ATTRIBID	ATTRIBNAME	VALUEID	VALUENAME
REH	Relation to host	CO	concordant
REH		DI	discordant
REH		IC	intrusive contact
REH		SB	stratabound
REH		SF	stratiform
REH		UN	unknown

SHA (Shape of occurrence)

ATTRIBID	ATTRIBNAME	VALUEID	VALUENAME
SHA	Shape	IR	irregular
SHA		LE	lenticular
SHA		PL	pipe-like
SHA		SH	sheeted
SHA		TA	tabular
SHA		UN	unknown

SMO (Post-mineralization structural modifications to occurrence)

ATTRIBID	ATTRIBNAME	VALUEID	VALUENAME
SMO	Structural modifier	FA	faulted
SMO		FO	folded
SMO		FR	fractured
SMO		SH	sheared
SMO		UN	unknown

VST (Vein style)

ATTRIBID	ATTRIBNAME	VALUEID	VALUENAME
VST	Vein style	AC	acicular
VST		BL	bladed
VST		CO	cockade
VST		CM	colloform mass
VST		CB	comb
VST		CR	crustiform
VST		FE	feathery
VST		FL	flamboyant
VST		GS	ghost sphere
VST		MA	massive
VST		MO	mosaic
VST		SA	saccharoidal
VST		ZO	zonal

VALUEID: Letter code descriptor corresponding to extendable attribute

DESCRIPTION: Text descriptor corresponding to extendable attribute (see VALUENAME in tables above)

Table : MINHOST

Contains attributes of host rocks to the occurrence

DEPOSNO: Unique identifier of individual mineral occurrences
ROCKTYPE: Broad classification of rock type(s) hosting an occurrence

ROCKTYPE
chemical sediment
clastic sediment
felsic
felsic gneiss
mafic
metabasite
metasediment
regolith
ultramafic
unknown

STRATNAME: Formal name (if available) of unit hosting the occurrence
MAPCODE: 3 or 4 letter map code for unit hosting the occurrence. Corresponds to map codes used on digital geological maps prepared for the South-West Forest area CRA.
INFORMAL: Subdivision of STRATNAME or name of unit if not formalized.
LITHNAME: Name of rock hosting the occurrence
METAGRADE: metamorphic grade of host rock

VALUEID	VALUENAME
ZE	zeolite
PP	prehnite-pumpellyite
BL	blueschist
GS	greenschist
AM	amphibolite
EC	eclogite
GR	granulite
KC	K-feldspar-cordierite hornfels
HB	hornblende hornfels
AE	albite-epidote hornfels

MINERAL RESOURCE INDEX

Organization: Geological Survey of Western Australia

Abstract: This dataset is a subset of the MINEDEX database on mineral deposits in WA maintained by the Geological Survey of Western Australia. MINEDEX is based on mineral project and site names and contains information on ownership, commodity group, site type and development status, location, and mineral resource data.

Contents:

Citation Information
Dataset Description
Spatial Domain (including Attribute List)
Dataset Currency and Status
Dataset Storage and Format
Dataset Quality

Citation Information

Data Set Title: South-West Forest Mineral Resource Index
Data Set Short Title:
Custodian: Geological Survey of Western Australia
Publication Date: September 1997
Acknowledgments:
References: Townsend, D.B., Preston, W.A., and Cooper, R.W., 1996. Mineral resources and locations, Western Australia: digital dataset from MINEDEX. Western Australia Geological Survey Bulletin 13, 19pp.

Dataset Description

Abstract: Four of the five tables in this index are a subset of the MINEDEX database on mineral deposits in WA maintained by the Geological Survey of Western Australia. MINEDEX is based on mineral project and site names and contains information on ownership, commodity group, site type and development status, location, and mineral resource data. A full description of the database is found in Townsend et al., 1996; Western Australia Geological Survey Record 1996/13.
One table in the index contains information on areas with potential mineral resources and attributes of coal basins, large mineralised areas, and areas rehabilitated following resource depletion.
Search Words: mineral deposits, mineral resources
Location Description: South-West Forest area, Western Australia

Spatial Domain

Bounding Co-ordinates: 114.0, -35.25, 118.0, -31.0
Bounding Polygon:
Attribute List: see attached list

Data Currency and Status

Beginning Date: 1900
Ending Date: 1996
Progress: In progress
Maintenance and Update Frequency: Continuous
Metadata Reviewed:

Dataset Storage and Format

Stored Data Format: Digital — dbf, dxf
Output Data Format: Digital — ASCII, ArcInfo
Native Data Format: Digital — points, polygons, text
Access Constraints: Data are Crown Copyright

Dataset Quality

Lineage Summary: All positional data were culled from reports and hard copy maps of various scales submitted by mineral exploration companies, DME files, geoscience literature, industry magazines and the press.
Scale: 1:50 000
Resolution: 50m
Cell Size:
Positional Accuracy: ± 100m.
Attribute Accuracy: Information from reports submitted by mineral exploration companies, DME files, geoscience literature, industry magazines and the press.
Logical Consistency: Points (centroids of small deposits) and polygons corresponding to mineral deposits indicated on on maps at various scales were transferred onto 1:50 000 maps and then digitized.
Completeness: The dataset contains spatial data and selected attribute data relating to all reported mineral deposits (including coal, industrial minerals, and construction materials), in the South-West Western Australia RFA area. The index also contains spatial and attribute information on large mineralised areas which could yield reserves in the future. Some attribute data from company reports confidential under WA State law were deleted from the dataset. The dataset is current as at 1/12/96.
Additional Information: The dataset is current as at 1/12/96.
Attribute List: See attached listing

Attribute List

There are five tables in the index provided as part of the South-West Forest Comprehensive Regional Assessment. Four of the tables (SWSITES, SWGPSITE, SWRES, SWOWNER) are subsets of MINEDEX. The fifth table has miscellaneous information relating to areas with potential resources and attributes of coal basins, large mineralised areas, and areas rehabilitated following resource depletion.

Table: SWSITES (MINEDEX)

This is the primary table of the four tables forming a subset of MINEDEX.

COMMODITY: This is a broad classification of commodities for the South-West Forest area and includes industrial minerals and construction materials.

COMMODITY
BARITE
BAUXITE - ALUMINA
CHROMITE - PLATINOIDS
CLAYS
COAL
CONSTRUCTION MATERIALS
DIATOMITE
DIMENSION STONE
GOLD
GRAPHITE
GYPSUM
HEAVY MINERAL SANDS
INDUSTRIAL PEGMATITE
LIMESTONE - LIMESAND
PEAT
SALT
SILICA - SILICA SAND

TIN - TANTALUM - LITHIUM	
VANADIUM - TITANIUM	

PROJECT: Mineral deposits are either SITES with common commercial ownership that are grouped together in an integrated operation, or SITES which have been grouped for the calculation of resources for a geological unit (eg. a strandline).
PROJ CODE: Unique identifier for a project, prefixed by "J"
SITE: Name for an individual element related to mineral deposit development.
General sites with names ending in *General* @ are collective group sites for areas or specific strandlines where the resources are held by more than one company and where individual resources may be confidential. The resource figure quoted for these General Sites is the total of all individual resources (confidential and/or published) tied into this group site. The linkage of General to individual sites is given in the Table: SWGPSITE.

1. Confidential resource outlines have not been included but appear as points.
2. On the Waroona Strandline mineralized areas have been generalized and specific orebodies have not been differentiated. The General @ sites for this strandline, however, contain total known resources for all deposits.
3. Bauxite resource outlines are for areas with >25% available alumina.

Anomalies (see Mineral Exploration Anomaly Index) have not been plotted where known resources occur. As confidential resources have been included as points only, there will be apparent anomaly gaps around them.

SITE CODE: Unique identifier for a site, prefixed by "S"
TYPE: Letter code for the type of site

Site type	Type
Deposit - open pit	DO
Deposit - underground	DU
Deposit - open pit/underground	DB
Deposit - tails	DT
Mine - open pit	MO
Mine - underground	MU
Mine - open pit/underground	MB
Mine - tails (retreatment)	MT
Process plant	P
Handling facility	H
Road/Railway	T
Cross reference	X

STAGE: Is the stage of development that the deposit was as at 20/12/96

Development	Stage
Under development	D
Operating	O
Care & maintenance	C
Shutdown	S

STAT: Letter code expressing confidentiality of data. "P" for non-confidential, "C" for confidential
LATITUDE: Latitude of centroid of resource or facility
LONGITUDE: Longitude of centroid of resource or facility
AMG ZONE: Australian Map Grid Zone in which centroid is situated
EASTING: metric AMG co-ordinates of centroid
NORTHING: metric AMG co-ordinates of centroid
ACCURACY:Indicates whether co-ordinates have been verified by WA Department of Minerals and Energy staff. "Y" means co-ordinates have been checked; null indicates no known check
GP SITE: A letter code to combine sites within projects to accommodate different reporting styles of mineral resources. "G" links mines, deposits, processing plants, handling facilities etc; "X" group sites are those mines and deposits that were once separate entities but are now a single reporting unit, either by expansion or merging of operations.

Table: SWGPSITE (MINEDEX)

Links SITEs to GP SITEs using alphanumeric codes

GP SITE: see above
SITE CODE: see above

Table: SWRES (MINEDEX)

Contains non-confidential resources for SITES and GPSITES

SITE CODE: Alphanumeric code for individual SITE (Link to SWSITES table)
RES NUM: Computer-generated number to separate resources for a GP SITE
CAT: Letter code indicating confidence in reource figure, either “ME”asured, “IND”icated, “INF”erred, or “DEM”onstrated
TYPE: Resource is either “I/S” (in situ), “DEV”elopable or “MIN”able
STAT: Confidential (“C”) or published (“P”). Confidential resources for individual SITEs are not included in this dataset.
MIN TYPE: Letter code for mineralization type used in this index.

MIN TYPE	DESCRIPTION
AUGRAN	GOLD DEPOSITS ALONG GRANITE-GREENSTONE CONTACTS AND IN GRANITOID ROCKS
AULAT	LATERITIC GOLD DEPOSITS
AUPOR	GOLD ASSOCIATED WITH FELSIC PORPHYRY WITHIN GREENSTONES
BACAV	VEIN AND CAVITY FILL DEPOSITS
BAULAT	LATERITIC BAUXITE DEPOSITS
CADUNE	LIMESAND IN COASTAL DUNE SANDS
CALIME	LIMESTONE DEPOSITS
CASEA	OFFSHORE LIMESAND DEPOSITS
CLRES	RESIDUAL CLAY DEPOSITS
CLTRAN	TRANSPORTED CLAY DEPOSITS
COPBIT	PERMIAN BITUMINOUS COAL
COPSBT	PERMIAN SUB-BITUMINOUS COAL
CRPGUM	PGE’S AND/OR CHROMIUM IN METAMORPHOSED MAFIC-ULTRAMAFIC ROCKS
HMSCAP	HEAVY MINERAL DEPOSITS IN THE CAPEL SHORELINE
HMSDON	HEAVY MINERAL DEPOSITS IN THE DONNELLY SHORELINE
HMSDUN	HEAVY MINERAL DEPOSITS IN THE QUINDALUP SHORELINE
HMSGIN	HEAVY MINERAL DEPOSITS IN THE GINGIN SHORELINE
HMSHV	HEAVY MINERAL DEPOSITS IN THE HAPPY VALLEY SHORELINE
HMSMES	HEAVY MINERAL DEPOSITS IN MESOZOIC FORMATIONS
HMSMIL	HEAVY MINERAL DEPOSITS IN THE MILYEAANUP SHORELINE
HMSMIS	HEAVY MINERAL DEPOSITS - MISCELLANEOUS
HMSMUN	HEAVY MINERAL DEPOSITS IN THE MUNBINEA SHORELINE
HMSWAR	HEAVY MINERAL DEPOSITS IN THE WARREN SHORELINE
HMSWRN	HEAVY MINERAL DEPOSITS IN THE WAROONA SHORELINE
HMSYOG	HEAVY MINERAL DEPOSITS IN THE YOGANUP SHORELINE
SIDUNE	MESOZOIC DUNE AND BEDDED SILICA SANDS
SNALL	ALLUVIAL/ELUVIAL TIN-TANTALUM DEPOSITS
SNPEGM	PEGMATITE TIN-TANTALUM-LITHIUM DEPOSITS
VTILAT	LATERITIC VANADIUM-TITANIUM DEPOSITS
VTIMAG	TITANIFEROUS MAGNETITE DEPOSITS

IN TOTAL: Indicates whether (“Y”) or not (“N”) the resource is to be included in the total resources of the State
TONNAGE: Tonnage of resource in millions of tonnes
GRADE: Quoted average grade of resource
UNIT: Units grade is measured in
MINERAL: Element or commodity produced

MINERAL	DESCRIPTION
ABEA	ALUMINA (AVAILABLE)
AGGREG	AGGREGATE

Au	GOLD
BADENS	
BaSO4	BARITE
C	CARBON (FIXED)
CaCO3	CALCIUM CARBONATE
COAL	COAL
Fe2O3	FERRIC OXIDE
GARNET	GARNET
GRAPH	GRAPHITE
GRAVEL	GRAVEL
HM	HEAVY MINERALS
ILM	ILMENITE
KAOLIN	KAOLIN
KYAN	KYANITE
LEUCO	LEUCOXENE
Li2O	SPODUMENE
LIME	LIMESTONE - LIMESAND
MgCO3	MAGNESITE
MICA	MICA
MONAZ	MONAZITE
PGE	PGE
QZTE	QUARTZITE
RESIO2	REACTIVE SILICA
RUTILE	RUTILE
SAND	SAND
SiO2	SILICA
SLIMES	SLIMES
SnO2	TIN (CASSITERITE)
Ta2O5	TANTALITE
TiO2	TITANIUM DIOXIDE
V2O5	VANADIUM
W.CLAY	WHITE CLAY
XENO	XENOTIME
ZIRCON	ZIRCON

CONT METAL: Calculated from TONNAGE x GRADE
UNIT (METAL): Units for contained metal
SOURCE: Abbreviation for bibliographic source of resource information
DATE: Date of last entry

Table: SWOWNER (MINEDEX)

Contains details of project equity

OWNER: Corporate entity with equity in project
%: Percentage of equity
PROJECT CODE: Link to SWSITES table

Table: SWFBAS

Text attributes of miscellaneous resource polygons

PolyNo: Link to spatial data
Name: Name assigned to area
Minarea: Type of area. Mineralised areas have been outlined by one or more of the following exploration methods; geological mapping, remote sensing or reconnaissance drilling. They are geologically similar to known resource areas. Detailed drilling is likely to confirm mineable resources within the area delineated.

Minarea	Description
Mineralised Area	Potential resource areas
Extracted Resource	Areas previously mined or sterilised by plant
Basin outline	Outer margin of coal basin

Rehabilitation Areas	Areas rehabilitated after mining completed

Commodity: MINEDEX commodity occurring within area
Comments: Additional relevant textural information

PETROLEUM WELLS INDEX (WELLS)

Organization: Geological Survey of Western Australia

Abstract: The index, a subset of a database on WA petroleum wells, contains information on all petroleum and gas wells drilled in the SW Forest area.

Contents:

Citation Information
Dataset Description
Spatial Domain (including Attribute List)
Dataset Currency and Status
Dataset Storage and Format
Dataset Quality

Citation Information

Data Set Title: South-West Forest Petroleum Wells Index
Data Set Short Title:
Custodian: Geological Survey of Western Australia
Publication Date: September 1997
Acknowledgements:
References:

Dataset Description

Abstract: The index is a subset of a database on WA petroleum wells maintained by the Geological Survey of Western Australia. It contains data on the location, spud date, depth drilled, completion status, production status, operator, and a brief commentary on all petroleum and gas wells drilled in the South-West Forest area.
Search Words: petroleum, petroleum exploration, drilling
Location Description: South-West Forest area, Western Australia

Spatial Domain

Bounding Co-ordinates: 114.0, -35.25, 118.0, -31.0
Bounding Polygon:
Attribute List: see attached list

Data Currency and Status

Beginning Date: 1964
Ending Date: 1996
Progress: In progress
Maintenance and Update Frequency: Continuous
Metadata Reviewed:

Dataset Storage and Format

Stored Data Format: Digital — dbf
Output Data Format: Digital — ASCII, ArcInfo
Native Data Format: Digital — points, text
Access Constraints: Data are Crown Copyright

Dataset Quality

Lineage Summary: Geodetic surveying techniques were used to provide latitude and longitude data

of drill collars.
Scale: 1:5 000
Resolution: 5m
Cell Size:
Positional Accuracy: ± 5m generally.
Attribute Accuracy: Information culled from statutory reports submitted by petroleum exploration licence holders.
Logical Consistency: Survey locations of drill collars entered into database.
Completeness: The dataset contains spatial data and selected attribute data relating to all petroleum wells in the South-West Forest area.
Additional Information: The dataset is current as at 1/12/96.
Attribute List: See attached listing

Attribute List

WellIndexNo: Unique numeric identifier of well within database
WellName: Official name of well
DecimalLat: Latitude of collar in decimal degrees (- for south latitude)
DecimalLong: Longitude of collar in decimal degrees
Basin: Official name of basin in which well was spudded
SubBasin: Official name of sub-basin (if applicable) in which well was spudded
Field: Official name of petroleum or gas field well was spudded in (if applicable)
TotalMetresDrilled: Length of drill stem between collar and drillbit
ProductionStatus: Whether well produced gas or was dry.
CompletionStatus: Whether well was completed by shut in as a possible gas producer, or was plugged and abandoned
OilShow: Character of oil shows, or nil oil shows
GasShow: Character of gas shows, or nil gas shows

GasShow
Excellent
Fair
Good
Nil
Poor
Producer

SpudDate: date well was spudded
Operator: Company nominated as operator of the permit
Comment: Further details of the well

GEOPHYSICAL SURVEYS INDEX (SURVEY1)

Organization: Geological Survey of Western Australia

Abstract: The index is a subset of a database that contains information on geophysical surveys conducted during petroleum exploration in Western Australia.

Contents:

Citation Information
Dataset Description
Spatial Domain (including Attribute List)
Dataset Currency and Status
Dataset Storage and Format
Dataset Quality

Citation Information

Data Set Title: South-West Forest Geophysical Surveys Index
Data Set Short Title:
Custodian: Geological Survey of Western Australia
Publication Date: September 1997
Acknowledgements:
References:

Dataset Description

Abstract: The index is a subset of a database on WA geophysical surveys carried out by petroleum licencees or government organizations in Western Australia. It contains information on the location, name, type, and line kilometres of geophysical surveys.
Search Words: petroleum, petroleum exploration, geophysical surveys
Location Description: South-West Forest area, Western Australia

Spatial Domain

Bounding Co-ordinates: 114.0, -35.25, 118.0, -31.0
Bounding Polygon:
Attribute List: see attached list

Data Currency and Status

Beginning Date: 1951
Ending Date: 1996
Progress: In progress
Maintenance and Update Frequency: Continuous
Metadata Reviewed:

Dataset Storage and Format

Stored Data Format: Digital — dbf
Output Data Format: Digital — ASCII, ArcInfo
Native Data Format: Digital — points, text
Access Constraints: Data are Crown Copyright

Dataset Quality

Lineage Summary: All positional data were culled from digital survey information provided by petroleum companies or from government surveys. In some cases, geodetic surveying techniques

were used to provide latitude and longitude data.
Scale: 1:50 000
Resolution: 100m
Cell Size:
Positional Accuracy: ± 100m.
Attribute Accuracy: Information culled from statutory reports submitted by petroleum exploration licence holders or from government survey reports.
Logical Consistency: Survey locations are entered into database.
Completeness: The dataset contains all known regional scale geophysical surveys conducted by petroleum licencees or by government agencies in the South-West Western Australia RFA area.
Additional Information: The dataset is current as at 1/12/96.
Attribute List: See attached listing

Attribute List

SurveyIndex: Unique number for geophysical survey
SurveyName: Name given to survey by licencee
EndDate:Date survey completed
Company: Licencee of permit in which survey was conducted
LinePrefix: Prefix given to line numbers in a particular survey (may be null)
Basin: Official name of basin in which well was spudded
Type: type of geophysical survey

Type
2D Reflection
2D Refraction
Aeromagnetic
Gravity
Magnetic

LineLength: Total length of survey lines
Units: Measurement units for total line length
PartNo: Indicates whether survey was conducted over one contiguous area (PartNo = 1) or more than one area (PartNo > 1)
SequenceNo: Number indicating the order of survey lines in an individual survey or the order of segments forming the boundary of a survey
LatDec: Decimal latitude of survey line start or survey boundary segment
LongDec: Decimal longitude of survey line start or survey boundary segment
Description: Wider classification for “Type” used for sorting purposes.

MINERAL POTENTIAL TRACT MAPS (21 MAPS)

Organisation: Bureau of Resource Sciences

Abstract: The GIS coverage/database represents mineral potential tracts of individual deposit types

Contents:

Citation Information
Dataset Description
Spatial Domain (including Attribute List)
Dataset Currency and Status
Dataset Storage and Format
Dataset Quality

Citation Information

Data Set Title: South-West Forest Mineral Potential Maps
Data Set Short Title:
Custodian: Bureau of Resource Sciences
Publication Date: September 1997
Acknowledgments:
References:

Dataset Description

Abstract: Mineral Potential Tract Maps are drawn based on the four geology layers: Precambrian, Permian, Mesozoic–Early Tertiary, and Regolith. It also uses separate layers containing dolerite and pegmatite dykes, veins, faults and lineaments. WAMEX, MINEDEX and WAMIN databases are also used to delineate tract maps. The tract maps are created in ARC/INFO by the Geological Survey of Western Australia and the Bureau of Resource Sciences. Delineation of tracts and the assessment of mineral potential is carried out by following the methodology of qualitative assessments developed by the United States Geological Survey. For description of methodology see the report. Description of deposit models, assessment criteria and brief description of tracts are included in the report.
Search Words: Mineral potential
Location Description: South-West Forest area, Western Australia

Spatial Domain

Bounding Co-ordinates: 114.0, -35.25, 118.0, -31.0
Bounding Polygon:
Attribute List: see attached list

Data Currency and Status

Beginning Date: 1997
Ending Date: 1997
Progress:
Maintenance and Update Frequency: Irregular
Metadata Reviewed:

Dataset Storage and Format

Stored Data Format: Digital — dbf, dxf
Output Data Format: Digital — ASCII, ArcInfo
Native Data Format: Digital — polygons, lines, points, text
Access Constraints:

Dataset Quality

Determined by that of primary datasets such as geology, WAMIN, MINEDEX, WAMEX
Lineage Summary:
Scale: 1:250,000
Resolution:
Cell Size:
Positional Accuracy:
Attribute Accuracy:
Logical Consistency:
Completeness:
Additional Information:
Attribute List: See attached listing

Attribute List

NAME_POT: Numerical symbol are used to represent levels of potential: High = 18; Moderate to high = 12; Moderate = 6; Low to moderate = 2; Low = 1
CERTAINTY: Expressed by symbols (in the increasing order of certainty) A, B, C, D. For details see the report.

COMPOSITE MINERAL POTENTIAL MAP

Organisation: Bureau of Resource Sciences

Abstract: The GIS coverage/database represents composite mineral potential map for the South-West Forests CRA

Contents:

Citation Information
Dataset Description
Spatial Domain (including Attribute List)
Dataset Currency and Status
Dataset Storage and Format
Dataset Quality

Citation Information

Data Set Title: South-West Forest Composite Mineral Potential Map
Data Set Short Title: Composite Mineral Potential Map
Custodian: Bureau of Resource Sciences
Publication Date: September 1997
Acknowledgments:
References:

Dataset Description

Abstract: Composite Mineral Potential Map is a collation of mineral potential tracts of individual deposit types. The map is created by using Spatial Analyst of Arc View 3. It represents the highest level of mineral potential assessed (in September 1997) for any specific area in the South-West Forests CRA region.
Search Words: Composite Mineral potential
Location Description: South-West Forest area, Western Australia

Spatial Domain

Bounding Co-ordinates: 114.0, -35.25, 118.0, -31.0
Bounding Polygon:
Attribute List: see attached list

Data Currency and Status

Beginning Date: 1997
Ending Date: 1997
Progress:
Maintenance and Update Frequency: Irregular
Metadata Reviewed:

Dataset Storage and Format

Stored Data Format: Digital — dbf, dxf
Output Data Format: Digital — ASCII, ArcInfo
Native Data Format: Digital — polygons, lines, points, text
Access Constraints:

Dataset Quality

Determined by that of primary datasets such as geology, WAMIN, MINEDEX, WAMEX
Lineage Summary:
Scale: 1:250,000
Resolution:
Cell Size: 250x250 metres
Positional Accuracy:
Attribute Accuracy:
Logical Consistency:
Completeness:
Additional Information:
Attribute List: See attached listing

Attribute List

GRID-CODE: Integer representing levels of mineral potential for the cell.

CUMULATIVE MINERAL POTENTIAL MAP

Organisation: Bureau of Resource Sciences

Abstract: The GIS coverage/database represents cumulative mineral potential map for the South-West Forests CRA

Contents:

Citation Information
Dataset Description
Spatial Domain (including Attribute List)
Dataset Currency and Status
Dataset Storage and Format
Dataset Quality

Citation Information

Data Set Title: South-West Forest Cumulative Mineral Potential Map
Data Set Short Title: Cumulative Mineral Potential Map
Custodian: Bureau of Resource Sciences
Publication Date: September 1997
Acknowledgments:
References:

Dataset Description

Abstract: Cumulative Mineral Potential Map is a collation of mineral potential (assessed in September 1997) tracts of individual deposit types. The map is created by using Spatial Analyst of Arc View 3. It takes into account the diversity of mineral potential in an area. Standard scores representing levels of mineral potential are added for overlapping areas to derive cumulative scores. Areas with high cumulative scores indicate potential for more that one deposit type.
Search Words: Cumulative Mineral potential
Location Description: South-West Forest area, Western Australia

Spatial Domain

Bounding Co-ordinates: 114.0, -35.25, 118.0, -31.0
Bounding Polygon:
Attribute List: see attached list

Data Currency and Status

Beginning Date: 1997
Ending Date: 1997
Progress:
Maintenance and Update Frequency: Irregular
Metadata Reviewed:

Dataset Storage and Format

Stored Data Format: Digital — dbf, dxf
Output Data Format: Digital — ASCII, ArcInfo
Native Data Format: Digital — polygons, lines, points, text
Access Constraints:

Dataset Quality

Determined by that of primary datasets such as geology, WAMIN, MINEDEX, WAMEX
Lineage Summary:
Scale: 1:250,000
Resolution:
Cell Size: 250x250 metres
Positional Accuracy:
Attribute Accuracy:
Logical Consistency:
Completeness:
Additional Information:
Attribute List: See attached listing

Attribute List

GRID-CODE: Integer representing levels of mineral potential for the cell.

WEIGHTED COMPOSITE MINERAL POTENTIAL MAP

Organisation: Bureau of Resource Sciences

Abstract: The GIS coverage/database represents weighted composite mineral potential map for the South-West Forests CRA

Contents:

Citation Information
Dataset Description
Spatial Domain (including Attribute List)
Dataset Currency and Status
Dataset Storage and Format
Dataset Quality

Citation Information

Data Set Title: South-West Forest Weighted Composite Mineral Potential Map
Data Set Short Title: Weighted Composite Mineral Potential Map
Custodian: Bureau of Resource Sciences
Publication Date: September 1997
Acknowledgments:
References:

Dataset Description

Abstract: Weighted Composite Mineral Potential Map is a collation of mineral potential tracts of individual deposit types. The map is created by using Spatial Analyst of Arc View 3. It represents the highest weighted level of mineral potential assessed (in September 1997) for any specific area in the South-West Forests CRA region. Each deposit type is assigned a weighting (score) on a scale of 1 to 10 by a panel of experts. The weighting reflects the relative importance of deposit type. For the weightings of individual deposit type see the report.

Search Words: Weighted Composite Mineral potential
Location Description: South-West Forest area, Western Australia

Spatial Domain

Bounding Co-ordinates: 114.0, -35.25, 118.0, -31.0
Bounding Polygon:
Attribute List: see attached list

Data Currency and Status

Beginning Date: 1997
Ending Date: 1997
Progress:
Maintenance and Update Frequency: Irregular
Metadata Reviewed:

Dataset Storage and Format

Stored Data Format: Digital — dbf, dxf
Output Data Format: Digital — ASCII, ArcInfo
Native Data Format: Digital — polygons, lines, points, text
Access Constraints:

Dataset Quality

Determined by that of primary datasets such as geology, WAMIN, MINEDEX, WAMEX
Lineage Summary:
Scale: 1:250,000
Resolution:
Cell Size: 250x250 metres
Positional Accuracy:
Attribute Accuracy:
Logical Consistency:
Completeness:
Additional Information:
Attribute List: See attached listing

Attribute List

GRID-CODE: Integer representing levels of mineral potential for the cell.

WEIGHTED CUMULATIVE MINERAL POTENTIAL MAP

Organisation: Bureau of Resource Sciences

Abstract: The GIS coverage/database represents weighted cumulative mineral potential map for the South-West Forests CRA

Contents:

Citation Information
Dataset Description
Spatial Domain (including Attribute List)
Dataset Currency and Status
Dataset Storage and Format
Dataset Quality

Citation Information

Data Set Title: South-West Forest Weighted Cumulative Mineral Potential Map
Data Set Short Title: Weighted Cumulative Mineral Potential Map
Custodian: Bureau of Resource Sciences
Publication Date: September 1997
Acknowledgments:
References:

Dataset Description

Abstract: Weighted Cumulative Mineral Potential Map is a collation of mineral potential (assessed in September 1997) tracts of individual deposit types. The map is created by using Spatial Analyst of Arc View 3. It takes into account the diversity of mineral potential in an area. The weighted cumulative mineral potential is similar to the weighted composite mineral potential in that the score for each tract is calculated by multiplying the deposit weighting by the mineral potential score. Where there is overlap of tracts, the scores of the overlapping tracts are summed and this total score is assigned to the overlap area.
Search Words: Weighted Cumulative Mineral potential
Location Description: South-West Forest area, Western Australia

Spatial Domain

Bounding Co-ordinates: 114.0, -35.25, 118.0, -31.0
Bounding Polygon:
Attribute List: see attached list

Data Currency and Status

Beginning Date: 1997
Ending Date: 1997
Progress:
Maintenance and Update Frequency: Irregular
Metadata Reviewed:

Dataset Storage and Format

Stored Data Format: Digital — dbf, dxf
Output Data Format: Digital — ASCII, ArcInfo
Native Data Format: Digital — polygons, lines, points, text
Access Constraints:

Dataset Quality

Determined by that of primary datasets such as geology, WAMIN, MINEDEX, WAMEX
Lineage Summary:
Scale: 1:250,000
Resolution:
Cell Size: 250x250 metres
Positional Accuracy:
Attribute Accuracy:
Logical Consistency:
Completeness:
Additional Information:
Attribute List: See attached listing

Attribute List

GRID-CODE: Integer representing levels of mineral potential for the cell.

APPENDIX D: LIST OF MINERAL OCCURRENCES, DEPOSITS, AND MINES

DEPOSIT/ OCCURRENCE	EAST (AMG)	NORTH (AMG)	MINERAL DEPOSIT/OCCURRENCE NAMES	COMMODITY STRING
1	411000	6558000	WANNAMAL-MOGUMBER	IM
2	419500	6555200	WANNAMAL	Bx
3	420000	6546000	LITTLE JIMPERDING HILL - BINDOON	Bx
4	406460	6545400	MUCHEA - WANDENA RD 2 & 3 / MIDLAND	CLAYS
5	422100	6540400	LITTLE JIMPERDING HILL	Bx
6	406460	6538600	MUCHEA - WANDENA RD 1 / MIDLAND	CLAYS
7	437450	6535000	J 64	V
8	417996	6533584	WANNAMAL - CHITTERING GENERAL	Bx
9	423600	6531600	CHITTERING EAST - DEWARS POOL RD / HAYDEN	CONSTRUCTION MATERIALS
10	408490	6530000	CHITTERING EAST - MINGHA RD / MARTIN	CONSTRUCTION MATERIALS
11	408250	6527200	CHITTERING - GRAY RD / HAYDEN	CONSTRUCTION MATERIALS
12	420000	6526000	RED HILL-SOUTH BINDOON	Bx
13	412838	6523918	CHITTERING GOLD	Au
14	410500	6519800	CHITTERING SOUTH - GT EASTERN HWY / PATTERSON	CONSTRUCTION MATERIALS
15	414500	6518278	CHITTERING	Bx
16	412300	6516500	BURROLOO	Bx
17	420000	6516000	JULIMAR	Bx
18	412916	6514607	CHITTERING VALLEY	Mo
19	419000	6514000	JULIMAR WEST	Bx
20	414610	6511817	UNNAMED	Au
21	435700	6511500	MUNNAPIN BROOK/JULIMAR EAST	Bx
22	406712	6509598	MUCHEA EAST - GREAT NORTHERN HIGHWAY / METRO	CLAYS
23	416425	6508510	MUCHEA EAST - CHITTERING VALLEY RD / HARDING	CONSTRUCTION MATERIALS
24	409602	6507744	MUCHEA EAST - HORSELY RD / READ	CONSTRUCTION MATERIALS
25	414392	6507181	UNNAMED	STAUR
26	431797	6506312	COBBLER POOL	CONSTRUCTION MATERIALS
27	420382	6504937	MUCHEA / MPBC GROUP	Bx
28	406605	6501328	UNNAMED	RUT
29	407247	6499964	BULLSBROOK / WSL	HEAVY MINERAL SANDS
30	407415	6498889	BULLSBROOK - CHEQUERS GOLF COURSE	HEAVY MINERAL SANDS
31	408098	6498986	BULLSBROOK - MORRISSEY RD / FALCONER	CONSTRUCTION MATERIALS
32	408089	6500002	BULLSBROOK - MORRISSEY RD / AMATO	CONSTRUCTION MATERIALS
33	409854	6500141	BULLSBROOK - JENKINS RD / MORRISSEY	CONSTRUCTION MATERIALS
34	409655	6501740	BULLSBROOK - JENKINS RD / CONGIU	CONSTRUCTION MATERIALS
35	409832	6502604	BULLSBROOK - JENKINS RD / QUARRY PARK	CONSTRUCTION MATERIALS
36	411489	6502987	CHITTERING RD - BOWGALE WEST	CLAYS
37	412864	6502383	CHITTERING RD - MCNAMARAS	CLAYS
38	413501	6501803	CHITTERING RD - BOWGALE EAST	CLAYS
39	412745	6500905	BULLSBROOK - CHITTERING RD / MIDLAND GROUP	CLAYS
40	413000	6500800	COCKMAN BLUFF	Bx
41	419200	6501500	LOWER CHITTERING	Bx
42	417157	6499633	UNNAMED	CN
43	436204	6503600	MORGANUP RD OLD / METRO	CLAYS
44	436635	6502063	MORANGUP RD - COOKS / METRO	CLAYS
45	438070	6504320	MORANGUP ROAD	CY
DEPOSIT/ OCCURRENCE	**EAST (AMG)**	**NORTH (AMG)**	**MINERAL DEPOSIT/OCCURRENCE NAMES**	**COMMODITY STRING**

46	438338	6503705	JIMPERDING	Mo
47	438642	6503673	UNNAMED	Au
48	438053	6502811	MORANGUP RD - ENGLANDS	CLAYS
49	438499	6502443	JIMPERDING	Au
50	442398	6503451	TOODYAY	QT
51	445500	6503300	TOODYAY RD / DASBOROUGH	CONSTRUCTION MATERIALS
52	447270	6504400	SANDPLAIN RD / VERNICE	CONSTRUCTION MATERIALS
53	447501	6503900	TOODYAY ZANINOVICH	SILICA - SILICA SAND
54	446200	6499500	SALT VALLEY RD / PERTH ROCK	DIMENSION STONE
55	446192	6498454	SALT VALLEY RD - HOUSE	CLAYS
56	447988	6497507	SALT VALLEY RD / METRO	CLAYS
57	452469	6497887	NANAMOOLIN	CK
58	450700	6497300	CLACKLINE RD / ATLAS	CONSTRUCTION MATERIALS
59	450311	6496257	CHITTY RD - WILLIAMSONS/ METRO	CLAYS
60	449706	6496007	CHITTY RD - WILLIAMSONS OLD / METRO	CLAYS
61	448448	6494863	CHITTY RD - MASLENS / METRO	CLAYS
62	450341	6495364	CHITTY RD - J&F WHITE / METRO	CLAYS
63	451845	6495003	CHITTY RD - J&F RED / METRO	CLAYS
64	446002	6494389	CHITTY RD / IB & T	CLAYS
65	446989	6491992	WUNDOWIE NORTHEAST	Bx
66	451300	6492700	CLACKLINE	Fe
67	452900	6492350	CLACKLINE	SIL
68	452468	6490975	CHITTY RD / CLACKLINE	CONSTRUCTION MATERIALS
69	432999	6492800	BAILUP	Bx
70	422700	6495000	SMITHS MILL HILL	Bx
71	409460	6495860	BULLSBROOK EAST - LOMBARDO	CLAYS
72	409881	6494335	BULLSBROOK EAST - NAMBAH	CONSTRUCTION MATERIALS
73	408900	6493250	BULLSBROOK SOUTH - DEVEREAUX	CLAYS
74	409652	6493088	BULLSBROOK SOUTH - MCLOUGHLIN	CLAYS
75	409170	6490959	BULLSBROOK SOUTH / IB & T	CLAYS
76	409355	6490837	BULLSBROOK SOUTH - GREAT NORTHERN HIGHWAY - PARNS	CLAYS
77	408537	6488181	UPPER SWAN - WALYUNGA	CONSTRUCTION MATERIALS
78	407842	6486389	UPPER SWAN - THOMSON AND REDWOOD/MIDLAND	CLAYS
79	407297	6485768	UPPER SWAN / PRESTIGE BRICK	CLAYS
80	407086	6485521	ELLENBROOK - RAILWAY PDE / METRO	CLAYS
81	407719	6485403	ELLENBROOK - ALMERIA / METRO	CLAYS
82	408644	6484950	UPPER SWAN / METRO BRICK	CLAYS
83	409483	6485265	ELLENBROOK - LEES / METRO	CLAYS
84	407940	6483760	UPPER SWAN - HALLETS / MIDLAND	CLAYS
85	422600	6492000	SMITHS MILL HILL	Bx
86	417010	6484927	GIDGEGANNUP - O BRIEN RD	CONSTRUCTION MATERIALS
87	422000	6486000	MUNDARING - WUNDOWIE GENERAL	Bx
88	428303	6487598	GIDGEGANNUP - BERRY RD	CONSTRUCTION MATERIALS
89	429400	6485000	TOODYAY RD / POGGIOLO	CONSTRUCTION MATERIALS
90	436605	6485344	WUNDOWIE	Au
91	442100	6486600	WUNDOWIE GRAVEL	CONSTRUCTION MATERIALS
92	444500	6488200	COATES	V
93	447896	6489593	WUNDOWIE	Bx
DEPOSIT/ OCCURRENCE	**EAST (AMG)**	**NORTH (AMG)**	**MINERAL DEPOSIT/OCCURRENCE NAMES**	**COMMODITY STRING**
94	448400	6490000	WUNDOWIE NORTH EAST	Bx

95	453400	6488400	CLACKLINE	Mica
96	460217	6488294	MOKINE	Mo
97	447497	6485004	BAKERS HILL - KWOLYININE HILL	Bx
98	443650	6481000	KWOLYININE HILL / BORGAS	CONSTRUCTION MATERIALS
99	427488	6481086	LILYDALE RD / SHIRE	CONSTRUCTION MATERIALS
100	423989	6483997	GIDGEGANNUP - RESERVE RD	CONSTRUCTION MATERIALS
101	423800	6482301	GIDGEGANNUP	Bx
102	423589	6481007	GIDGEGANNUP HILL	CLAYS
103	372477	6227513	DARRADUP - KRAUKLAS RD	CONSTRUCTION MATERIALS
104	414350	6478901	RED HILL NORTH / MIDLAND	CONSTRUCTION MATERIALS
105	414693	6478873	RED HILL - 136/7 / MIDLAND	CLAYS
106	414560	6478100	RED HILL NE - STONEWARE / MIDLAND	CLAYS
107	413652	6477572	RED HILL - 193 / MIDLAND	CLAYS
108	413950	6476950	RED HILL - BELLS / MIDLAND	CLAYS
109	414602	6477056	RED HILL WASTE FACILITY	CONSTRUCTION MATERIALS
110	411547	6477830	RED HILL / PIONEER	CONSTRUCTION MATERIALS
111	411745	6473848	ROCK OF AGES	Mo
112	416200	6468400	GLEN FORREST	CK
113	408800	6467337	HELENA VALLEY	CONSTRUCTION MATERIALS
114	419639	6468437	MAHOGANY CREEK	Mo
115	418990	6474013	PARKERVILLE	Bx
116	438100	6476300	BEECHINA	Bx
117	439093	6474059	THE LAKES	CONSTRUCTION MATERIALS
118	448251	6479200	INKPEN ROAD	Bx
119	455200	6476900	BERRYBROW	Bx
120	447000	6472000	EBENEZER FLATS	Bx
121	441089	6469636	CHIDLOW / TUMA	CONSTRUCTION MATERIALS
122	460000	6471280	YORK - WAMBYN	DIMENSION STONE
123	464400	6464200	MT OBSERVATION - MT TALBOT	Bx
124	443000	6462100	YETAR SPRING	Bx
125	439360	6456050	MT DALE PEGMATITE	Sn, Ta, Li
126	459799	6452300	MT GOONAPIN	Bx
127	408179	6454706	MADDINGTON - ORANGE GROVE / BORAL	CONSTRUCTION MATERIALS
128	411720	6454644	NEW VICTORIA DAM	CONSTRUCTION MATERIALS
129	420342	6452282	PICKERING BROOK	CONSTRUCTION MATERIALS
130	408499	6451199	BARRINGTON	CONSTRUCTION MATERIALS
131	417021	6447914	KARRAGULLEN / MARSH	CONSTRUCTION MATERIALS
132	410250	6442991	ARMADALE / BORAL	CLAYS
133	416729	6438889	CHURCHMAN	Bx
134	408700	6436700	SW HIGHWAY / WA LIMESTONE	CONSTRUCTION MATERIALS
135	409633	6435812	BYFORD - WUNGONG DAM	CLAYS
136	410700	6431400	NETTLETON RD / METRO	CLAYS
137	408332	6429147	BYFORD / PIONEER	CONSTRUCTION MATERIALS
138	410392	6429813	NETTLETON RD / SHIRE	CONSTRUCTION MATERIALS
139	413441	6430195	UNNAMED	Bx
140	415769	6430005	UNNAMED	Bx
141	412477	6429500	UNNAMED	Bx
142	413712	6429300	UNNAMED	Bx
DEPOSIT/ OCCURRENCE	**EAST (AMG)**	**NORTH (AMG)**	**MINERAL DEPOSIT/OCCURRENCE NAMES**	**COMMODITY STRING**
143	412758	6428816	JARRAHDALE ALCOA	Bx

144	412757	6428816	KALAMUNDA - DALE GENERAL	Bx
145	416502	6429146	UNNAMED	Bx
146	414682	6427102	UNNAMED	Bx
147	416535	6426219	UNNAMED	Bx
148	413177	6425465	JARRAHDALE / METRO	CLAYS
149	414088	6424979	UNNAMED	Bx
150	410733	6425394	UNNAMED	Bx
151	411842	6424494	UNNAMED	Bx
152	408615	6423202	UNNAMED	Au
153	413400	6420816	BALMORAL RD / SHIRE	CONSTRUCTION MATERIALS
154	408499	6416491	SCRIVENER RD / SHIRE	CONSTRUCTION MATERIALS
155	410657	6414817	KARNET	Bx
156	416973	6409328	CLINTON	Bx
157	422000	6409400	LANG	Bx
158	426150	6407644	MT SOLUS	Bx
159	427952	6407565	CAMERON	Bx
160	407607	6405550	MYARRA	Bx
161	409000	6405800	KEYSBROOK ROAD	Bx
162	416100	6405300	CLINTON SOUTH	Bx
163	419100	6405500	JARRAHDALE	PEG
164	412500	6403600	MYARRA SOUTH	Bx
165	420600	6404000	CLINTON EAST	Bx
166	412300	6400900	WILSON	Bx
167	418800	6402200	TORRENS	Bx
168	424861	6401999	O'NEIL	Bx
169	411088	6389676	UNNAMED	Bx
170	405934	6389150	DANDALUP / READYMIX	CONSTRUCTION MATERIALS
171	420800	6388600	SCOTT	Bx
172	407907	6387618	UNNAMED	Bx
173	408659	6385419	UNNAMED	Bx
174	409363	6384685	DEL PARK - HUNTLY	Bx
175	409363	6384686	DWELLINGUP - WAROONA GENERAL	Bx
176	418400	6385700	BANKSIADALE	Bx
177	441972	6384868	MT WELLS	Bx
178	438838	6381893	WATTLE	Au
179	427700	6381250	INGLEHOPE NORTHEAST	Bx
180	419364	6381631	HOLYOAKE	Bx
181	419900	6381400	HOLYOAKE EAST	Bx
182	410962	6380635	BOOBBEYER - DWELLINGUP	CONSTRUCTION MATERIALS
183	401991	6379411	MEELON	IM LCXN MZ RUT ZRCN
184	406215	6373230	COOLUP	IM LCXN MZ RUT ZRCN
185	410386	6372315	WAROONA	Bx
186	409200	6376800	TEESDALE	Bx
187	413344	6379085	HOLMES	Bx
188	421919	6377955	INGLEHOPE	Bx
189	417600	6376500	PLAVINS WEST	Bx
190	419862	6374829	PLAVINS	Bx
191	428662	6377728	PINDALUP	Bx
DEPOSIT/ OCCURRENCE	**EAST (AMG)**	**NORTH (AMG)**	**MINERAL DEPOSIT/OCCURRENCE NAMES**	**COMMODITY STRING**
192	428400	6376400	CHADOORA	Bx

193	437588	6378005	HEDGES	Au
194	439770	6377415	BODDINGTON	Au
195	427400	6373400	CURARA	Bx
196	430100	6373400	PINDALUP WEST	Bx
197	433100	6372400	WURAMING	Bx
198	436700	6372400	HOTHAM / ALCOA	Bx
199	441015	6370696	MT SADDLEBACK	Bx
200	421400	6370000	PLAVINS SOUTH	Bx
201	421504	6367851	YARRAGIL	Bx
202	426000	6370300	AMPHION	Bx
203	434473	6368808	BOMBALA	Bx
204	444900	6368100	MARRADONG / ALCOA	Bx
205	448010	6365993	MARRADONG	Bx
206	450509	6363165	UNNAMED	Au
207	399638	6367132	WAROONA NORTH - WALMSLEY	HEAVY MINERAL SANDS
208	398836	6361855	HAMEL - FERRARO	HEAVY MINERAL SANDS
209	399137	6360503	WAROONA SOUTH / CABLE	HEAVY MINERAL SANDS
210	407746	6356922	WAGERUP - HARVEY GENERAL	Bx
211	407746	6356922	WILLOWDALE	Bx
212	418300	6357600	MT KEATS	Bx
213	420700	6360000	NANGA BAUXITE	Bx
214	431404	6361396	TAREE	Bx
215	444200	6362000	BODDINGTON	Au
216	445580	6361720	BODDINGTON	Co
217	445800	6361000	BODDINGTON	Au
218	447959	6360625	UNNAMED	Bx
219	448997	6356021	SADDLEBACK - TUNNEL ROAD	Bx
220	448997	6356021	SADDLEBACK GROUP	Bx
221	449590	6354414	UNNAMED	Bx
222	448260	6351413	UNNAMED	Bx
223	449279	6347660	UNNAMED	Au
224	426833	6354033	HOWSE	Bx
225	416800	6351800	DRIVERS HILL	Bx
226	412794	6350161	HOFFMAN	Bx
227	420193	6350009	SPION KOP	Bx
228	398947	6351201	YARLOOP	HEAVY MINERAL SANDS
229	408200	6349000	LOGUE BROOK	Bx
230	409896	6346285	CLARKE HILL	Bx
231	400001	6344497	HARVEY RIDGE	Bx
232	412000	6345200	HOFFMAN SOUTH	Bx
233	419717	6344946	UNNAMED	Bx
234	408200	6341711	DINGO KNOB	Bx
235	415368	6340575	TOWER HILL	Bx
236	420600	6339400	TALLANALLA	Bx
237	425100	6342400	CHALK	Bx
238	426652	6341686	UNNAMED	Bx
239	431600	6342800	OPOSSUM SPRING	Bx
240	403012	6336489	THOMAS RD / METRO	CLAYS
DEPOSIT/ OCCURRENCE	**EAST (AMG)**	**NORTH (AMG)**	**MINERAL DEPOSIT/OCCURRENCE NAMES**	**COMMODITY STRING**
241	423000	6333600	ROSS	Bx

242	420400	6331800	TALLANALLA	V
243	407500	6328000	MORNINGTON RIDGE	Bx
244	407000	6320000	COLLIE - BALINGUP GENERAL	Bx
245	407006	6319987	WORSLEY / BRIDGE	Bx
246	397007	6316005	COLLIE ROAD	Bx
247	413018	6262071	MEANEYS BRIDGE	TC
248	402651	6310519	WELLINGTON DAM CATCHMENT	CONSTRUCTION MATERIALS
249	415523	6310824	ALLANSON	COAL
250	415100	6310200	BLACK DIAMOND	COAL
251	417800	6310000	WESTRALIA - COLLIE	COAL
252	412815	6255942	NEW ZEALAND GULLY / GREENBUSHES	Sn, Ta, Li
252	418800	6308500	COOPERATIVE	COAL
253	427000	6310500	EWINGTON 2	COAL
254	427297	6309287	EWINGTON 1	COAL
255	388742	6308060	DARDANUP / ISK	HEAVY MINERAL SANDS
256	419700	6305400	WYVERN	COAL
257	419800	6305000	GRIFFIN - COLLIE	COAL
258	419800	6305000	PHOENIX - COLLIE	COAL
259	422800	6308100	WALLSEND	COAL
260	423800	6307100	PROPRIETARY	COAL
261	428100	6305600	STOCKTON	COAL
262	429957	6305949	COLLIE / ELLERY GROUP	CONSTRUCTION MATERIALS
263	429956	6305951	SHOTTS ROAD - COLLIE	CONSTRUCTION MATERIALS
264	433500	6305500	COLLIE PREMIER SUB-BASIN	COAL
265	434500	6305800	WESTERN NO.1	COAL
266	433505	6304652	PREMIER / WCL	COAL
267	433499	6304000	COLLIE CARDIFF	COAL
268	425866	6303701	COLLIE BASIN OPEN CUTS GROUP	COAL
269	425866	6303701	COLLIE BASIN UNDERGROUND GROUP	COAL
270	426049	6303518	WESTERN NO.7	COAL
271	427142	6302325	WESTERN NO.2	COAL
272	431200	6302200	WESTERN NO.4	COAL
273	431818	6302236	WESTERN NO.3	COAL
274	436901	6303163	CHICKEN CREEK	COAL
275	435672	6301462	MUJA	COAL
276	436800	6300000	HEBE	COAL
277	437591	6300119	COLLIE - MUJA GROUP	COAL
278	438400	6299400	CENTAUR	COAL
279	429610	6300434	COLLIE / WESTERN GROUP	COAL
280	428350	6300300	CARDIFF	COAL
281	426750	6299500	CARDIFF - NEATH	COAL
282	428805	6297563	WESTERN NO.5	COAL
283	430716	6297360	WESTERN NO.6	COAL
284	387826	6302504	DARDANUP / WSL	HEAVY MINERAL SANDS
285	391109	6299380	IRONSTONE ROAD	Au
286	418178	6299419	MUNGALUP	Bx
287	425293	6299047	COLLIE	SIL
288	425293	6299047	COLLIE ROAD SOUTH	CONSTRUCTION MATERIALS
DEPOSIT/ OCCURRENCE	**EAST (AMG)**	**NORTH (AMG)**	**MINERAL DEPOSIT/OCCURRENCE NAMES**	**COMMODITY STRING**
289	427270	6297300	COLLIE	Pb

290	416800	6296800	MUNGALUP	Bx
291	402005	6293502	UNNAMED	UNSPECIFIED
292	391230	6295880	CROOKED BROOK	Au
293	398860	6292960	WATERFALL GULLY	Au
294	391317	6290560	UNNAMED	UNSPECIFIED
295	391252	6289694	UNNAMED	UNSPECIFIED
296	391209	6288621	DONNYBROOK	SS
297	402350	6286120	KATTERUP PEGMATITE	PEG
298	421172	6283266	UNNAMED	UNSPECIFIED
299	390120	6281500	BROOKMANS	Au
300	390175	6281300	QUEEN OF THE SOUTH	Au
301	390145	6281125	EMPRESS HELENA	Au
302	390320	6281100	ARC OF GOLD	Au
303	390485	6280865	DONNYBROOK	Au
304	390600	6280769	CAMMILERI'S	Au
305	373764	6196721	SCOTT COASTAL PLAIN - SOUTH COAST GENERAL	HEAVY MINERAL SANDS
306	390864	6280145	MT CARA	Au
307	390880	6279895	HUNTERS VENTURE	Au
308	391069	6279900	BULLINGTON	Au
309	377761	6281281	HAPPY VALLEY NORTH	HEAVY MINERAL SANDS
310	373584	6275557	HAPPY VALLEY CENTRAL	HEAVY MINERAL SANDS
311	392227	6278094	UNNAMED	Au
312	392640	6273550	MITCHELL	Au
313	437605	6274093	WILGA OPEN CUT	COAL
314	368475	6270375	HAPPY VALLEY SOUTH	HEAVY MINERAL SANDS
315	319251	6278700	MT DUCKWORTH	MNLSD
316	318413	6274148	TELFER EAST	HEAVY MINERAL SANDS
317	316400	6273001	SMITHS BEACH	HEAVY MINERAL SANDS
318	319151	6269600	PETTERD AND CROSS REEF	Au
319	314300	6269650	CAPE CLAIRAULT	HEAVY MINERAL SANDS
320	315453	6259300	WOODLANDS	HEAVY MINERAL SANDS
321	316839	6259450	WILYABRUP	DIMENSION STONE
322	324700	6264400	METRICUP	HEAVY MINERAL SANDS
323	333000	6250001	VASSE	COAL
324	333461	6253590	TREETON	COAL
325	341035	6268079	AMBERGATE WEST	HEAVY MINERAL SANDS
326	350892	6261767	ACTON PARK	IM LCXN MZ RUT ZRCN
327	353782	6262922	TUTUNUP EXTENDED	HEAVY MINERAL SANDS
328	346999	6256000	WHICHER	COAL
329	375700	6259800	JARRAWOOD	COAL
330	392700	6268100	KIRUP PEGMATITE	PEG
331	394050	6268199	MINE HILL	Au
332	400750	6268089	MULLALYUP	INDUSTRIAL PEGMATITE MINERALS
333	400750	6268089	MULLALYUP PEGMATITE C	PEG
334	400749	6268420	MULLALYUP PEGMATITE B	PEG
335	405000	6270500	KIRUP EAST A	CK
336	406300	6269499	KIRUP EAST B	CK
337	406339	6270214	UNNAMED	MNLSD
DEPOSIT/ OCCURRENCE	**EAST (AMG)**	**NORTH (AMG)**	**MINERAL DEPOSIT/OCCURRENCE NAMES**	**COMMODITY STRING**
338	401170	6264641	MULLALYUP PEGMATITE D	PEG

339	401256	6265260	MULLALYUP PEGMATITE A	PEG
340	388760	6311139	BUREKUP / WSL	HEAVY MINERAL SANDS
341	430536	6265297	BOYUP	COAL
342	430524	6262809	BOYUP BASIN / GRIFFIN	COAL
343	455353	6256731	UNNAMED	Au
344	412645	6257699	UNNAMED	FEST
345	401071	6257164	FERNDALE	UNSPECIFIED
346	392344	6252252	DUDINYILLUP - NANNUP	CONSTRUCTION MATERIALS
347	399894	6251186	SOUTHAMPTON	UNSPECIFIED
348	397540	6242860	MANJIMUP C	Bx
349	407981	6254716	UNNAMED	Sn
350	411702	6256826	WHITE WELL - GREENBUSHES	Sn, Ta, Li
351	412151	6256042	UNNAMED	Sn
353	413433	6255544	UNNAMED	Sn
354	412138	6255443	UNNAMED	Sn
355	411334	6255291	UNNAMED	Sn
356	411310	6254697	BISHOPS	CLAYS
357	413129	6254354	UNNAMED	Sn
358	411253	6254104	UNNAMED	Sn
359	415324	6254302	SALT WATER GULLY	CLAYS
360	414872	6253915	UNNAMED	Sn
361	414206	6253876	UNNAMED	Sn
362	413143	6253811	UNNAMED	Ta
363	412132	6253059	UNNAMED	Sn
364	413511	6253071	GREENBUSHES PEGMATITE	PEG
365	414205	6252936	FOXES NORTH	Sn, Ta, Li
366	413615	6252840	NEW ENTERPRISE NORTH	Sn, Ta, Li
367	414284	6252599	FOXES LODE - KAPANGA	Sn, Ta, Li
368	413823	6252534	NEW ENTERPRISE	Sn, Ta, Li
369	413942	6252443	UNNAMED	Sn
370	415088	6252531	WAGEBADENUP	Sn
371	412076	6252171	UNNAMED	Sn
372	412851	6251970	GREENBUSHES ALLUVIAL GROUP	Sn, Ta
373	414061	6251827	WESTERN QUEEN - GREENBUSHES	Sn, Ta, Li
374	415216	6251734	UNNAMED	Sn
375	414422	6251472	UNNAMED	Sn
376	412456	6251110	UNNAMED	Sn
377	414248	6250273	UNNAMED	Sn
378	332316	6236870	UPPER CHAPMAN	HEAVY MINERAL SANDS
379	328400	6234500	BOODGIDUP BROOK	Au
380	328501	6234200	WITCHCLIFFE	MNLSD
381	315420	6232300	REDGATE	HEAVY MINERAL SANDS
382	327124	6233108	BLACKWOOD PLATEAU - LOWER SOUTHWEST GENERAL	HEAVY MINERAL SANDS
383	332100	6231200	CHAPMAN BROOK	Au
384	337200	6225500	WITCHCLIFFE	COAL
385	336200	6222001	ALEXANDRA BRIDGE	HEAVY MINERAL SANDS
386	328504	6219296	KARRIDALE WEST	HEAVY MINERAL SANDS
387	329160	6219500	BULLANT	HEAVY MINERAL SANDS
DEPOSIT/ OCCURRENCE	**EAST (AMG)**	**NORTH (AMG)**	**MINERAL DEPOSIT/OCCURRENCE NAMES**	**COMMODITY STRING**
388	335850	6219800	BLACKWOOD	COAL

389	334800	6216300	WARNER GLEN	HEAVY MINERAL SANDS
390	333200	6214200	GLENARTY CREEK	HEAVY MINERAL SANDS
391	340000	6210000	BEENUP	HEAVY MINERAL SANDS
392	330550	6206640	LION ISLAND	MNLSD
393	336500	6205500	BEENUP - LOCATION E AND NATIONAL PARK	HM
394	332000	6202199	SWAN LAKE	HEAVY MINERAL SANDS
395	328803	6199300	FLINDERS BAY	HEAVY MINERAL SANDS
396	334000	6202500	SWAN LAKE - LOCATION E	MNLSD
397	336900	6202400	LEDGE POINT	HEAVY MINERAL SANDS
398	343000	6202550	BULLRUSH SWAMP	HEAVY MINERAL SANDS
399	343000	6209000	SCOTT RIVER	Fe
400	347500	6207000	SCOTT RIVER/CABLE	HEAVY MINERAL SANDS
401	345500	6203000	BULLRUSH SWAMP	HM
402	353250	6210200	SCOTT RIVER/KINGSGATE	HEAVY MINERAL SANDS
403	350530	6208730	SCOTT RIVER / KINGSGATE	HEAVY MINERAL SANDS
404	354291	6203431	MINYEAANUP SHORELINE	IM LCXN RUT XENO ZRCN
405	359662	6213620	BROCKMAN - SCOTT RIVER	HEAVY MINERAL SANDS
406	362324	6210178	KOOKABURRA ROAD	CONSTRUCTION MATERIALS
407	360790	6201001	WOODARBURRUP	HEAVY MINERAL SANDS
408	369000	6202340	FOURACRES	HEAVY MINERAL SANDS
409	367500	6191972	BOLGAMUP	HEAVY MINERAL SANDS
410	390900	6280660	THE WILD WAVE	Au
411	376400	6192500	JANGARDUP SOUTH	HEAVY MINERAL SANDS
412	416500	6482000	BRIGADOON-BELLS	Bx
413	379505	6237249	NANNUP SW GROUP	CONSTRUCTION MATERIALS
414	379500	6237250	RIVER ROAD - NANNUP	CONSTRUCTION MATERIALS
415	394020	6234399	MANJIMUP D	Bx
416	386850	6233299	MAJENUP	Au
417	403270	6231040	WILLOW SPRINGS	Sn
418	422372	6234766	GLEN LYNN SIDING	TC
419	431350	6235000	YORNUP NORTHEAST	Cr
420	408698	6231180	UNNAMED	Sn
421	408300	6231000	DONOVANS FIND - SMITHFIELD	Sn, Ta, Li
422	408261	6231000	SMITHFIELD ALLUVIAL	Sn
423	408258	6230900	SMITHFIELD PEGMATITE	PEG
424	408590	6229730	NATIVE DOG GULLY ALLUVIALS	Sn
425	408590	6229730	NATIVE DOG GULLY PEGMATITE	PEG
426	409767	6228529	ROSS'S SWAMP	KY
427	403680	6228110	MANJIMUP E	Bx
428	409940	6225430	DONNELLY RIVER	KY
429	421910	6227500	MANJIMUP B	Bx
430	424660	6227759	YORNUP SOUTH	Ni
431	424600	6223200	YORNUP SOUTH	Cr
432	420820	6221839	PALGARUP	Ni
434	406254	6222211	YANMAH	Au
435	407080	6221749	MANJIMUP BROOK	KY
436	392460	6218240	MANJIMUP F	Bx
437	400529	6212910	UNNAMED	Gt
DEPOSIT/ OCCURRENCE	**EAST (AMG)**	**NORTH (AMG)**	**MINERAL DEPOSIT/OCCURRENCE NAMES**	**COMMODITY STRING**
438	405509	6212840	DONNELLY RIVER	Gt

439	413345	6212156	MANJIMUP	Bx
440	420800	6215400	MANJIMUP	DIMENSION STONE
441	386263	6205683	UNNAMED	COAL
442	389600	6200000	NANNUP SOUTH	PGE
443	410345	6222250	MANJIMUP A	Bx
443	390917	6194182	UNNAMED	Gt
444	395922	6187352	CALLCUP HILL	MNLSD
445	396600	6185800	FLY BROOK	COAL
446	420247	6200567	MANJIMUP	MNLSD
447	420532	6167300	NORTHCLIFFE	MNLSD
448	425073	6167992	UNNAMED	HM
449	409701	6145321	POINT D'ENTRECASTEAUX	LST
450	467385	6189448	COWERUP SWAMP	PEAT
451	490200	6182200	FURNISS	Gt
452	549900	6188200	MARTIGALLUP	Gt
453	556053	6153358	ALBANY/WSL	SIL
454	555999	6144200	REDMOND	Au
455	517000	6129000	DENMARK/CABLE	HEAVY MINERAL SANDS
456	518254	6128810	PARRY INLET	MNLSD
457	476245	6127800	UNNAMED	COAL

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GLOSSARY

Archaean: period of geological time greater than 2500 million years ago
Available Al_2O_3: amount of alumina which can be readily extracted from bauxite using a modified Bayer process.
Banded iron-formation: a finely banded sedimentary rock composed of alternating layers of iron-rich minerals and chert or fine-grained quartz formed by precipitation from solution (e.g. the iron ores in the Hamersley Range).
BIF: an abbreviation for banded iron-formation (see above).
Cretaceous: period of geological time between 144 and 65 million years ago.
Fault: fracture along which there has been movement.
Felsic: composed chiefly of light-coloured minerals (feldspar and quartz).
Fluvial: produced by action of a stream or river.
Fluvioglacial: produced by meltwater streams flowing from glacial ice.
Gneiss: a layered metamorphic rock in which bands of granular minerals alternate with bands of flaky or elongate prismatic minerals.
Graben: trough bounded by faults.
Granite: a medium to coarse grained igneous intrusive rock consisting principally of quartz and feldspar.
Granofels: an even-grained metamorphic rock.
Greenstone: dark green, altered or metamorphosed mafic igneous rock.
Greenstone belt: areas of the earth dominated by greenstones and with minor felsic volcanics and metasedimentary rocks.
Igneous: formed from or related to molten material (magma).
Jurassic: period of geological time between 205 and 144 million years ago.
Lacustrine: produced in a lake.
Ma: million years ago
Mafic rock: igneous rock composed chiefly of dark-coloured iron and magnesium-rich minerals.
Orogen: a region that has been subjected to intense folding and other deformation.
Orthogneiss: gneiss formed by metamorphism of an igneous rock.
Paragneiss: gneiss formed by metamorphism of a sedimentary rock.
Pegmatite: an exceptionally coarse-grained igneous rock usually found as irregular dykes, lenses or veins.
Permian: period of geological time between 297 and 253 million years ago.
Phanerozoic: period of geological time younger than the Precambrian (ie. younger than 545 million years ago).
Pleistocene: period of geological time between approximately 2 million years ago and 8 000 years ago.
Precambrian: period of geological time older than 545 million years ago.
Proterozoic: period of geological time between 2500 and 545 million years ago.
Schist: a strongly layered metamorphic rock that can be readily split into thin flakes or slabs.
Synorogenic: occurring at the same time as intense folding and other deformation
Synvolcanic: occurring at the same time as volcanism
Tectonic: structural or deformational
Tertiary: period of geological time between 65 Ma and approximately 2 million years ago.
Triassic: period of geological time between 253 and 205 million years ago.
Ultramafic rock: igneous rock containing more than 90 % iron and magnesium-rich minerals.