NSW WESTERN REGIONAL ASSESSMENTS

**Nandewar**

# Mineral and Petroleum Resources and Potential

**FINAL**
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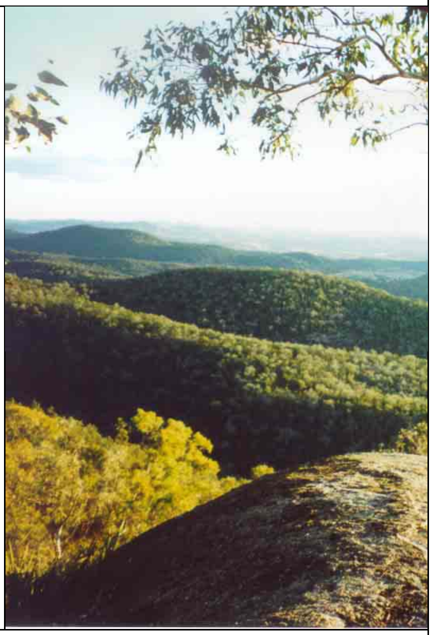
RESOURCE AND CONSERVATION ASSESSMENT COUNCIL

NSW WESTERN REGIONAL ASSESSMENTS

## Nandewar

# MINERAL AND PETROLEUM RESOURCES AND POTENTIAL

*Roger McEvilly, Kirstine Malloch, John Watkins,Victor Tadros, Leslie Wiles, Julie Moloney, Ricky Mantaring*



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## INFORMATION



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# Preface and Acknowledgments

The Mineral and Petroleum Resources and Potential project has been funded by the Resource and Conservation Assessment Council and the Department of Mineral Resources, and managed by the Resource and Conservation Division, Department of Infrastructure, Planning and Natural Resources. The project was completed under the technical direction of the Geological Survey of New South Wales, a division of the New South Wales Department of Mineral Resources (DMR).

This project required analysis and integration of a large amount of both existing and newly acquired data and information, within a complex and extremely varied geological province. For this reason, many staff members provided input at various times to the report. The final product includes contributions made by many people over the short length of time that was available to complete the project.

The project was managed through the Strategic Assessments Sub-program headed by John Watkins as Manager. Roger McEvilly, Acting Senior Geologist, Strategic Assessments, and Kirstine Malloch, Geologist, Strategic Assessments, were the technical supervisors and compilers for the metallic and industrial mineral sections of the report. Technical supervision and compilation of the coal sections of the report was under the direction of Julie Moloney, Principal Geologist, Leslie Wiles, Geologist, and Dr Victor Tadros, Acting Principal Geologist. Ricky Mantaring, Senior Geologist, Coal and Petroleum were responsible for the technical supervision and compilation of the petroleum and coal seam methane sections of the report. Ross Spencer, Geophysicist, prepared the geophysical data sets and Llew Cain, GIS Geologist was responsible for the compilation and management of the figures, databases, and GIS analysis. Nancy Vickery, Geologist, and Mark Dawson, Geologist, compiled the geological section of the report. John Watkins and Kirstine Malloch edited the report.

Other staff members who were directly involved with the Nandewar mineral potential project include:

- Dave Suppel, Peter Downes, Lindsay Gilligan, Greg MacRae, Iain Paterson and John Chapman (Head Office).
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# Project Summary

**This report describes a project undertaken for the Resource and Conservation Assessment Council as part of the regional assessments of western New South Wales. The Resource and Conservation Assessment Council advises the State Government on broad-based land use planning and allocation issues. An essential process for the Western Regional Assessments is to identify gaps in data information and the best ways in which to proceed with data gathering and evaluation. The resources, maps, figures and data sets assembled will assist the development of a whole-of-Government approach to land use and natural resource management for the Nandewar study area.**

## Project objective

The Mineral and Petroleum Resources and Potential project for the Nandewar study area was completed by the Geological Survey of New South Wales division of the New South Wales Department of Mineral Resources. The objective of the project is to provide an up-to-date assessment of the mineral and petroleum resources and potential of the Nandewar study area to guide and assist land use planning and natural resource management.

## Methodology

The project was conducted largely as an analytical and interpretive review integrated with new information gained through the ‘Geology – Integration and Upgrade’ mapping project. The project used the best available expert advice to assess mineral and petroleum resource potential together with open-file exploration industry data.

The assessment required the assembly and integration of large amounts of data and information, and its critical assessment through a number of established resource assessment procedures.

## Key results and products

Mining and exploration have made a major contribution to the economy of the Nandewar study area. Many of the towns and settlements have origins related to past mining. Mining of a wide range of commodities continues throughout the area and provides many of the raw materials used in the construction, agriculture and the gemstone industry.

The area has a long history of gold, tin, sapphire, diamond, coal, asbestos, diatomite and limestone mining. The historic production value for various mineral commodities in the Nandewar study area from 1852 (the time of the first gold rush in the area) to 2003 is approximately $2.24 billion. The average annual value of recent production from the Nandewar study area is approximately $15.8 million of which $13.6 million was derived from industrial minerals (limestone, sapphire, diatomite, zeolite, diamond, serpentinite, rhodonite, jade) and $2.2 million was from construction materials.

From 1964 to 2003, exploration has mainly focused on gold, diamond, limestone, sapphire, coal, molybdenum, tungsten, copper, diatomite, magnesium, and kaolin. Potentially significant new projects include magnesium processed from tailings at the former Woodsreef Asbestos Mine, and coal near Murrurundi, Werris Creek and Ashford. Annual exploration expenditure within the Nandewar study area has averaged about A$2 million (2003) over the last ten years.

The results of the resource potential analysis are set out in Chapter 7 (Resource Potential) where the occurrence, distribution and potential of 23 deposit styles within the Nandewar study area is discussed. The commodities are grouped into the following categories:

- coal and petroleum
- industrial minerals and construction materials
- metallic mineral

Tract maps for each of the 23 deposit sytles have been combined in **Figures 7-DD** and **7-EE** (Weighted Composite and Cumulative Mineral and Petroleum Potential). The weighted mineral potential data indicates that areas of highest potential are scattered widely in the Nandewar study area. They include:

- the Ashford, Werris Creek and Murrurundi areas (coal)
- the Nandewar Range area (petroleum and coal seam methane)
- the Barraba area (diatomite, magnesium and gold)
- the Attunga area (base and precious metals and limestone)
- the Werris Creek area (zeolite, gold and silver)
- the Bingara area (gold and diamond)
- the Inverell area (diamond, tin, sapphire and kaolin)
- construction materials adjacent to major roads
- gold in a narrow elongated zone through the middle of the Nandewar study area

# Acronyms and Abbreviations

a.d.: air dried basis

Ag: silver

As: arsenic

Au: gold

B: boron

Ba: barium

bcm: bench cubic metres

Be: beryllium

Bi: bismuth

Ca: calcium

CaO: calcium oxide

Cl: chlorine

CM: metric carat

Co: cobalt

CO2: carbon dioxide

Cr: chromium

Cs: cesium

CSM: coal seam methane

cts: carats

Cu: copper

DMR: Department of Mineral Resources

F: flourine

FeO: iron oxide

g: gram

H: mercury

Hf: hafnium

HGI: hardgrove grindability index

HMS: heavy mineral sands

K: potassium

K-Ar: Potassium -Argon dating

kcals: kilocalories

La: lanthanum

Li: lithium

m3: cubic metres

Ma: Million years ago

mD: milli darcies

Mg: magnesium

MgO: magnesium oxide

MJ/kg: million joules/kilogram

mm: millimetre

Mn: manganese

Mo: molybdenum

Mt: million tonnes

Na: sodium

Nb: niobium

Ni: nickel

NPWS: National Parks and Wildlife Service

oz: ounce

P: phosphorous

Pb: lead

PGE: platinum group elements

PGM: platinum group minerals

ppm: parts per million

RACAC: Resource and Conservation Assessment Council

RACD: Resource and Conservation Division

Rb: rubidium

REE: Rare Earth Elements

Ro: vitrinite reflectance

ROM: run of mine

S: sulphur

Sb: antimony

Sc: scandium

SE: specific energy

SiO2: silicon dioxide

Sn: tin

Sr: strontium

t: metric tonne

Ta: tantalium

TD: total depth

Te: tellurium

Th: thorium

Ti: titanium

U: uranium

VHMS: volcanic hosted massive sulphide

W: tungsten

yr: year

Zn: zinc

# Glossary

**alluvial deposits:** sedimentary deposits which consist of material which has been transported, suspended, or laid down by a stream. The deposits may be modern (ie active) or fossil (ie palaeochannel).

**asbestos:** a white to green, fibrous form of the mineral serpentine which was used widely in fire-retardant and heat-resistant applications. Asbestos can be hazardous to health if dust is inhaled over a period of time. Two forms exist: tremolite, and chrysotile.

**aventurine:** a shiny red or green translucent quartz containing microscopically visible, exsolved haematite or mica.

**basin:** a segment of the earth's crust which has been downwarped or downfaulted, in which thick layers of sediments have accumulated over a long period of time.

**bauxite:** a rock composed primarily of hydrous aluminium oxides and formed by weathering in areas with good drainage. A major ore of aluminium.

**Besshi-Cyprus VHMS:** varieties of metal-rich mineral deposit styles, characterised by sulphide concentrations formed during active volcanism on the sea floor. The type example for Besshi deposits is in Japan. The type example for Cyprus deposits is on the island in the Mediterranean of the same name.

**cairngorm:** a variety of smoky quartz.

**caldera:** a large, circular depression in a volcanic terrane, typically originating in collapse, explosion, or erosion.

**chert:** a sedimentary form of amorphous or extremely fine-grained silica, partially hydrous, found in concretions and beds.

**coal:** the metamorphic product of stratified plant remains, usually accumulated in peat beds and progressively compressed and indurated until it is finally altered into volatile graphite-like material.

**coal measures:** a sequence of rocks containing coal.

**coal seam methane/coal bed methane:** natural methane gas contained within or derived from coal deposits. It may be contained within the internal crystal structure, or be expelled into the surrounding strata.

**citrine:** a variety of crystalline quartz, yellow to brown and transparent.

**diamond:** a mineral composed entirely of carbon crystallised under high pressure.

**diatomite:** a siliceous chert-like sediment formed from the hard parts of diatoms.

**diatreme:** a volcanic vent filled with breccia by the explosive escape of gases.

**dimension stone:** natural building stone that may be cut to specific size requirements. It includes granite, gabbro, anorthosite, marble, limestone, slate and sandstone. It can be rough or finished stone.

**epithermal deposits:** deposits formed by the precipitation of ore minerals from thermal springs. The deposits are characterised by the presence of fine grained silica and quartz in silicified breccias with gold, pyrite, antimony and other sulphides. Economic elements of interest may include gold, silver, lead, zinc, and copper.

**facies:** the set of all characteristics of a sedimentary rock that indicates its particular environment of deposition and which distinguish it from other facies in the same rock.

**fault:** fracture along which there has been movement.

**felsic:** composed chiefly of light-coloured minerals (feldspar and quartz).

**fluvial:** produced by the action of a stream or river.

**fossil fuel:** a general term for combustible geologic deposits of carbon in reduced (organic) form and of biological origin, including coal, oil, natural gas, oil shales, and tar sands.

**garnet:** a silicate mineral that usually occurs as small, rounded, red or pink crystals mainly in metamorphic rocks, but also in intrusives.

**graben:** trough bounded by faults.

**granite:** a medium to coarse grained igneous intrusive rock consisting principally of quartz and feldspar.

**greisen:** granitic rocks altered by gaseous emanations from the solidifying magma.

**hydrothermal vein:** a cluster of minerals precipitated by hydrothermal activity in a rock cavity.

**igneous:** formed from or related to molten material (magma).

**in situ:** in the natural or original position. Applied to a rock, soil, or fossil when occurring in the situation in which it was originally formed or deposited.

**jasper:** a dense opaque to slightly translucent cryptocrystalline quartz containing iron oxide impurities; characteristically red.

**kaolin:** a soft nonplastic white rock composed principally of kaolin minerals.

**Kuroko VHMS:** an important base metal-rich mineral deposit style, characterised by concentrations of sulphides formed during active volcanism on the sea floor. The type example is located in the Kuroko district in Japan. A present day example is the 'black smokers' observed on the sea floor of the Eastern Pacific, off the coast of Papua New Guinea.

**lacustrine:** produced in a lake.

**lahar:** a mudflow of unconsolidated volcanic ash, dust, breccia, and boulders mixed with rain or the water of a lake displaced by a lava flow.

**limestone:** a sedimentary rock composed principally of calcium carbonate ($CaCO_3$), usually as the mineral calcite.

**mafic rock:** igneous rock composed chiefly of dark-coloured iron and magnesium-rich minerals.

**magma:** molten rock material that forms igneous rocks upon cooling. Magma that reaches the surface is referred to as lava.

**magnesite:** a white mineral composed of magnesium carbonate and an important source of magnesium. Magnesite is a common alteration mineral in ultramafic rocks.

**magnetite:** a black, magnetic, iron oxide mineral, and an important source of iron.

**mineral:** a naturally occurring element or compound with a precise chemical formula and a regular internal lattice structure. Organic matter is not normally referred to as a mineral, although there are some important exceptions (eg coal, diatomite).

**mineral occurrence:** an anomalous concentration of a particular mineral or minerals at a given location in or on the earth's crust. A mineral occurrence may also refer to old mine workings where the minerals worked are unknown. A mineral occurrence may or may not have an identified resource status, and is usually synonymous with a mineral deposit.

**mineral potential:** the mineral potential of an area is its likelihood of having a particular type and size of mineral deposit based on expert judgements of geoscientists involved in the assessment. Levels of potential are sometimes categorised according to levels of certainty. The assessment of potential resources is subject to the amount and the quality of data available to the assessors, and combines knowledge of geology, geochemistry, geophysics, mineral occurrences, deposit genesis, results of previous exploration, and current and projected technology and demand.

**mineral resource:** a mineral resource is a concentration of material of intrinsic economic interest in or on the earth's crust in such form and quantity that there are reasonable prospects for eventual economic extraction. The location, quantity, grade, geological characteristics and continuity of a mineral resource are estimated, interpreted or known from specific geological data and knowledge. Mineral resources are subdivided in order of increasing geological confidence into inferred, indicated, and measured categories.

**nephrite:** a compact fine grained greenish or bluish amphibole constituting the less valuable type of jade.

**nugget:** a small mass of metal found free in nature.

**orogeny:** the processes of mountain formation, especially of the intense deformation of rocks by folding and faulting, often accompanied by metamorphism, invasion of molten rock, and volcanic eruption.

**orogenic gold:** gold deposits formed during the process of orogeny. By convention, the term usually refers only to gold deposits formed by metamorphic processes, at various levels of the crust.

**ore reserve:** an ore reserve is the economically mineable part of a measured or indicated mineral resource. Ore reserves are subdivided into probable ore reserve and proven ore reserve. They have a higher degree of reliability to mineral resources, and take into account all economic and social factors associated with mining and quarrying of the resource.

**porphyry deposits:** this class of deposits include copper-molybdenum-gold and some tin deposits where sulphide and/or oxide ore minerals are distributed in stockworks and disseminated grains in an adjacent to porphyritic intrusives of intermediate to felsic composition.

**prehnite:** a light green to white lustrous calci-alumino silicate.

**oil/gas seep:** a natural flow of oil and/or gas to the earth's surface.

**oil shale:** a dark-coloured shale containing organic material that can be crushed and heated to liberate gaseous hydrocarbons.

**orogen:** a region that has been subjected to intense folding and other deformation.

**palaeochannel:** a remnant of a stream channel cut in older rock and filled by the sediments of younger overlying rock.

**petroleum play:** a specific combination of geological features which is perceived as having potential for petroleum accumulation.

**prase:** a translucent and dull leek green or light grey-yellow-green variety of chalcedony.

**pyroclastic rock:** a rock formed by the accumulation of fragments of volcanic rock scattered by volcanic explosions.

**rhodonite:** a pink or brown manganese silicate.

**replacement deposit:** a deposit of ore minerals formed by hydrothermal solutions that have dissolved the original minerals.

**ruby:** the red variety of sapphire. The ruby or pale pink colour is caused by trace amounts of chromium.

**sapphire:** any of the gem varieties of the mineral corundum, especially the blue variety. The blue colour is caused by trace amount couplings of iron and titanium.

**seismic:** a geophysical technique using low-frequency sound waves to determine the subsurface form of sedimentary rocks.

**serpentine:** a greenish metamorphic mineral characterised by long, waxy or fibrous crystals. Usually associated with ultramafic rocks. Asbestos is one form of serpentine. Serpentinite is the rock made up of such minerals.

**serpentinite:** a rock made up of predominantly serpentine minerals.

**shows:** the detectable presence of hydrocarbons observed during the drilling of a well.

**skarn**: a lime bearing silicate derived from limestone and dolomite with the introduction of silicon, iron, and magnesium. May also contain anomalous concentrations of introduced base and precious metals, and/or may comprise various industrial mineral products.

**smoky quartz:** a smoky yellow, smoky brown, or brownish grey, often transparent variety of crystalline quartz containing inclusions of carbon dioxide. Also known as cairngorm, smokestone.

**source rock:** a sedimentary rock which is capable of generating hydrocarbons under optimum maturation conditions of temperature, pressure and time.

**stratigraphy:** the science of the description, correlation, and classification of strata in sedimentary rocks, including the interpretation of the depositional environments of those strata.

**subduction zone:** a dipping planar zone descending away from a trench and defined by high seismicity, interpreted as the shear zone between a sinking oceanic plate and an overriding plate.

**synorogenic:** occurring at the same time as intense folding and other deformation.

**synvolcanic:** occurring at the same time as volcanism.

**tectonic:** pertaining to the structure and movements of the earth's crust.

**trap:** a geological structure in which hydrocarbons build up to form an oil or gas field.

**ultramafic rock:** igneous rock containing more than 90 % iron and magnesium-rich minerals.

**vein:** a thin, sheet-like body of igneous rock or of minerals such as quartz, calcite, barite, etc., deposited in a crevice or fracture in a rock.

**volcanic pipe:** the vertical chamber along which magma and gas ascend to the surface. Also a formation of igneous rock that cooled in a pipe and remains after the erosion of the volcano.

**zeolite:** a large family of hydrous silicate minerals.

**zircon:** a brown, green, pale blue, red, orange, golden-yellow, greyish, or colourless mineral of zirconium silicate. The colourless form is the most common gemstone variety.

# i Introduction

## 1.1 BACKGROUND

In 1999, the NSW Government initiated a series of regional assessments of western New South Wales starting with the Brigalow Belt South Bioregion. The Nandewar Western Regional Assessment follows from, and builds upon the Brigalow assessment.

The assessments have been coordinated through the Resource and Conservation Assessment Council (RACAC). RACAC and the participating agencies provided funding for the various projects. The purpose of the Western Regional Assessments (WRAs) is to improve our knowledge of natural resources, to help future land use planning decision-making, and to encourage partnerships to protect the environment. A number of government agencies including the Department of Mineral Resources are involved, as are many local and regional stakeholders. The Nandewar WRA area is the second area to be assessed as part of the initiative. The Nandewar WRA area, herein referred to as the ‘Nandewar study area’, includes the Nandewar Bioregion and additional areas to the east such that the area extends to the western boundary of the Upper and Lower North East Comprehensive Regional Assessment areas.

In January 2003, the Department of Mineral Resources commenced the regional assessment of the Nandewar study area. The Department of Mineral Resources has undertaken two major projects as part of the Nandewar assessment:

NAND04 Nandewar Geology Integration and Upgrade; and

NAND07 Nandewar Mineral and Petroleum Resources and Potential.

The Western Regional Assessments in western New South Wales requires modelling of many natural and economic parameters. At various times, mineral (including metallic and industrial minerals) and petroleum deposits may have accumulated in particular geological settings. The primary objective of the Mineral and Petroleum Resources and Potential Project was to assess the mineral and petroleum resources and potential of the Nandewar study area by review of the known data and the collection of new information from key areas. This report is the Department of Mineral Resources’s final report on the Mineral and Petroleum Resources and Potential Project.

Note that the term ‘mineral’ in this report refers to minerals under the *Mining Act 1992* and includes metallic minerals, industrial minerals, some construction materials, and coal. Construction materials include unprocessed sand, clay, and crushed rock. The term ‘petroleum’ refers to oil, natural gas, oil shale, and coal seam methane gas under the *Petroleum (Onshore) Act 1991*.

# 1 Legislative and Administrative Framework

## 1.1 LEGISLATION AND ADMINISTRATION OF EXPLORATION AND MINING TITLES

### 1.1.1 Minerals and Coal

Exploration and mining in New South Wales for minerals is principally governed by the *Mining Act 1992*, administered by the Department of Mineral Resources, and by the associated regulations and conditions.

Under the *Mining Act 1992*, there are three principal forms of title**,** Exploration Licences (EL's), Assessment Leases (AL's) and Mining Leases (ML's). The Mineral Claim (MC) is a title that can be granted to cater for smaller operations, prospecting and mining in areas up to two hectares in size. Under the Mining Act, tenures for exploration and mining can be granted over any land, and over both Crown and privately owned minerals. Although the Crown owns most minerals, there are cases, particularly where original land grants occurred in the 1800's, where the minerals are owned privately.

### 1.1.2 Exploration Licences for Minerals and Coal (EL, AUTH)

Exploration Licences (EL) enable exploration and prospecting to be undertaken. The size of areas that can be granted, range from about three square kilometres (one unit) to about 300 square kilometres (100 units). A unit is an area bounded by a minute of longitude by a minute of latitude. Areas of more than 100 units can be granted if appropriate to do so. Exploration licences are normally granted for a period of two years and may be renewed for further periods. These licences allow for geological and geophysical surveying, sampling, drilling, trenching and other exploration techniques.

Before any licence holder can carry out any exploration activity the holder must enter into an access arrangement with the landholder. Exploration licences contain conditions, including ones specifying the work program to be completed (coal) or the amount required to be expended on exploration during the period of the licence (minerals). A security deposit must also be lodged to cover the exploration licence holder's obligations to comply with the licence conditions.

Some current coal exploration licences were granted prior to the 1992 Act and are referred to as Authorisations (AUTH). They sometimes cover the area of an active coal mine where surface access is not provided by the mining lease. This enables the operator to continue exploration and assessment activities during mining operations.

Exploration Licences are designed for exploration over a specific area of land. However, certain parts of the area may be excluded. The standard exclusions of lands are:

- National Parks, Nature Reserves, Historic Sites, Aboriginal Areas, Regional Parks and Karst Conservation Reserves under the *National Parks and Wildlife Act 1974*, as at the date of grant of the licence
- Flora Reserves excluded from the operations of the *Mining Act (1992)* under the provisions of the *Forestry Act 1916*, as at the date of grant of the licence
- land vested in the Commonwealth of Australia.

### 1.1.3 Assessment Leases for Minerals and Coal (AL)

The Assessment Lease (AL) is a relatively new title having been introduced by the *Mining Act 1992*. Its purpose is to enable detailed evaluation of mineral deposits to be carried out after the normal period of exploration has expired, but where, for agreed reasons, the project is not ready for a Mining Lease. Such reasons can be of an economic nature, for example, the deposit found is not presently economic to develop, or there could be practical reasons such as a need to develop specific processing methods to extract a particular mineral from the host rock. There is no maximum size for an assessment lease; the dimensions of areas being such as are necessary and appropriate. These titles can be granted for a period of five years and renewed for a further period of five years. Similar conditions on expenditure, reporting of progress and security are required as for exploration licences. Where access to lands is required, appropriate access arrangements and consents must be obtained.

### 1.1.4 Mining Leases for Minerals and Coal (ML)

Mining Leases (ML) are granted to enable mining operations to be carried out. There is no maximum size for a mining lease and dimensions and area can be such as are necessary and appropriate for the particular mining operation. Mining Leases are generally granted for a period of 21 years depending upon circumstances, and can be renewed. Mining Leases enable operations, subject to appropriate conditions, to be undertaken by open cut (surface) or underground methods. Royalty is payable on all minerals recovered at the rate prescribed in the Regulation of the *Mining Act 1992* or at such additional rates as may be specified. The holders of mining leases are required to lodge a security deposit with the Minister commensurate with the size of the mining operation to ensure compliance with conditions of the lease.

Applicants for, and holders of titles under the *Mining Act 1992,* are required to comply with the provisions of other relevant legislation such as the *Environment Planning and Assessment Act 1979*. In particular, Mining Lease applicants are required to obtain development consent before a mining lease can be granted. The consent authority is generally the local council but where mining proposals are classified as a State Significant Development, the consent authority is the Minister for Planning. The lodgement of the development consent application normally includes the submission of an Environmental

Impact Statement (EIS) that is put on display for public comment as part of the development process. Depending upon circumstances, a Commission of Inquiry into the development may be required and the recommendations of the inquiry are taken into consideration as to whether or not development consent should be granted and, if so, upon what conditions will be included in the consent and the title. In granting Mining Leases, the views of all relevant Government agencies are obtained and appropriate conditions to meet respective requirements are formulated for inclusion in the lease documents.

### 1.1.5 Construction Materials

Construction material extraction is controlled by a number of State and Local Government agencies. Some materials, like clay and shale used for brick making, are classed as minerals under the *Mining Act 1992* and can be extracted under mining titles issued by the Department of Mineral Resources.

Most construction materials are not prescribed minerals under the *Mining Act 1992* and hence a mining title is not required to explore for, or mine these minerals. The only statutory responsibility the Department of Mineral Resources has with respect to the extraction of these materials is its responsibility under the *Mines Inspection Act 1901 (as amended)* for ensuring the safety of mining and quarrying operations. Materials that are not prescribed minerals are owned by the landowner where they occur on freehold land, and by the Crown in the case of Crown Land. Where such materials occur on Crown Land, a Crown Lands Licence to extract them must be obtained from the Department of Lands. Where such materials occur in State forests, a forest materials licence to extract them must be obtained from State Forests of New South Wales.

Where construction materials are present on private land, they may be extracted by the landowner, or by anyone having an agreement with the landowner, after obtaining development consent from the local Council or other relevant consent authorities.

In addition to any requirement to obtain a mining title or Crown Land Licence, all mining and quarrying proposals require development consent. The consent authority is normally the local Council but where mining or extractive industry proposals are classified as State Significant Development, and in some other circumstances, the consent authority is the Minister for Planning.

The Department of Mineral Resources has a recognised and accepted role in assessing the State's resources of construction materials and providing advice on their management and extraction.

### 1.1.6 Petroleum

The ownership of petroleum in New South Wales is vested in the Crown. Exploration and production of petroleum (including conventional petroleum, natural gas and coal seam methane gas) is treated separately to minerals.

Petroleum is regulated by the *Petroleum (Onshore) Act 1991* and the associated regulations. To-date, no overriding legislation has been introduced to cater for possible development priority conflicts between coal seam methane and coal mining, although this has occurred in some other jurisdictions such as Queensland. Presently any such issues would be resolved by Government policy decisions. As in all mining legislation, best industry practice is required during exploration and production operations for rehabilitation and protection of the environment.

There are three titles that are relevant to the exploration for, and evaluation of, oil and gas. They are the Exploration Licence (EL), the Assessment Lease (AL) and the Special Prospecting Authority (SPA). These titles are to be distinguished from a Production Licence (PL) which is a separate title permitting the extraction and sale of oil and gas.

### 1.1.7 Exploration Licences for Petroleum (PEL)

An Exploration Licence for petroleum (PEL) can be granted over private or Crown land. The size of any single Exploration Licence ranges from a minimum of one block to a maximum of 140 contiguous blocks. One block is five minutes of latitude and five minutes of longitude along its edges. The term of an Exploration Licence is up to six years and is renewable subject to satisfactory work performance of the area for successive periods. Exploration Licences are designed for exploration over a specific area of land. However, certain parts of the area may be excluded. The standard exclusions of lands are:

- the surface lands within or overlying the external boundaries of colliery holdings as recorded pursuant to Section 163 of the *Mining Act 1992*
- National Parks, Nature Reserves, Historic Sites, Aboriginal Areas, Regional Parks and Karst Conservation Reserves under the *National Parks and Wildlife Act 1974*, as at the date of grant of the licence
- Flora Reserves excluded from the operations of the *Petroleum (Onshore) Act 1991* under the provisions of the *Forestry Act 1916*, as at the date of grant of the licence
- land vested in the Commonwealth of Australia.

### 1.1.8 Assessment Leases for Petroleum (AL)

Assessment Leases (AL's) of not greater than four (4) blocks may be granted for a term not exceeding six years to enable exploration companies who have made a discovery to carry out more detailed resource evaluation. Petroleum Production Leases (PPL's) of not greater than four (4) blocks may be granted for a term not exceeding 21 years. However development consent is required under the *Environmental Planning and Assessment Act 1979*, along with approvals from other relevant Government agencies before production operations can commence.

A State royalty of 10% of the wellhead value is payable for production operations. Provision is made for the Government to set the royalty at a lower rate in special circumstances. New discoveries attract a royalty holiday for a period of five years from the start of production. The royalty then commences in year six at 6% and increases by 1% for each year to a maximum of 10% in year ten.

### 1.1.9 Special Prospecting Authority (SPA) for Petroleum

Special Prospecting Authorities (SPA's) are designed to permit scientific research. They can be of any size agreed upon by the Government and may be granted for a term not exceeding 12 months.

## 1.2 AREAS DESIGNATED UNDER SECTION 117(2) DIRECTION G28 (*ENVIRONMENTAL PLANNING AND ASSESSMENT ACT 1979*)

Areas designated by the Department of Mineral Resources in response to Section 117(2) Direction G28 under the *Environmental Planning and Assessment Act 1979* have an identified mineral, construction material or petroleum value, often with identified resources, or with high mineral potential. A council cannot prepare a Local Environmental Plan (LEP) that would prohibit or restrict mining in these areas (where these uses are currently permissible) without first consulting with the Department of Mineral Resources. If the Department objects to the proposed plan, the council must refer the draft plan to the Department of Infrastructure, Planning and Natural Resources, seeking approval to proceed to public exhibition.

There are currently (November, 2003) 105 Section 117 areas whose boundaries are within or overlap the Nandewar study area. The location of the Section 117 areas is shown in **Figure 1-A.**

| |
|---|
| Note: Only the southern part of the study area has been assessed for designated areas under Section 117. Figure 1-A only represents this part. |

## 1.3 ENVIRONMENTAL MANAGEMENT

A comprehensive framework of legislation overseen by the Department of Mineral Resources regulates the New South Wales minerals and petroleum sector. The New South Wales Government requires industry to meet strict environmental guidelines.

The Department of Mineral Resources works closely with other government agencies, particularly the Department of Environment and Conservation (DEC) and the Department of Infrastructure, Planning, and Natural Resources (DIPNR). By drawing upon the technical expertise of these agencies, an integrated approach to site environmental management is achieved. This whole-of-government approach carries through from initial approval of a mining operation, the mining operation itself and finally to mine closure and rehabilitation.

Before any new mining project in this State is approved, its proponent is required to examine potential environmental risks posed by the project, requiring widespread consultation with the community and State and Local Government. The Department of Mineral Resources reviews the environmental impact assessment of a mining project. With the exception of some small-scale proposals, mining and extractive industries are listed as designated development in Schedule 3 of the *Environmental Planning and Assessment Regulation 2000*.

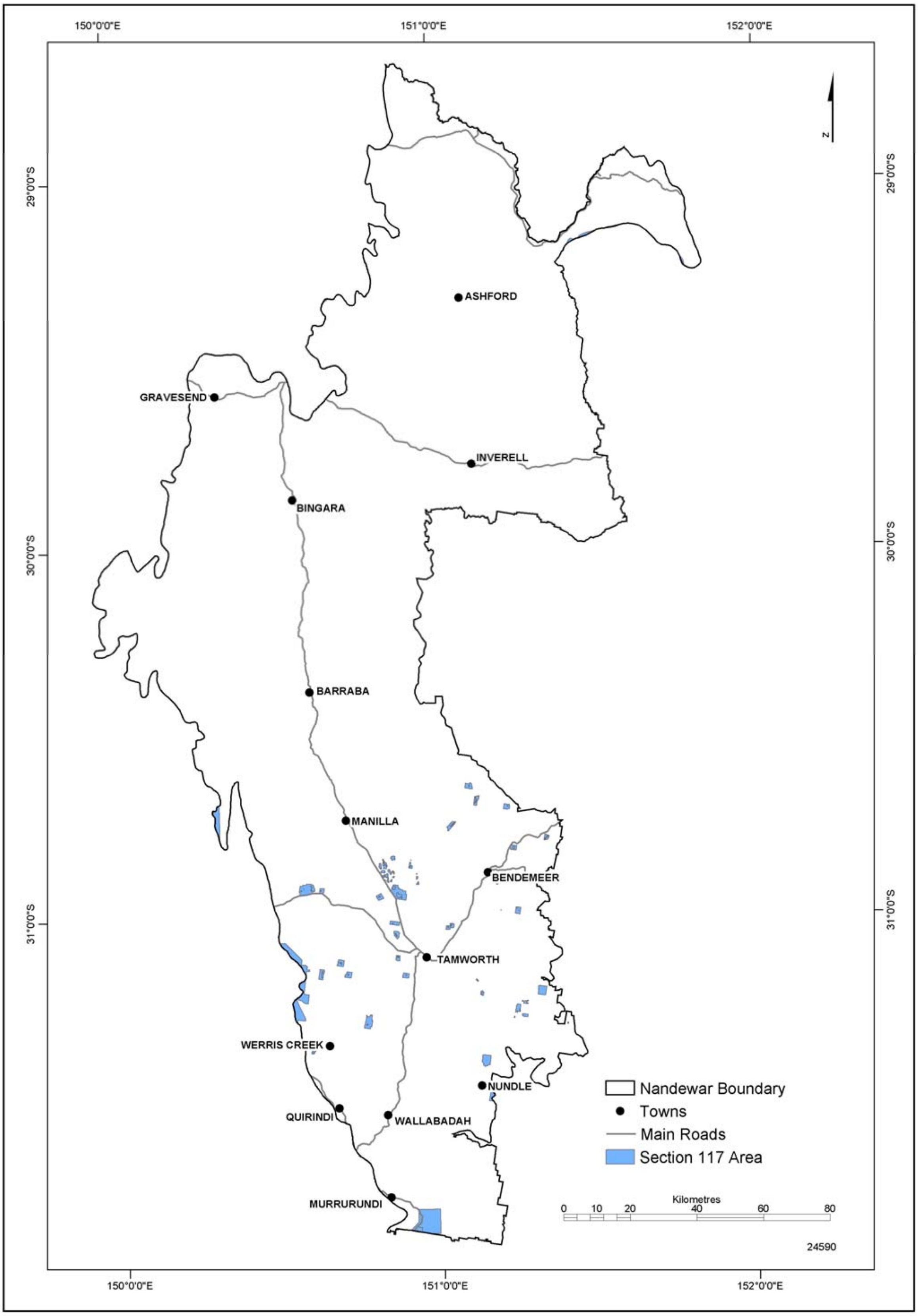



*Figure 1-A. Section 117s, Nandewar study area, November 2003*

Note: the area north of Manilla has not been assessed under Section 117. The figure only shows the location of designated Section 117 areas within assessed LGAs.

This requires the preparation, by the proponent, of a comprehensive Environmental Impact Statement (EIS) to accompany the application for development consent.

If a project is approved, appropriate conditions are imposed by the Department of Mineral Resources to ensure that it operates in an environmentally responsible manner. Central to these conditions is the role of security bonds to ensure funds are available for the effective rehabilitation of mined land in the event of default by the operator. Security bonds are regularly reviewed throughout the project's life to reflect the outstanding rehabilitation liability.

Responsible mining in New South Wales involves the application of the world's best environmental and rehabilitation practices. The environmental performance of operating mines is reported and reviewed at least annually by the Department of Mineral Resources in consultation with other agencies, councils and community groups.

Mine rehabilitation which aims to return the land to its pre-mining land capability or an alternative agreed outcome is a statutory requirement under the *Mining Act 1992*. As community expectations and concerns for the environment have increased, mine closure rehabilitation requirements are assuming a central role in mine start-up considerations. The Department sees progressive rehabilitation as a means of promoting planning for mine closure during mine life rather than leaving this until after production ceases.

Historically progressive rehabilitation has not always been the case. New South Wales has a number of derelict mine sites, many dating from around 1850 or earlier, for which effective provision for rehabilitation was not made by the operator. This situation is not unique to New South Wales. Worldwide the burden for rehabilitation of abandoned mines has largely fallen to the community. The New South Wales Government currently provides around $1.6 million a year for the rehabilitation of derelict mines. Funding is allocated through the Derelict Mined Lands Rehabilitation Program and is administered by the Department of Mineral Resources in consultation with the Department of Environment and Conservation, Department of Lands and the NSW Minerals Council.

The Department of Mineral Resources, out of its commitment to continual environmental improvement and responsible mining and exploration, has developed policies which set out the expectations and obligations for the exploration and mining industries and for the Department. These policies recognise that environmental management and rehabilitation are integral parts of the exploration and mining processes. The policies also recognise that the concerns and interests of the community and the landholders affected by exploration or mining should be recognised in the planning, operational and rehabilitation phases.

The legislation and policies administered by the Department of Mineral Resources have been developed to promote continued access to land for exploration and mining by assisting industry to practice responsible environmental management for the benefit of the citizens of New South Wales.

The net effect of the local and regional demand for minerals, construction materials and petroleum products on the environment both within and bordering the Nandewar study area has been declining since the late 19th century. Projected mineral demand and likely developments within the Nandewar study area are not expected to produce significant environmental changes. This is largely to be expected even if production for some commodities is increased, due to the effects of economies-of-scale, stricter rehabilitation requirements, alternative sources, lower costs and more efficient and better researched exploration and mining technology. The development of larger domestic and international mineral projects, particularly in more recent decades, has also reduced the scattered effect of marginal, smaller operations, particularly for gold, tin and sapphires. In addition, some projects focus attention on more environmentally friendly commodity alternatives, including commodities that have the potential to reduce net greenhouse gas emissions such as magnesium and coal seam methane.

# 2 Exploration and Land Access

The Department of Mineral Resources has a role to ensure that the people of New South Wales benefit from the responsible assessment, development, and management of their mineral and petroleum resources. The Department also has a role in assessing the State's resources of construction materials and providing advice on their management and extraction.

Core to the Department's corporate values is the ability for the Department to respond to the needs of the community and industry and also to work in partnership with other government agencies to provide appropriate land use advice to government. This advice is aimed at making the most effective use of the State's resources and minimising the potential for conflict between exploration, mining and other land uses.

Exploration for mineral deposits can often be considered a significant input into the regional economy independent of the results of the search for minerals. The annual exploration expenditure for various minerals in the Nandewar study area over the last decade has averaged about A$2 million (2003).

## 2.1 NATURE OF EXPLORATION

Mineral and petroleum exploration is a long term and ongoing process. Exploration is an extremely costly, commercially high-risk activity and for many commodities regions are sometimes explored many times over before a major discovery is made.

Exploration activity is cyclic and based on a number of factors including international commodity prices, state of the domestic and international economy, mining and exploration technology, and recent discoveries. New information, new technology, new concepts and better understanding of geological processes often change the perceived potential of areas and regions. Examples of technological change relevant to the Nandewar study area include coal seam methane technology (developed in the last 10 to 15 years), carbon-in-pulp gold extraction (developed in the last 30 years), and hot dry rock potential (proposed in the last 5 to 10 years). Another example of international and technological change relevant to the Nandewar study area concerns expected increased demand for magnesium, which is present in large quantities in tailings from the former Woodsreef Mine. These tailings are currently being investigated for their magnesium potential.

New technology and new models are continually being developed and refined. Large resources of nearly all mineral types continue to be found throughout the world, and new technology continually allows new deposits to be developed at lower costs and with fewer environmental effects.

It is important to stress that mineral and petroleum resources are extremely unevenly distributed over the landscape, and some of these resources can be very difficult to locate. However both highly prospective tracts of land, and land which is has little or no mineral potential, can be defined. Therefore it is possible in many instances to balance competing landuse objectives with known and potential mineral and petroleum values in a regional context.

## 2.2 METALLIC AND INDUSTRIAL MINERALS

Exploration for metallic and industrial minerals is largely undertaken by private industry, under titles issued by the Department of Mineral Resources. Areas are often explored many times over before the initial clue that leads to a discovery is found. Examples of particular relevance to the Nandewar study area include hard-rock diamond deposits, which for various geological reasons (see chapter seven) can be amongst the most difficult of all deposits to locate in the landscape. Gold deposits are another example within the Nandewar study area, which can be particularly difficult to locate. It was not until the early 1990's than an outcropping gold-silver deposit at Mount Terrible in the Nandewar study area was located, despite around 150 years of intermittent exploration in the region.

The advent of Carbon-In-Pulp and Carbon-In-Leach gold extraction technologies in the 1970's provide 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. The technologies 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.

Persistent exploration and re-evaluation of the geology can also lead to discoveries. The Ridgeway gold-copper deposit near Cadia Hill is concealed by a blanket of Tertiary basalt and was recently discovered by a drilling program, 140 years after the first discoveries in the area.

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 future mineral development of the State.

In order to examine the implications of alternative land access arrangements for exploration and mining in the region it is important to understand both the nature of mineral exploration and its likely costs and benefits. The typical sequence of events of a major, modern mineral exploration program is described below.

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 (for example mapped 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 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, metallurgical characteristics of the deposits
- pre-feasibility studies
- acquisition of mining tenements, if justified, at the appropriate stage of program

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 five to 20 year lead-time. This estimate results from a typical 3 to 10 years exploration program prior to the mine development phase.

It is important to note that the exploration process starts with assessment 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 cost of a single major metallic mineral exploration project at an advanced stage of exploration may reach figures of the order of tens of millions of dollars or more, with no certainty of success or approval. However the potential returns may also be very high. The environmental impact associated with exploration may also increase as the area being explored is reduced as the exploration methods used may become more invasive (for example, drilling, costeaning, bulk sampling).

Modern exploration, which is increasingly using remote sensing from satellites or aircraft, is able to proceed to surface exploration phases with little physical land disturbance. The early stages of a surface exploration program involves activities such as mapping, geophysical measurements and geochemical sampling of stream sediments that have little or no effect upon the environment. Follow-up investigations that would require other techniques that could have some localised and temporary effects may include:

- rock chip sampling
- collecting soil samples
- electrical, gravity, magnetic, seismic or radiometric ground surveys

If the results of this work were positive, additional follow-up work would probably include some drilling. Drill holes are required to be rehabilitated to best practice standard by the *Mining Act 1992* and by the title conditions.

## 2.3 CONSTRUCTION MATERIALS

Exploration for construction material resources differs from metallic and industrial mineral exploration in a few significant ways. Because construction materials are high-bulk, low unit value commodities, transport costs are a major component of the final price and hence resources should ideally be located as close to the markets as possible.

Exploration for construction material resources typically involves an initial identification of 'target' areas. These areas may contain suitable deposits, based on an assessment of geological, socio-economic and environmental factors, including particularly, distances to markets and road access.

Potential sources of construction materials within the target area are identified by evaluating available geological and technical data including geological maps, topographic maps, air photos, geological reports, existing quarries, and constraints on quarrying. This is followed by field reconnaissance, including examination of outcrops and exposures such as road cuttings and quarries, as well as preliminary assessment of potential access routes, current land use and broad environmental constraints.

Once a potential resource has been identified, more detailed exploration is normally conducted to determine its size and quality. The extent and method of such exploration depends on the commodity involved, the intended use(s), the proposed scale of the quarrying operation, and the complexity of the geology. Drilling is generally used to assess the size, thickness, amount of overburden, and other characteristics of the deposit. Samples obtained from drillholes are tested to determine the suitability of the material for the intended applications. Bulldozers or backhoes may be used to obtain subsurface data and samples from deposits of sand, gravel and other unconsolidated materials. In some cases, larger test pits may be excavated to obtain bulk samples for testing. Further drilling and sampling may be undertaken to assist in quarry design.

Unprocessed construction materials for local use for roads and fill are not generally required to meet very stringent specifications. Exploration for such deposits may be limited to reconnaissance inspection and sampling to identify potential extraction sites, followed by limited backhoe testing or auger drilling.

## 2.4 COAL

Coal exploration differs from metallic and industrial mineral, and construction material exploration in several significant ways. Firstly, the extent of the coal measure sequences is reasonably well understood in most localities. Secondly, the Department of Mineral Resources usually has the role of conducting the initial phases of the assessment to the point where resources have been identified. Areas are then tendered to private industry for detailed assessment and ultimately, mining.

Drilling is the fundamental tool throughout most phases of the assessment. In the initial stage, boreholes are drilled on a wide spaced grid (12 to 16 kilometres spacing) to establish the presence, depth and thickness of the coal seams. The boreholes are fully cored and provide sufficient sample for detailed chemical analysis of the coal. If the target seams are within basic parameters, for example less than 600 metres in depth, greater than 1.5 metres in thickness, and less than 35% ash (mineral residue after combustion), then 'infill' drilling will be conducted down to a spacing of two kilometres in selected areas.

Further exploration and assessment then depends on whether the resource is suitable to be mined by open cut or underground methods. In most cases, drilling for open cut resources will be conducted to 0.5 kilometre centres. Detailed drilling will also be conducted along any seam subcrop line to determine its location and the extent of oxidation. Large diameter boreholes are often drilled to recover bulk samples for analysis and coal preparation plant design. Drilling for underground resources is usually conducted to at least one kilometre centres but additional holes will be drilled to closely define changes in coal quality and/or to identify any structures or igneous intrusions that might have an impact on the mine plan and the recovery of the resource.

Geophysical techniques are now routinely used in coal exploration. Aeromagnetic surveys help to determine the presence of igneous bodies at depth, which may have damaged or destroyed the coal. Seismic surveys help to locate any structures affecting the coal that may impact on mine design or viability.

Coal exploration activities are required to be conducted to industry best practice with minimal surface impact. Drilling operations require a 5 metre by 10 metre cleared space but usually can be sighted in established clearings without damage to trees. Seismic lines can usually be conducted along established roads or across cleared land. Where lines cross bush areas, line clearing is no longer necessary, as only ground cover is slashed to provide access to the equipment and to assist regrowth. Rehabilitation of all exploration activities is required under the *Mining Act 1992* and the licence conditions.

## 2.5 COAL SEAM METHANE

Coal seam methane (CSM) exploration has similarities both to coal and to petroleum exploration (see below). The target reservoirs are coal seams and drilling using coal rigs is used to investigate important parameters such as the number, thickness and quality of the coal seams. Coal samples are tested for gas content and composition, for permeability, and other reservoir characteristics. Regional studies including geophysical surveys are important to locate areas with high gas contents and high production potential.

Drilling operations will concentrate on the most prospective areas and gas production testing will commence. This will usually involve a pilot production operation with between three and 15 boreholes spaced on a 250 to 500 metres grid. There are several stimulation (completion) techniques used to produce the gas from the coal, the main ones being hydraulic fracturing, and cavity completions. Sites for these operations are larger than normal drill sites and therefore additional equipment and staff are needed during the stimulation operations. After stimulation, water flows from the holes and after a period up to six months, gas production will commence. If the results of the pilot field are positive, planning for full-scale production will commence including design for water disposal and gas collection and treatment. Ultimately, the rates of flow over time of methane to the surface will control costs of the gas and the economic development of gas fields.

## 2.6 PETROLEUM

Petroleum exploration licence areas are large because the exploration targets are large, broad-scale structures, and are only located through an understanding of the regional surface and subsurafce geology. Exploration costs are high and the process is iterative with each step focusing in increasing detail at the areas with maximum resource potential.

Petroleum exploration involves a number of different processes for searching for and assessing petroleum deposits. Today, sophisticated techniques rely upon identifying subtle physical properties of deposits or the geological conditions that might host 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 each stage will increase the understanding of a region's geology and enable refinement of future exploration techniques. Typically, the exploration history in a region involves several phases, the results of each providing a steady increasing knowledge base. Some exploration techniques rely on naturally occurring phenomena such as slight variations in the earth's gravity and magnetic fields, which are acquired passively by simple field readings. These are relatively cheap methods that can be interpreted to provide a good overview of the regional geology and assist in identifying those areas likely to contain hydrocarbons. Techniques, such as seismic reflection, are more active and require the introduction of an energy pulse into the ground. The results, once computer processed, provide images of the sub-surface in much the same way that the ultrasound technique provides images of the human anatomy.

There are several reasons why exploration might continue in some areas over many years, without a discovery being made. New technology, changes in economic climate, and better understanding of geological processes that control the distribution of petroleum, all influence the location and intensity of exploration activity. In some cases however, exploration effectively downgrades an area to little or no potential.

Exploration occurs in distinct phases with the initial phase usually involving the collection of reconnaissance or regional data, surface mapping, acquisition of remote sensing data, magnetics, and gravity data. All of which are used to define broad scale geological features and highlight areas of interest that might be worthy of more intensive future investigations. Subsequent phases of exploration tend to focus on specific targets or ‘sweet-spots’ along ‘fairways’ where both perceived exploration risk is lowest and prospectivity highest.

Conventional petroleum, and increasingly coal seam methane exploration, make extensive use of seismic reflection techniques which involve an energy source on the surface (previously dynamite, now a mechanical vibratory source) passing a pulse of energy into the subsurface. This energy is reflected off the various geological layers and upon bouncing back to the surface is detected by a series of listening devices (geophones) spread out over distances of four to five kilometres. In order to reduce distortion the geophones are usually placed along a straight traverse, hence seismic data is usually collected along ‘lines’ with the introduction of energy at vibration points being repeated many times along each traverse in order to amplify the weak geological reflections against other white noise. The laying out and collection of geophones usually requires some vehicular access. In the initial stages, seismic lines are often recorded along pre-existing thoroughfares.

Because many geophones are used (often over 2,000 per recording) there is considerable statistical redundancy. This means that geophone positioning can accommodate local vegetation and terrain conditions. Clearing seismic traverses of grass and other vegetation, a common practice 30 years ago, is no longer necessary with modern digital telemetry recording systems. Moreover, modern processing techniques now also accommodate ‘crooked’ line recording, so that in open forest country lines and geophones can be located around trees. Surface clearing is minimal and sufficient only for access by geophone, source and recording vehicles. Seismic acquisition is a transient process, with daily production rates of 5 to 15 kilometres. Typically lines are scouted, surveyed and pegged at regular intervals for source and geophone positioning. Once recording is complete, pegs are removed. Individual lines are subject to sporadic traffic movements for a maximum of two to three days for any given survey. Remedial work nowadays is usually not required following the survey.

Currently there is no technology available to define, using measurements at the earth’s surface, the presence of commercial quantities of hydrocarbons within the underlying rock units. Accordingly, once surface-based geological and geophysical studies have identified an area of extreme interest (prospect) it is necessary to drill to recover rock samples and any contained fluids in order to assess whether economic quantities of oil and gas might exist at depth.

Exploration drilling for petroleum requires a drilling rig considerably larger than for coal exploration because the diameter of the holes drilled is larger. Drilling requires the clearing of a well site and levelling of the land surface for the safe installation of drilling equipment. An earth dam for water and drilling mud supply and detention is also usually built, the total area involving approximately one hectare. Clearing of surrounding vegetation is also necessary in the event of controlled release of gas and liquids that may be encountered whilst drilling. Facilities to flare any gas tested also need to be in-place.

Exploration wells are usually drilled over a period of two to three weeks. If the well is dry then it will be plugged and abandoned and the site rehabilitated, so that there are no permanent impacts of the drilling activity. Development drilling to assess a discovery has a longer-term impact, with wellhead infrastructure being put in place. Production testing may occur over a period of several months during which time the reservoir and gas characteristics are monitored and evaluated. Once production operations are approved, pipelines connecting wellheads to the collection facilities are constructed and the surrounding areas are rehabilitated. Access to the wellhead must be maintained for routine monitoring, maintenance and servicing.

Because exploration is primarily a data gathering process it is necessarily dynamic, so that most regions can never be regarded as being completely explored. The direct costs facing explorers increase as the target areas become smaller and exploration methods become more expensive. The environmental impact associated with exploration also increases as the areas being explored become smaller and the applied exploration methods become more invasive, such as close space development drilling, or 3D seismic programs. All activities are required to be carried out to best practice standard and on completion of the operations rehabilitation of all sites is required and monitored. The long-term impact of petroleum exploration and production operations is minimal.

## 2.7 PUBLIC LAND TENURE AND EXPLORATION

The Western Regional Assessment is a broad-based whole-of-government process applying to areas not already covered by New South Wales forest agreements. It considers environmental, economic and social values of forest and non-forest land systems focusing on conservation, land management and regional planning.

The process aims to achieve conservation outcomes through a range of mechanisms to ensure natural values are protected and at the same time ensure that economic and social objectives are maximised. The National Forest Policy Statement and the New South Wales Biodiversity Strategy require the protection of biodiversity and maintenance of ecological processes and commits New South Wales to the development of a comprehensive, adequate and representative (CAR) reserve system to help achieve this.

Conservation measures to achieve a CAR reserve system may be provided through different levels of reservation or zoning. In relation to public land the levels are Dedicated Reserves, Informal Reserves and Values protected by Prescription.

**Dedicated Reserves** include National Parks, Nature Reserves, Forest Management Zones 1 (FMZ1) and Reserves for Environmental Protection. Areas within this category are designed to meet the requirements of JANIS (1997) dedicated (formal) reserves and as such are equivalent to the International Union for the Conservation of Nature (IUCN, 1994) 'Protected Area' categories I-IV. Activities not permitted include gravel/hard rock quarrying and mineral and petroleum exploration and production.

**Informal Reserves** include Forest Management Zones 2 (FMZ2) and State Conservation Areas (SCA). Forest Management Zone 2 permits access for mineral and petroleum exploration with conditions that are reviewed by State Forests prior to approval. Exploration and quarrying for construction materials is not permitted in FMZ 2.

A new informal reserve category recently created through the National Parks and Wildlife Amendment Bill 2001 is the State Conservation Areas (SCA). SCA's are places of environmental importance and/or cultural significance, potentially containing significant mineral or petroleum resources. They are "exempted areas" under the provisions of the *Mining Act 1992* and "land reserved for a public purpose" under the *Petroleum (Onshore) Act 1991*. Accordingly, an explorer requires an approval from both the Minister for Mineral Resources (under the mining legislation) and the Minister for Environment (under s. 47J of the *National Parks and Wildlife Act 1974*) prior to undertaking exploration in an SCA. The Department of Mineral Resources together with the National Parks and Wildlife Service has recently developed guidelines for exploration and mining in SCAs.

**Values protected by Prescription** includes Forest Management Zone 3 (FMZ 3). This category is designed to comply with JANIS 'values Protected by Prescription' and access for activities such as mineral and petroleum exploration are permitted with standard conditions. Exploration and quarrying for construction materials is not permitted in FMZ 3.

# 3 Geological Summary

A detailed report on the geology of the Nandewar study area is presented in a separate major report, NAND04 (Dawson et al. 2004). A brief summary of the geological history of the Nandewar study area follows.

## 3.1 GEOLOGICAL OVERVIEW

The Nandewar study area encompasses a diverse and geologically complex region that includes the New England Fold Belt, Permian to Cretaceous sedimentary basins, Mesozoic and Tertiary igneous complexes, and Quaternary cover. **Figure 3-A** shows a map of the geological systems of the study area and **Table-3-A** shows a simplified stratigraphy together with the associated mineralisation.

The rapid upgrade of the geology relies on enhancing existing geological knowledge by interpreting newly available geophysical data in conjunction with a broad range of other, generally remotely sensed data. Important remote-sensed data that aids geological mapping includes radiometric data, magnetic data and gravimetric (gravity) data.

Approximately one third of the Nandewar study area is not covered by high-resolution airborne radiometric data. **Figure 3-B** shows an image of the available high-resolution radiometric data that is a seamless merge of a number of different surveys that had different acquisition parameters. Applying a colour to each of the potassium (red), thorium (green) and uranium (blue) radioelement channels has created a ternary radiometric image. Unlike magnetic data that reflects sources from all depths, the radioelement response is due to surficial material only. This makes the data particularly useful for surface mapping, especially when ground is inaccessible.

The airborne magnetic data for the Nandewar study area are shown in **Figure 3-C**. Although the image is continuous, it is made up from 13 different surveys that have been merged into a single seamless coverage. Approximately two thirds of the Nandewar study area is covered by detailed data. The less detailed data are located at the northern and southern ends of the area. This is seen in a loss of detail or apparent 'blurring' of the magnetic image.

The Bouguer gravity data for the Nandewar study area are shown in **Figure 3-D**. In addition to the usual corrections applied to gravity data these data have had an isostatic correction applied to them. This additional correction removes the effects of large variations in thickness of the earth's crust beneath areas of topographic highs. Since most of the data over the area are widely spaced, the information contained in the gravity data indicates large-scale structure and therefore is more applicable to the interpretation of the regional structure of the area.

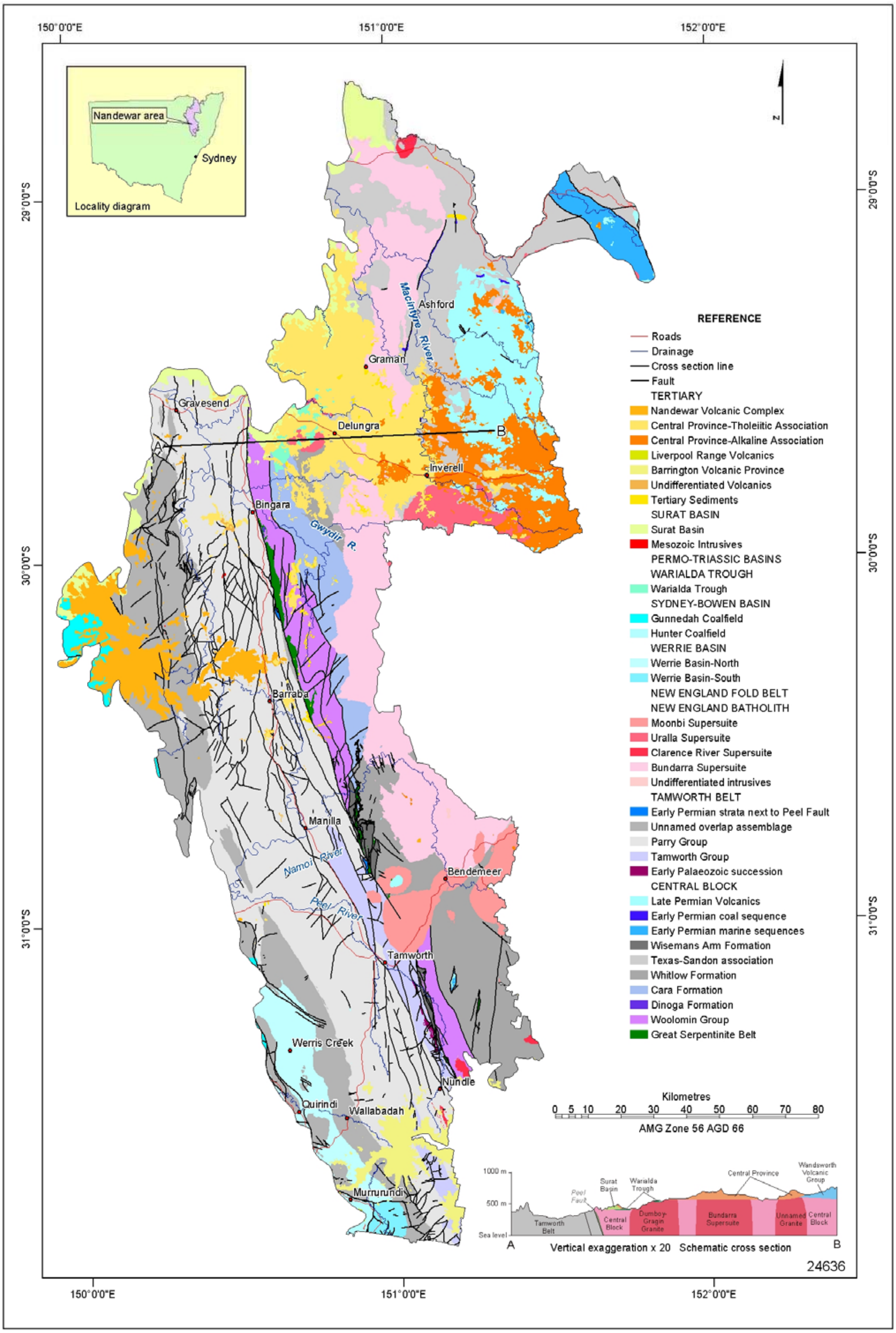



*Figure 3-A. Geological systems in the Nandewar study area*

*Table-3-A. Simplified stratigraphy and associated mineralisation, Nandewar study area*

| Period | Major Geological Province | | | Mineralisation |
|---|---|---|---|---|
| | Basins | Tamworth Belt | Central Block | |
| **Quaternary** | Alluvium, colluvium, terraces | | | Sapphire, alluvial diamond, alluvial gold, secondary tin, other gemstones |
| **Tertiary** | Alluvium, colluvium, terraces<br>Alkaline and tholeiitic volcanics: Nandewar Volcanic Province, Central Province (tholeiitic and alkaline associations), Liverpool Range Volcanics, Barrington Volcanic Province | | | Sapphire, alluvial diamond, alluvial gold, secondary tin, other gemstones, sediment- hosted magnesite, diatomite, kaolin (secondary), primary diamond?, bentonite, phosphate, mineral pigment |
| **Cretaceous** | Surat Basin<br>Alluvium?, colluvium?, terraces? | | | Alluvial gold?, alluvial diamond?, secondary tin? |
| **Jurassic** | Surat Basin | Alkaline Intrusives | Alkaline Intrusives | Primary diamond?, garnet, minor coal, CSM? |
| **Triassic** | Sydney-Bowen Basin, Surat Basin, Warialda Trough | Minor Moonbi Supersuite | Uralla Supersuite, Moonbi Supersuite | Primary diamond?, tin (greisen and vein), kaolin (primary), porphyry Cu-Au, orogenic gold, silver-bearing polymetallic vein, minor coal, epithermal Au-Ag?, CSM? |
| **Late Permian** | Sydney-Bowen Basin, Werrie Basin | Minor Moonbi Supersuite,<br>Minor Clarence River Supersuite | Uralla Supersuite, Clarence River Supersuite, Moonbi Supersuite, Wandsworth Volcanic Group, Great Serpentinite Belt (serpentinisation) | Coal, CSM?, flint clay, epithermal Au-Ag?, orogenic gold, petroleum?, serpentine, bentonite, WMoCuAu skarn, garnet-wollastonite skarn, W-Mo vein/pipe, porphyry Cu-Au, silver-bearing polymetallic vein, tin (greisen and vein), magnesite, bentonite |
| **Early Permian** | Sydney-Bowen Basin, Werrie Basin | Early Permian Strata next to Peel Fault | Clarence River Supersuite?, Great Serpentinite Belt<br>(serpentinisation), Bundarra Supersuite, Marine Sequence, Ashford Coal Measures | Coal, epithermal Au-Ag, VHMS?, porphyry Cu-Au?, oil shale, CSM?, petroleum?, serpentine, flint clay, tin (greisen and vein), magnetite skarn, orogenic gold? |
| **Late Carboniferous** | | Carboniferous Overlap Assemblage | Carboniferous Marine Sequence | Zeolite, orogenic gold?, epithermal Au-Ag? |
| **Early Carboniferous** | | Carboniferous Overlap Assemblage, Parry Group | Carboniferous Marine Sequence | Limestone, VHMS, minor heavy mineral sands, epithermal Au-Ag? |
| **Devonian** | | Parry Group, Tamworth Group | Woolomin Group, Dinoga Formation | Rhodonite, limestone, VHMS |
| **Silurian to Cambrian** | | Unnamed Early Palaeozoic | Woolomin Group, Great Serpentinite Belt | Podiform chromite, Ni-Cu-PGM?, VHMS, serpentine, asbestos (and magnesium) |

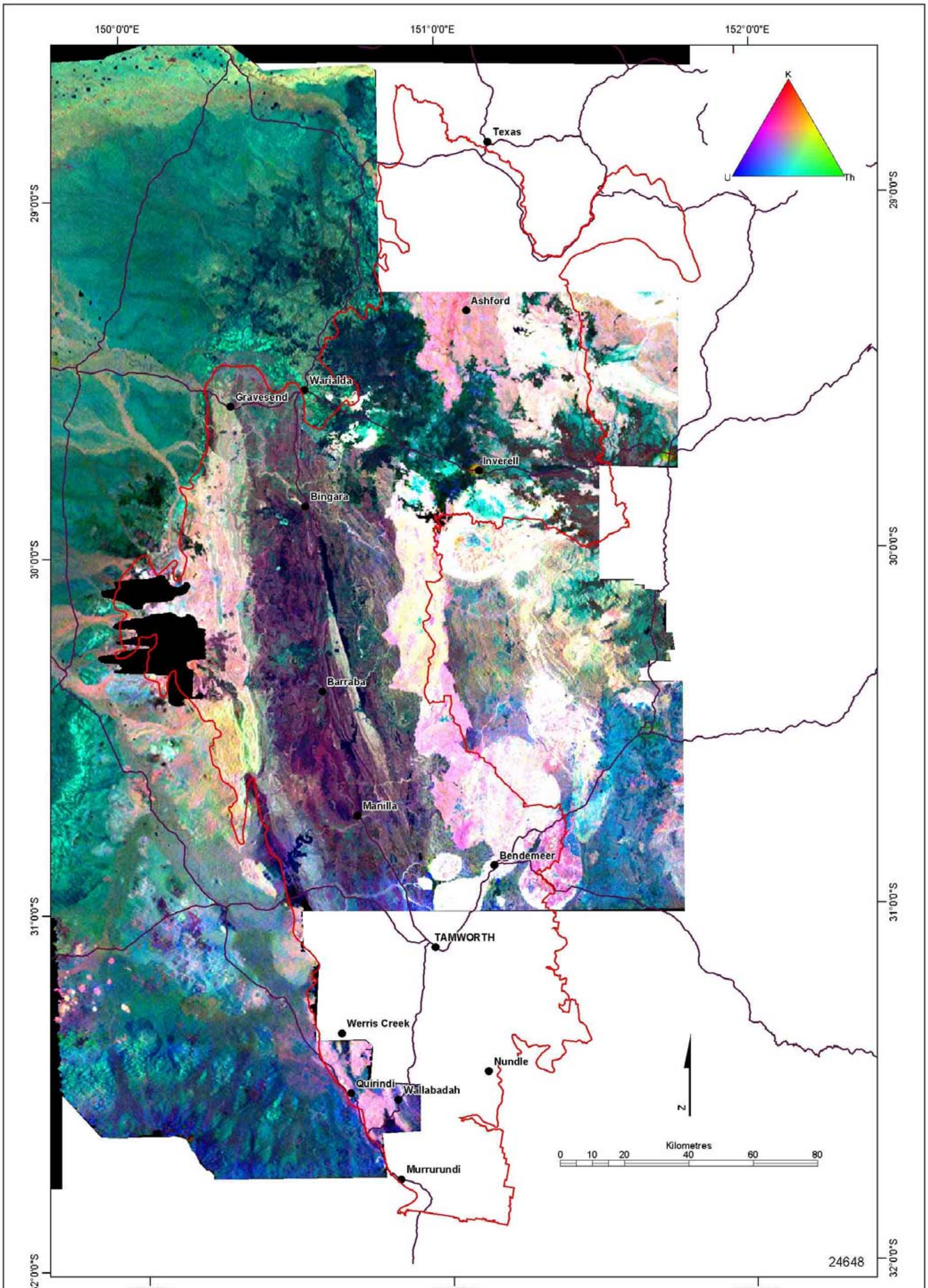



*Figure 3-B. Ternary radiometric image, Nandewar study area*

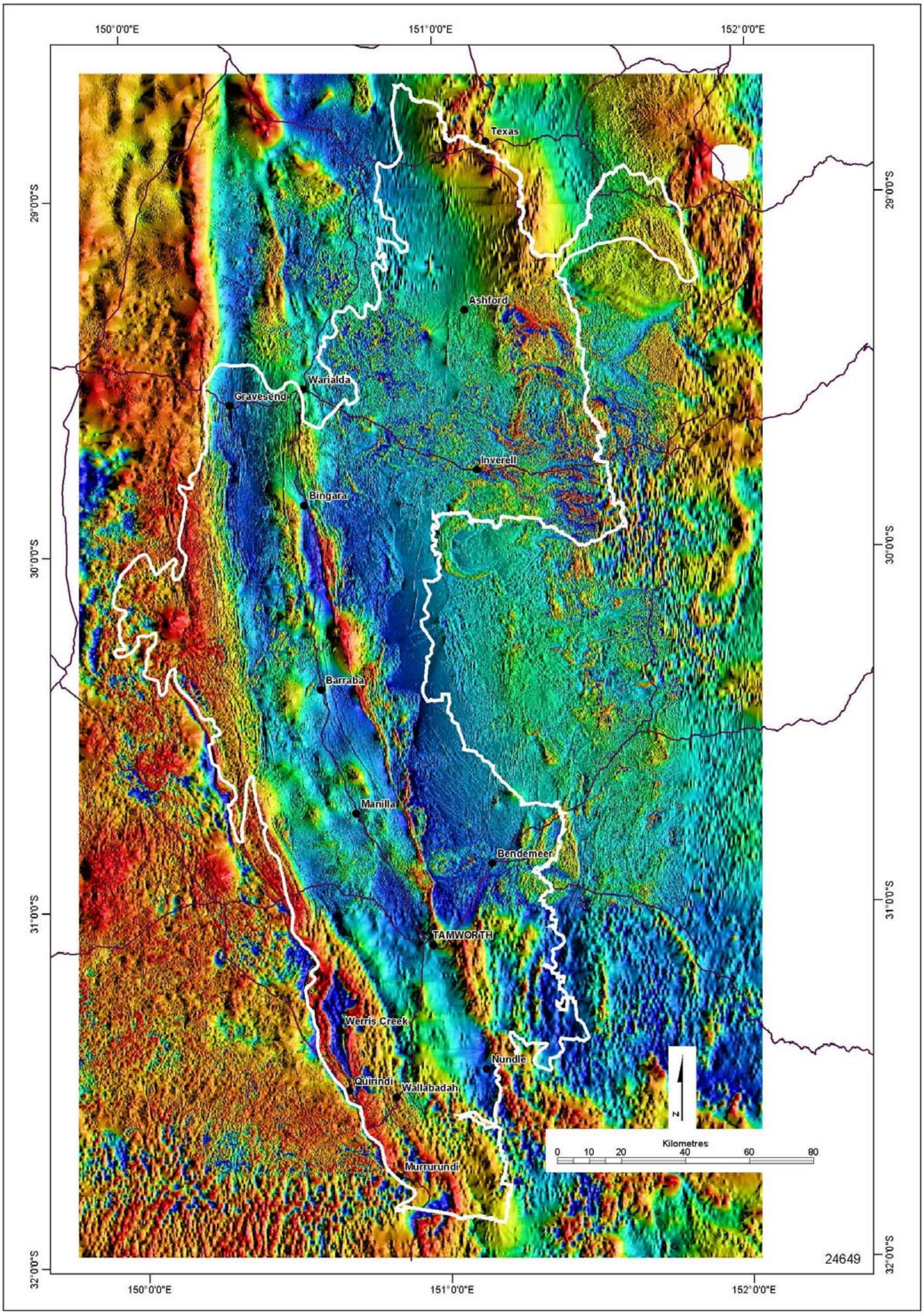



*Figure 3-C. Total magnetic intensity image, Nandewar study area*

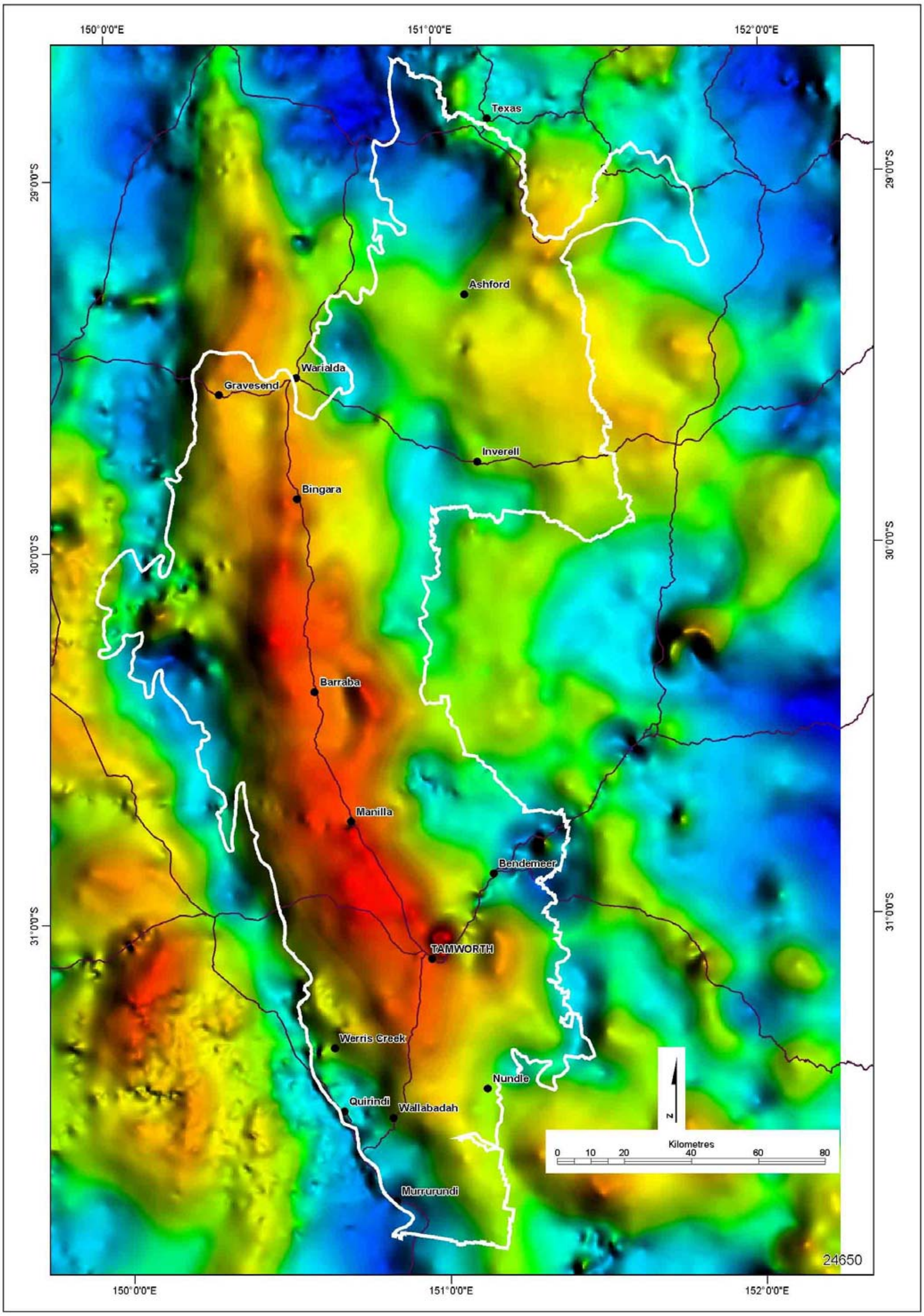



*Figure 3-D. Bouguer gravity image, Nandewar study area*

### 3.1.1 New England Fold Belt

The New England Fold Belt extends for over 1500 kilometres from Bowen in the north to Newcastle in the south and is bounded to the west by the Hunter-Mooki fault system. Broadly, the rocks that comprise the New England Fold Belt are Cambrian to Triassic metasediments and igneous rocks. In the Nandewar study area, the New England Fold Belt is dissected by the north-south trending Peel Fault. This fault separates the gently folded and coherent packages of deep marine to terrestrial sediments (Tamworth Belt) to the west, from highly deformed, dismembered sequences of deep marine sediments of the Central Block to the east (Murray, 1997). The highly deformed Central Block sediments represent, in part, a subduction zone complex. Cratonisation of the New England Fold Belt occurred from the Late Carboniferous to the Middle Triassic by the intrusion and extrusion of predominantly felsic to intermediate magmas. The manifestation of these intrusions is the New England Batholith.

#### Central Block

The sediments of the Central Block comprise a number of dismembered terranes that include the Weraerai, Djungati and Anaiwan of Flood and Aitchison (1988). These terranes amalgamated and accreted to form a significant portion of the southern New England Fold Belt during late Palaeozoic-early Mesozoic time.

*Serpentinite*

The Peel Fault contains a series of serpentinite lenses along its length that represent highly deformed, dismembered portions of Cambrian age ophiolite sequences. The serpentinite has been dated by Aitchison and Ireland (1995) using zircon U-Pb methods as Middle Cambrian in age, therefore representing the oldest rocks within the Central Block.

*Metasediments*

The Woolomin Group is the oldest and most westerly sedimentary package within the Central Block. Radiolarian data indicate deposition between the middle Silurian to Late Devonian in an environment influenced by volcanic island arc activity with little terrigenous input (Aitchison *et al*., 1992). Aitchison *et al*. (1992) postulated that significant differences in sedimentation between the Woolomin Group and Wisemans Arm Formation with that of other well documented subduction complexes may indicate that the red ribbon-bedded chert succession represents the remnants of a once extensive ocean rather than a true subduction complex. Disruption of these rocks occurred during the latest Devonian to Early Carboniferous and coincided with arc volcanism and related tectonic activity (Aitchison *et al*., 1992).

Sediments of the Central Block young progressively to the east and are less deformed away from the Peel Fault. The Cara Formation unconformably overlies, and is in fault contact with the Woolomin Group and Wisemans Arm Formation. The Whitlow Formation unconformably overlies the Cara Formation and is in turn, overlain by the Texas and Sandon beds. These sediments were deposited in a deep marine setting between the Late Devonian to Early Carboniferous, forming a subduction complex. Aitchison *et al.* (1992) interpreted the age of subduction as being Early Carboniferous based on radiolarian data and postulated that the oceanic crust subducted beneath the arc related to the Anaiwan terrane was not part of an extensive oceanic basin.

#### *Early Permian sedimentary rocks*

Overlying the Cambrian to Carboniferous terranes are a series of small Early to early Late Permian basin sediments and Late Permian felsic volcanics. Marine sediments of the Manning Group, Bondonga beds, and other undifferentiated sediments outcrop as disparate packages scattered throughout the Nandewar study area. These sediments are developed predominantly on Devonian to Carboniferous sediments of the Central Block. A narrow northeast striking belt of terrestrial sediments outcrops immediately east of the northern portion of the Bundarra Supersuite and hosts significant coal deposits. The Ashford Coal Measures comprise fluvial sandstones and shales and interbedded cobble conglomerate and coal horizons that are, in part, thrust under the granite on their western side.

#### *Late Permian Volcanics*

The Wandsworth Volcanic Group was defined by Barnes *et al*. (1991) to encompass a coherent group of terrestrial and shallow marine volcanics in the Central Block of the New England Fold Belt. Volcanism took place in the Late Permian in response to a major period of plutonism and produced thick sequences of predominantly rhyolitic to rhyodacitic and minor andesitic tuffs and ignimbrites. In the study area the Wandsworth Volcanic Group includes the Emmaville Volcanics and several undifferentiated outcrops of Permian volcanics. The volcanic sequence was deposited unconformably on basement of Carboniferous to Permian age (Barnes *et al*., 1991). In many localities a thin terrestrial to shallow marine sedimentary sequence, commonly conglomeratic, underlies or grades into the volcanic sequence (Korsch, 1977; Barnes *et al*., 1991). Shaw and Flood (1981) postulated that at many locations the volcanic sequence is intruded by high level, and possibly comagmatic plutons of Late Permian to Early Triassic age. Many units within the Wandsworth Volcanic Group are poorly described, including those within the Nandewar study area.

### Tamworth Belt

The Tamworth Belt comprises faulted and gently folded, mildly metamorphosed Middle Cambrian to Early Permian sedimentary and volcanic rocks. Flood and Aitchison (1988) redefined part of the Tamworth Belt as the Gamilaroi terrane and interpreted the assemblages therein to represent an Early to Middle Devonian island arc succession with associated pyroclastic and epiclastic sediments with minor limestone and radiolarian chert. Geographically, the Tamworth Belt extends from Port Macquarie to Warialda as a 40 to 100 kilometre wide belt in a north-northwest direction. The Tamworth Belt is separated from the Central Block on the east by the Peel-Manning Fault system and disconformably underlies and overthrusts the rocks of the Surat, Werrie and Sydney-Bowen Basins to the north and west. Rocks constituting the Tamworth Belt have been subdivided into five groups according to age, composition and distribution. These groups are: 1) Middle Cambrian to Ordovician ‘unnamed early Palaeozoic succession’; 2) Early to Middle Devonian Tamworth Group; 3)

Late Devonian to Early Carboniferous Parry Group; 4) late Early to Late Carboniferous ‘Carboniferous overlap assemblage’; 5) Permian sequence near the Peel Fault. The Tamworth Belt dominates the western half of the Nandewar study area from Croppa Creek in the north to southeast of Murrurundi.

### New England Batholith

The New England Batholith covers an area of approximately 16 000 square kilometres, incorporating all the granites in the New England Fold Belt of northeastern New South Wales and southern Queensland (Bryant, 2001). The batholith is covered in part by Tertiary volcanics and sediments and nearly exclusively intrudes sediments of the Central Block. For this reason, and the metal zonation in deposits related to the granites of the New England Batholith, Weber and Scheibner (1977; quoted in Scheibner and Basden, 1998) postulated that westward dipping subduction initiated the magmatic activity.

In 1982 Shaw and Flood divided the New England Batholith into five suites, now redefined as supersuites (Bryant, 2001). They include two Late Carboniferous to Early Permian S-type supersuites (the Bundarra and Hillgrove) and three Late Permian-Early Triassic I-type supersuites (the Moonbi, Uralla and Clarence River). A further association of ‘leucogranites’ was identified as being strongly fractionated, weakly reduced I-type intrusions that host a number of historically important metalliferous deposits and are the source of significant alluvial deposits. Many members of this association have recently been tentatively reclassified as belonging to the Uralla Supersuite.

## 3.1.2 Permian to Cretaceous Basins

Periods of extension and compression between the Early Permian and Early Cretaceous on the western side of the New England Fold Belt started development of thick sedimentary basins. Initially developed as rift basins in a back-arc environment, the basins evolved in the Permian to become a foredeep of the New England Fold Belt. Three structural elements of these Permian to Cretaceous basins occur within the study area, the Sydney-Bowen Basin, Werrie Basin, Warialda Trough and the Surat Basin.

### Sydney-Bowen Basin

The Sydney-Bowen Basin occurs to the west of the Hunter-Mooki Fault and consists of Early Permian to Middle Triassic volcanic and sedimentary rocks of both marine and terrestrial depositional regimes.

### Werrie Basin

The Werrie Basin unconformably overlies the Tamworth Belt, with the western boundary defined by the Hunter-Mooki Thrust. Overall the Werrie Basin contains a series of Early to Late Permian sedimentary and igneous rocks and shows similarities in depositional environment with the Sydney-Bowen Basin.

### Warialda Trough

The Warialda Trough is a Middle Triassic terrestrial sedimentary sequence that unconformably overlies the New England Fold Belt, and is unconformably overlain by the Surat Basin and Tertiary volcanics. Members of the Warialda Trough outcrop southeast of Warialda and continue as a series of parallel belts to the north in the subsurface.

### Surat Basin

The Early Jurassic to Early Cretaceous Surat Basin sedimentary sequence unconformably overlies the Permian and Triassic sediments of the Sydney-Bowen Basin, the New England Fold Belt, and the Middle Triassic strata of the Warialda Trough. The sediments were deposited in an Early Jurassic to Early Cretaceous continental basin and contain early terrestrial volcanics and fluvial sediments, and later marine transgressive-regressive sequences that have been folded into very gentle regional anticlines and synclines. Tertiary sediments and volcanics in turn unconformably overlie the Surat Basin. In the Nandewar study area, members of the Surat Basin outcrop in a thin (less than ten kilometres) strip from the Nandewar Ranges to west of Texas.

## 3.1.3 Tertiary Units

Extended periods of little tectonic activity in the Late Cretaceous and earliest Tertiary resulted in deep weathering surfaces. Uplift associated with the onset of spreading of the Coral Sea in the Palaeogene (approximately 65 Ma) activated erosion and deposition of high-level gravels. These gravels were then overlain by a series of lavas and pyroclastic material from central volcanoes and lava field provinces from the middle Eocene to Miocene (Barnes *et al*., 2002). The early Tertiary sediments and subsequent volcanic piles are developed on basement of New England Fold Belt, producing prominent volcanic edifices, the eroded remnants of which are still recognisable in the landscape today. Lava field provinces produced large flat-topped tablelands in the northern portions of the study area. Major volcanic centres include the Mount Royal volcano in the south, part of the Barrington Volcanic Province, the Nandewar Volcano in the central west of the study area and the northerly Central Province.

## 3.1.4 Quaternary

Gravels, sand, silt and clay have been deposited along and in the flood plains of most of the major and minor rivers and streams of the Nandewar study area. The Nandewar study area comprises the Namoi, Hunter, Gwydir and Macintrye rivers catchment areas with valley fill alluvium with associated alluvial terraces being the dominant quaternary systems.

## 3.1.5 Structure

Folding, faulting and metamorphism disrupts the sedimentary and igneous rocks within the Nandewar study area. Many episodes of deformation have been observed from the

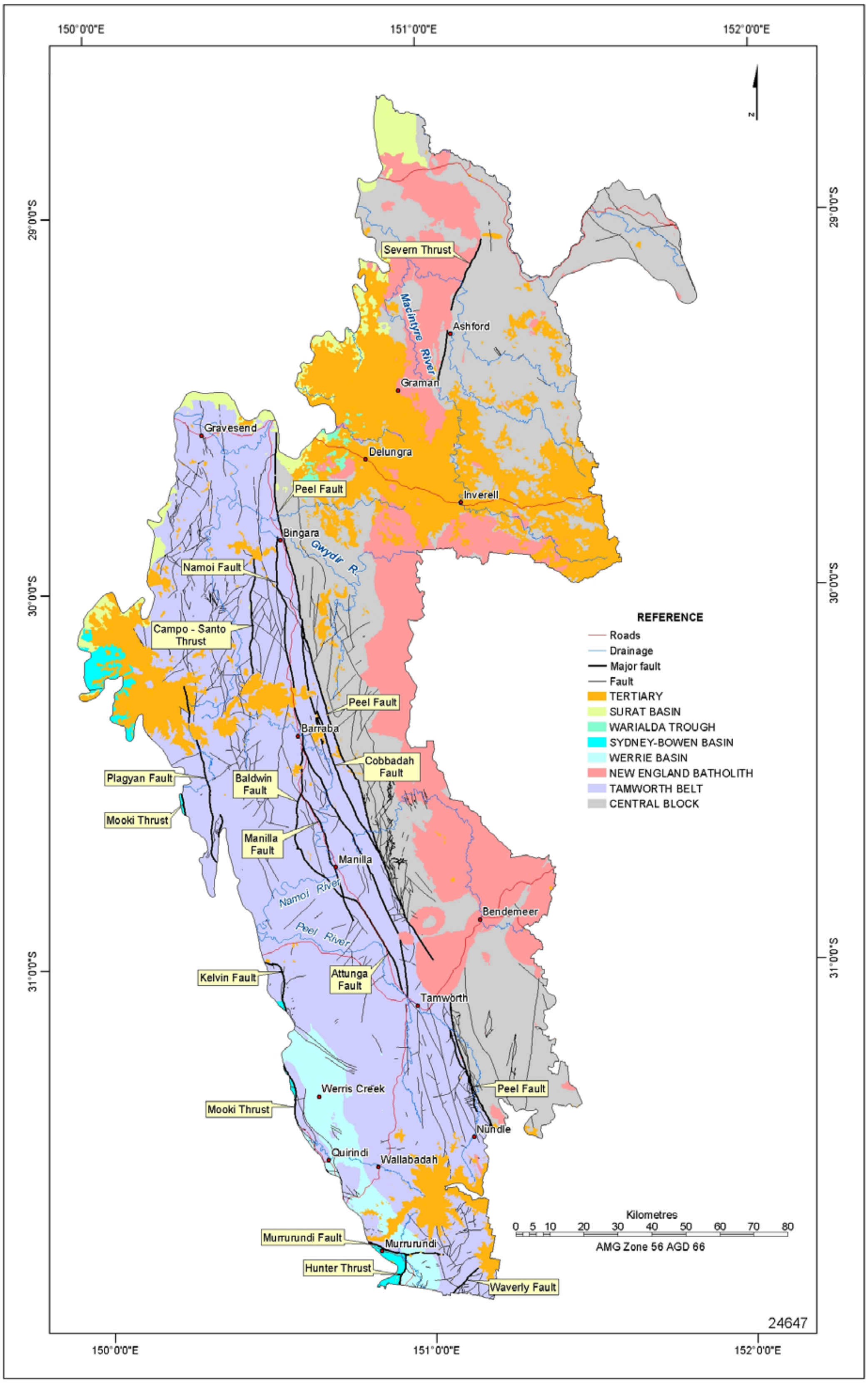



*Figure 3-E. The distribution of faults in the Nandewar study area.*

Ordovician through to the Tertiary. The major deformations are in response to the accretion of the New England Fold Belt onto Gondwana. A diagram showing the distribution of mapped faults with respect to the major geological systems in the study area is shown in **Figure 3-E**. **Figure 3-F** is a schematic cross-section of the Nandewar study area showing the relationship of structures.

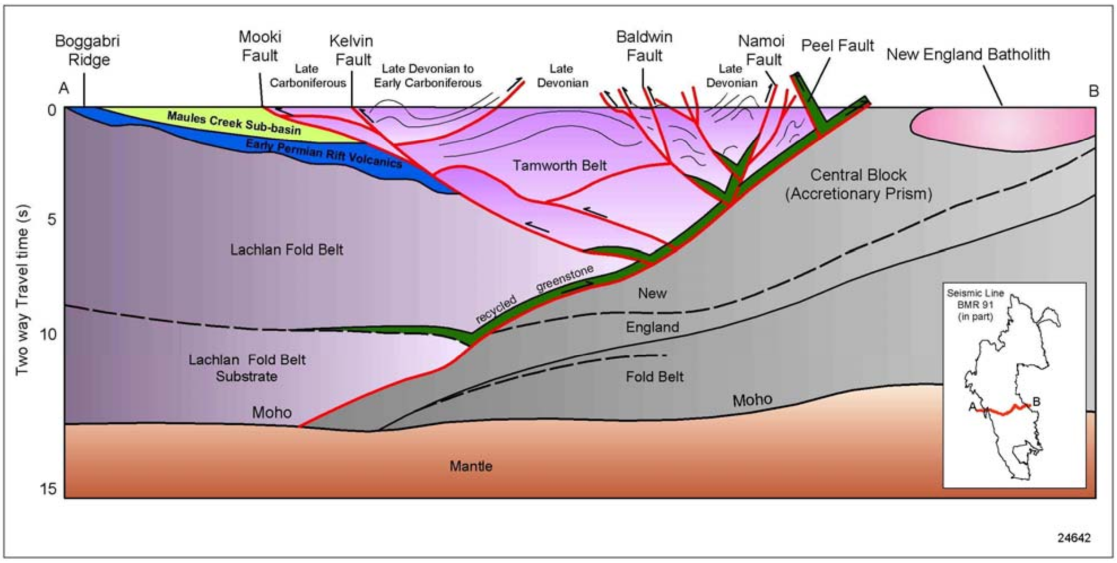



***Figure 3-F. Schematic cross-section of the Nandewar study area interpreted from seismic survey (BMR91.GO1) from Boggabri to Manilla (modified after Korsch et al. 1995)***

# 4 Mining and Exploration History

## 4.1 INTRODUCTION

The Nandewar study area hosts a wide range of mineral commodities and deposit types. The distribution and range of metallic mineral and coal occurrences is shown in **Figure 4-A**. The figure shows a clear linear cluster of gold, chromium, copper and manganese occurrences that trend north northwesterly through the central part of the Nandewar study area. This linear cluster of deposits follows the Peel Fault (see **Figure 3-E**). A cluster of tin occurrences in the northern part of the study area is associated with the Gilgai Granite and the Tingha Monzogranite **(Figure 3-A).** The industrial mineral and construction material occurences **(Figure 4-B)** are more evenly distributed throughout the study area. A cluster of sapphire occurrences in the northern part of the study area is associated with Tertiary basalt**. Figure 4-A** also shows the distribution of the known occurrences of coal in the study area. Coal is associated with Permian sequences in the Werrie Basin and in the Ashford area **(Figure 3-A).**

## 4.2 SUMMARY OF PAST PRODUCTION (1852-2003)

The historic production value for various mineral commodities in the Nandewar study area from 1852 (the time of the first gold rush in the area) to 2003 is approximately $2.5 billion **(Table 4-A).** The figures shown are in A$2003 and are minimum values only. Note that 'A$2003' refers to the value of production in Australian dollars, at their 2003 commodity prices. In other words, if 100 000 ounces of gold was produced from 1852-1900, at 3 pounds per ounce, this is adjusted to 100 000 ounces of gold at $550 dollars per ounce (ie the current (2003) Australian gold price).

Commodities currently mined in the Nandewar study area include limestone, diamond, diatomite, sapphire, construction sand, unprocessed construction materials, river gravel and zeolite.

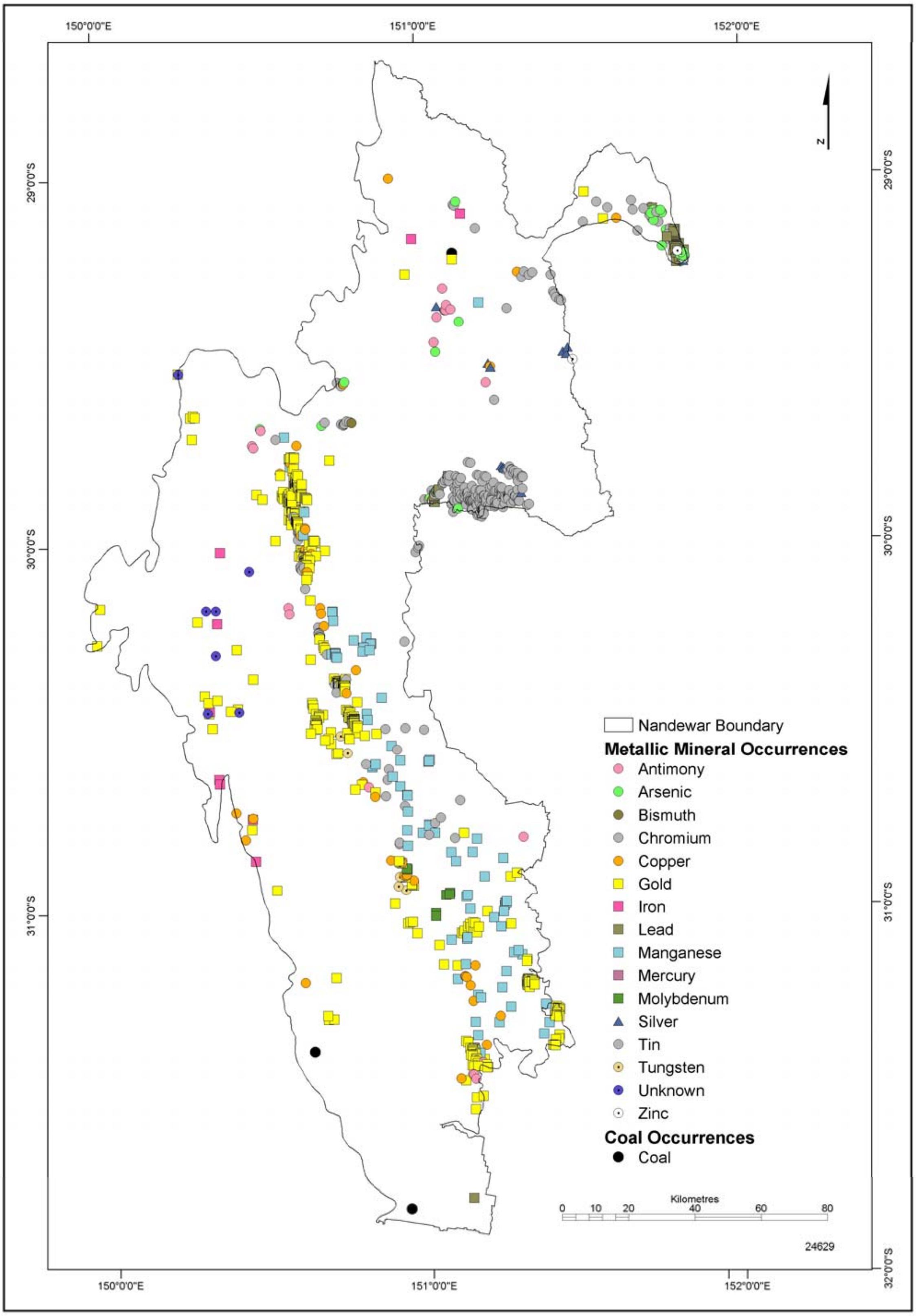



*Figure 4-A. Metallic mineral and coal occurrences, Nandewar study area*

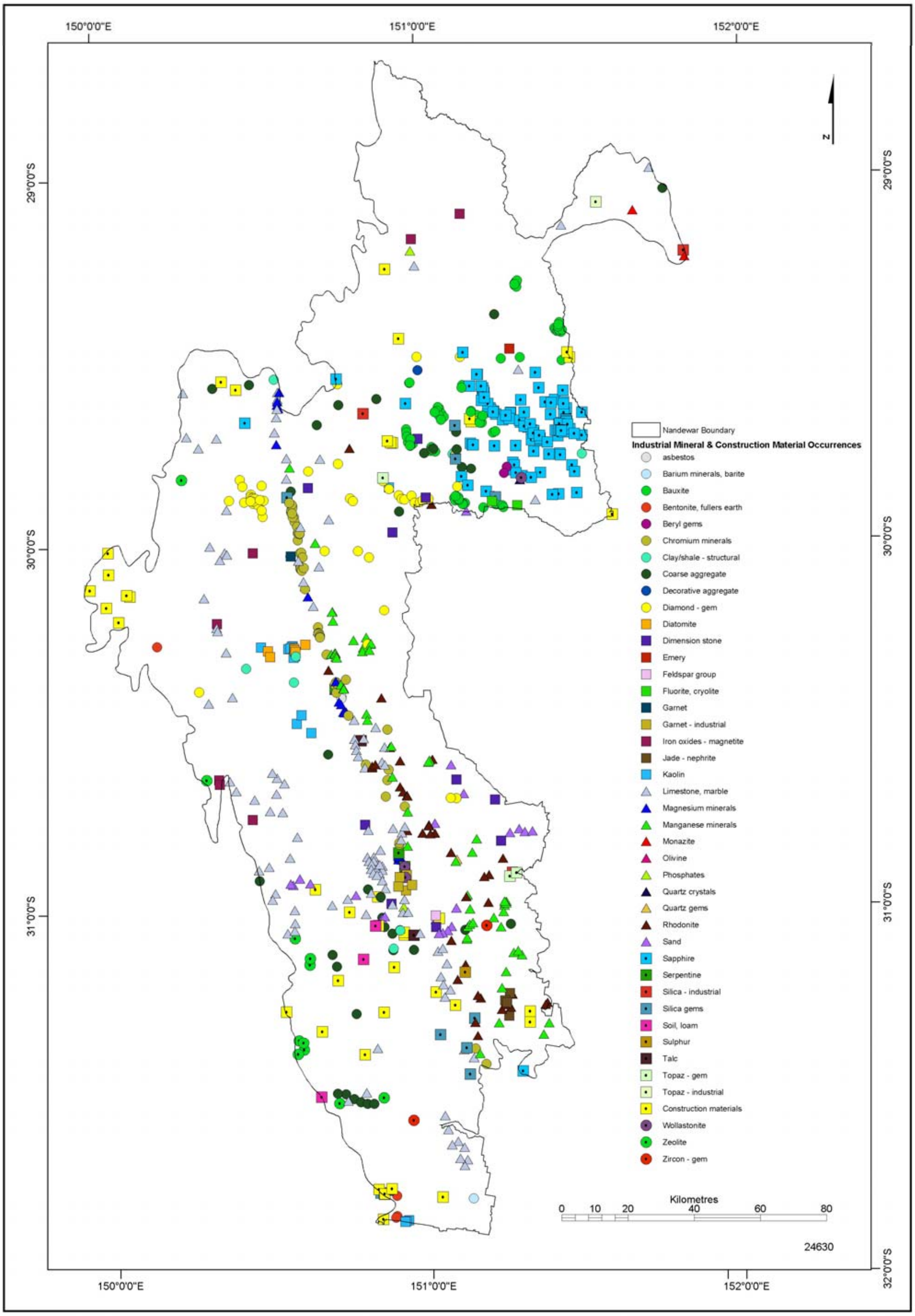



*Figure 4-B. Industrial mineral and construction material occurrences, Nandewar study area*

*Table 4-A. Past production of mineral and petroleum commodities, Nandewar study area, 1852 to 2003 (A$2003).*

| Commodity | Main Periods of Production | Examples | Production Value 1852-2003 (A$2003) |
|---|---|---|---|
| **Asbestos** | 1971-83 | Woodsreef Mine | About $600 million[1] |
| **Coal** | 1870-1914<br>Late 1800's-1930<br>1925-1966 (Willow Tree Formation)<br>1959-1980s | Temi workings<br>Old Bickham Mine<br>Werris Creek Coal Mine<br>Ashford Coal Mine | >$150 million[2] |
| **Limestone** | 1920s-intermittent to present | Sulcor Quarry, Jacksons Quarry | Estimated >$150 million[3] |
| **Gold** | 1852-1890's | Nundle, Bingara, Upper Bingara, Weabonga, Tea Tree Creek, Crow Mountain | >$230 million[4] |
| **Tin** | 1870s-1890's, 1905-14 | Tingha-Gilgai Tin division (part) | >$192 million[5] |
| **Sapphire** | Late 1960's to early 1980's, 1990's-2003 | Frasers Creek, Kings Plains (Including Kew Valley, Strathdarr, Cubba, and others), Swan Brook, Weaan | >$150 million[6] |
| **Diatomite** | 1923-1974 intermittent, 1982-present | Barraba | Estimated $60 million[7] |
| **Diamond** | 1872-1922 intermittent, and 1997 to present | Monte Christo, Eaglehawk, Staggy Creek, Streak of Luck, Malacca, Kirk's Hill | Between $25-$50 million[8] |
| **Oil Shale** | 1860s, 1909-1913 | Temi workings | About $45 million[9] |
| **Copper** | 1894-99, 1907-26, 1951-60 (Gulf Creek), 1968-74 (Fishers), 1904-1916, 1939-1945 (Attunga Copper Mine) | Gulf Creek, Fishers, Mount Everest, Attunga Copper Mine | >$10 million[10] |
| **Zeolite** | 1990's-present | Escott Mine | About $4 million[11] |
| **Construction materials** | N/A | | Estimated >$500 million[12] |
| **Other** | <1852-present | | <$100 million |
| | | **Total** | **>A$2.24 billion** |

[1] From production of 24.2 Mt 1971-1983 and 1970's asbestos price - inflation adjusted (MacNevin 1971).

[2] The Ashford Mine recorded about 1.86 Mt at around $70/t (A$2003). Werris Creek Coal Mine figures recorded about 325 Mt at around $70 per tonne. (US$40-65 per tonne, 2003 coal price, or about A$60-90 per tonne).

[3] Royalty Branch, Department of Mineral Resources.

[4] At an average gold price between 1993 to 2003 of about A$550/oz. The figure is also under-recorded as production from many of the fields is known to have been greater.

[5] From greater than 30 000t cassiterite (equivalent to about 24 000 tonnes tin) produced in the Nandewar study area at the 2003 price of about A$8 000 per tonne (2003). (A recorded greater than 70 000 tonnes of cassiterite produced from the Tingha-Gilgai division to 1997, about half of which is from areas within the Nandewar study area (Brown and Stroud 1997). (Weiderman 1981 p79, figures also suggest much greater than 60 000t).

[6] From greater than A$250 million recorded for the New England region to 1997, most of which is from within the Nandewar study area (Brown and Stroud 1997).

[7] Greater than A$25 million recorded to 1985 (2003). (Holmes et al., 1989). Also estimated A$35 million produced from 1985-2003 (2003).

[8] At an approximate value of A$100/carat (2003). Sampling in the 1990s from the Monte Christo Mine at Bingara yielded an average price of US$61 per carat (approximately A$100 per carat, Minfo 1999). The recorded production in the Nandewar study area from 1872 to 2003 is about 250 000 carats (ie around A$25 million (2003)). However the estimated total is up to 500 000 carats, at approximately A$100 per carat amounts to A$50 million (2003) (Barron et al. 1996, MacNevin 1977).

[9] From a recorded 89 224 tonnes at 500 litres per tonne, equivalent to 45 million litres, adjusted A$2003 price of about $1 per litre (Pratt, 1996). (Figure is very approximate).

[10] At 2003 copper price of about A$4 000 per tonne, from greater than 2 500t of recorded copper production. (Crowley n.d., Downes 1999).

[11] From about 20 000 tonnes of ore produced from 1989 to 2003 at about A$200 per tonne. (Royalty Branch, Department of Mineral Resources).

[12] Includes recorded and estimated unrecorded production. Some quarries do not provide data to the Department of Mineral Resources.

## 4.3 MINING AND EXPLORATION HISTORY

Mining and exploration have made a major contribution to the economy of the Nandewar study area. Many of the towns and settlements have origins related to past mining. Mining of a wide range of commodities continues throughout the area and provides many of the raw materials used in the construction, agriculture and gemstone industries. Mineral exploration is an industry in its own right, and companies spend large amounts of money exploring for mineral deposits, especially for the high value commodities such as gold. The area has a long history of gold, tin, sapphire, diamond, coal, asbestos, diatomite and limestone mining predominantly from seven major mineral fields **(Figure 4-C).** From north to south, the mineral fields are:

1. Ashford – coal
2. Inverell – sapphire, tin, diamond
3. Bingara – gold, diamond
4. Barraba – diatomite, asbestos, magnesium, gold
5. Attunga – limestone, skarn minerals
6. Nundle – gold
7. Werrie Basin – coal

A detailed discussion of the individual historic mining fields in the Nandewar study area is given in a variety of publications including Brown and Stroud (1997), Henley et al. (2001), Weidermann (1981, 1998), Brown et al. (1992), Gilligan and Brownlow (1987), Hume (1995), Nay and Burt (1993), Bayley and Lobsey (1953) and MacNevin (1977).

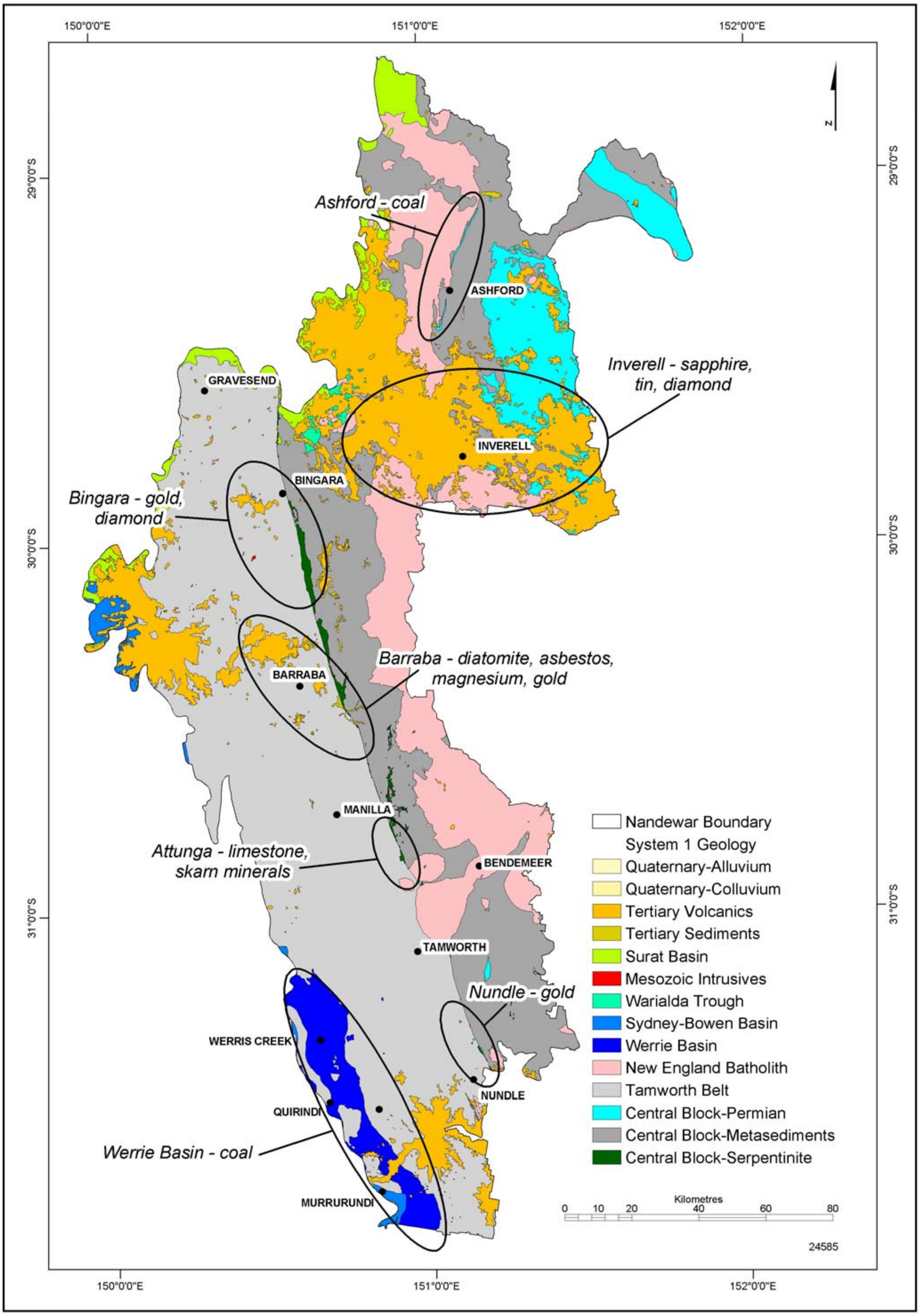



***Figure 4-C. Major mineral fields, Nandewar study area***

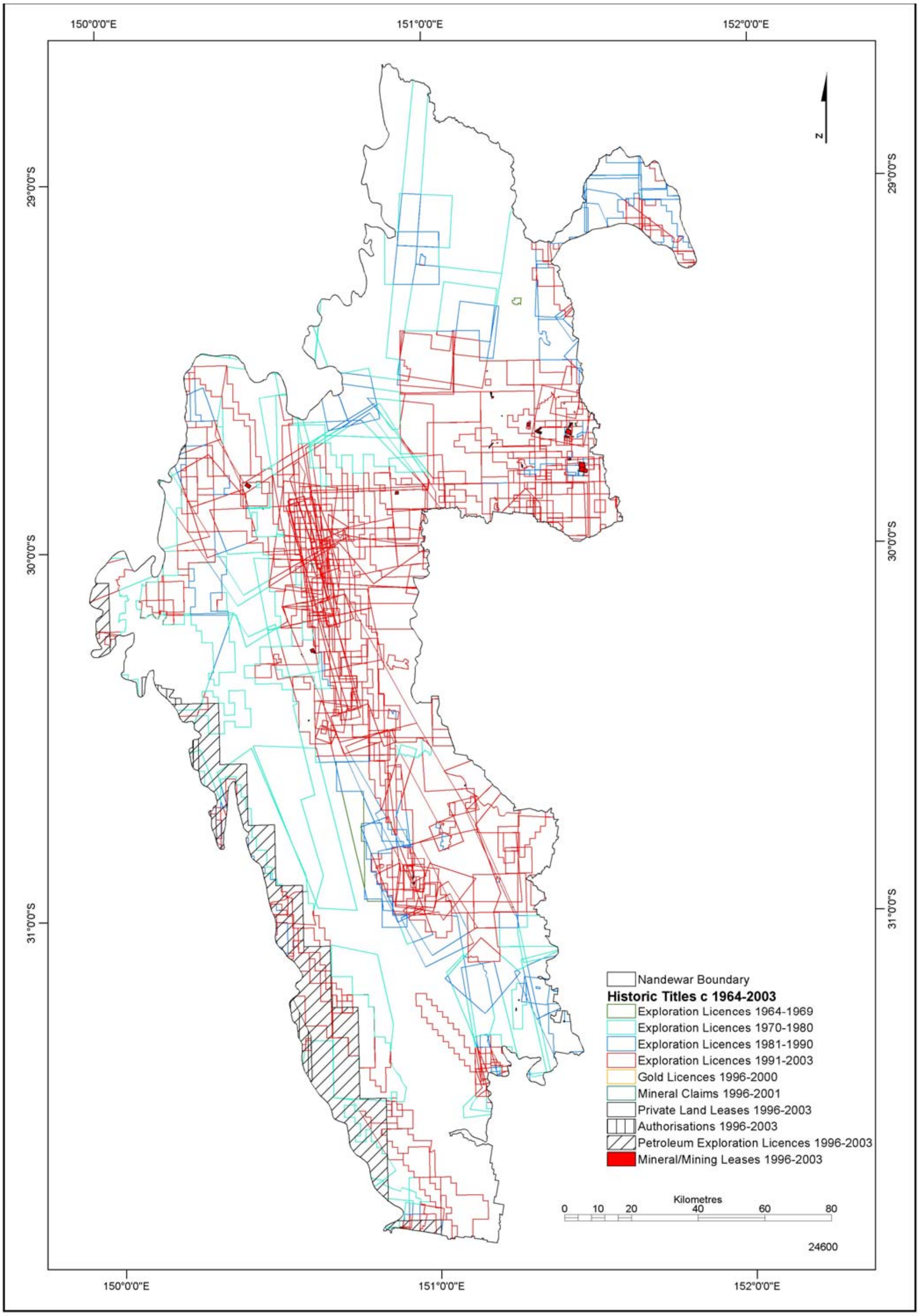



*Figure 4-D. Historic titles (1964 – 2003), Nandewar study area.*

The Nandewar study area contains numerous prospects in varying geological environments with different mineralising styles. The area has not been systematically or comprehensively explored using modern exploration methods. **Figure 4-D** shows the historic exploration and mining titles in the study area from 1964 to 2003. The figure shows that the exploration conducted during this time has been concentrated within the Inverell and Bingara areas, along the Peel Fault and within the Werrie Basin.

Limitations in the quantity of modern detailed geophysical data for the region have also been a factor restricting extensive exploration. Up until the recent Discovery 2000 Peel Project conducted by the Department of Mineral Resources, the only detailed geophysical data collected within the area were by individual exploration companies over parts of their tenements.

Exploration methodology for both minerals and petroleum has greatly improved since 1960 as a result of the development of better predictive geological models and improved field and laboratory techniques. These improved methodologies as well as improvements in mining and metallurgy and changes to domestic and international commodity prices have influenced exploration trends since this time.

From 1960 to 2003, exploration has focused on a variety of commodities including gold, diamond, limestone, sapphire, coal, molybdenum, tungsten, copper, diatomite, magnesium, and kaolin. Potentially significant new projects include magnesium processed from tailings at the former Woodsreef Asbestos Mine, and coal near Murrurundi, Werris Creek and Ashford.

Annual exploration expenditure within the Nandewar study area has averaged about A$2 million (2003) over the last ten years.

The following brief overview discusses the mining and exploration history of the more significant commodities within the study area.

### 4.3.1 Coal and Petroleum

#### Coal

Coal, with an estimated value of around A$150 million (2003), has been produced from the Nandewar study area since the late 19th century. Coal was produced from mines located in the Werrie Basin and at Ashford. In recent years much larger resources than what has been historically mined have been identified in the Nandewar study area.

Underground mining in the northern part of the Werrie Basin commenced at Werris Creek in 1925 after the Preston Coal Company had sunk four prospective shafts during the previous year **(Photograph 4-A).** Historical data indicates that coal was mined from the Tunnel (Lower) Seam and the Black (Upper) Seam. The mine was a small-scale operation employing a total of 13 people in 1928. The company continued to mine the coal resources until 1963 when contracts to supply coal to the railway were eventually cancelled (Pratt

1996). Incomplete records indicate that 325 000 tonnes of coal were mined between 1941 and 1963.

Mining in the southern part of the Werrie Basin also commenced around the early part of the 20th century, following the first reported discovery of coal during the sinking of water bores in the late 1800's. Coal was won by underground mining from an area northeast of Wingen, and just southwest of the current Bickham Proposal. The mine extracted coal from the lowest of seven seams in the Koogah Formation, however the steep dip of seams, flooding of the mine, and finally the onset of the Great Depression contributed to the closure of the mine in the 1930's (Hunter Development Brokerage 2003).

***Photograph 4-A. Historic Werris Creek Coal Mine***

In 1884, J. McDonald discovered coal near Ashford in the bed of what became known as Coal Gully, a tributary of the Severn River approximately 13 kilometres north of Ashford. Around the early part of the 20th century a small colliery was opened by means of an inclined tunnel driven on the base of the seam near the site of the original discovery. Earliest production was 712 tons by the Fraser Creek Mine Syndicate in 1901. In 1908, 855 tons of coal was produced under the name of the Ashford Coal Mine. Most of the coal produced was coked in beehive ovens for use at the Silver Spur Mine near Texas. An additional few hundred (tons) were produced before the mine closed in 1925.

In 1949, the then Bureau of Mineral Resources and the then New South Wales Department of Mines carried out a detailed mapping and drilling program at Ashford to define coal reserves to supply a proposed alumina plant and a local power plant (Owen et al. 1954). The drilling outlined sufficient reserves of coal for the Northwest County Council to build a small power plant **(Photograph 4-B)** adjacent to a new open cut mine **(Photograph 4-C)** and the supply of coal to this installation commenced in 1958. By 1976, the North West County Council (under Joint Coal Board supervision in 1962) had completed over 6 000 metres of drilling in the Ashford area. The drilling had outlined five major coal areas, of which the Ashford Colliery area and the area immediately north and south were identified as having economic potential. The mine closed in 1988.

From 1978 to 1979 White Industries Limited drilled an additional 11 131 metres in 230 holes of which only 39 seam cores were obtained and 36 were analysed. This drilling, and subsequent work by White Industries Limited (White Industries 1987) provide the most comprehensive data available on the Ashford area and has been used for the assessments in this report.

Small to moderate size resources of coal remains in the Ashford mine area. Despite the coal's coking properties, the Ashford Colliery only supplied the local power station due to the small reserves and the distance to ports. During its life, recorded production from the Ashford Colliery was 1.86 million tonnes of coal. In recent years interest has again been evident in the area, largely due to the generally high quality of the Ashford seam. The seam attains a thickness up to 17 metres, has a low raw coal ash content and has a high value as a coking coal. An exploration licence has recently been granted over the old Ashford Colliery area.

***Photograph 4-B. Northwest County Council's disused Ashford power plant (2003)***

***Photograph 4-C. Western face of main open cut showing thrust faulting, Ashford Colliery***

Coal exploration has increased significantly in the Nandewar study area in the last decade, largely due to a monopolisation and gradual decline of larger coal resources in the Hunter, Western, and Newcastle Coalfields. Exploration interest has been increasing particularly around Murrurundi and Werris Creek in the far south, from the early to mid 1990's, and more recently around Ashford in the far north.

### Coal Seam Methane

Coal Seam Methane (CSM) has traditionally been regarded as an unconventional source of natural gas but it has become a significant energy source in recent decades. Despite large coal resources in the State, CSM as a commodity has only been recognised commercially in New South Wales in the last decade. This is because the technology that is required to commercially extract methane from underground coal seams has only been developing since the 1970s. This technology is most advanced in the United States of America, where around 8% of the country's gas needs are now supplied from CSM, with further increases up to 17% expected. In Australia, pioneering CSM projects in Queensland (Fairview CSM field) and New South Wales (Camden CSM Project, Narrabri Project) are at an advanced stage of development or assessment.

Exploration for CSM within the Nandewar study area is current around Warialda in the far north where Pangaea Oil & Gas is evaluating the CSM potential of the Warialda Trough (Surat Basin) within PEL 437. Australian Coal Bed Methane is also actively exploring the CSM potential of the Maules Creek and Werrie Subbasins as part of PEL 1 and 286.

### Petroleum

Traces of a 'mineral oil' substance and gas bubbles were reported from water bores and 'natural artesian springs' near Tamworth in 1922 (Kenny, 1923a,b). Shallow artesian bores in a local artesian basin at times gave off considerable quantities of gas bubbles. The outrush of gas was reputedly more pronounced after the bores had been plugged partially for some time. Oil films on water bores were collected and analysed, along with a black greasy material from one bore, both of which revealed traces of petroleum. It was concluded at the time that the oil "may have formed by the destructive distillation of the soft parts of (the) vegetable and animal representatives" from the surrounding (Tamworth Belt) strata (Kenny, 1923b).

In the Nandewar study area, three exploration wells were drilled in the vicinity of Tamworth between 1921 and 1923 to test the petroleum potential of the Tamworth Belt sedimentary rocks. The wells were apparently drilled to test the validity of sketchy reports of oil shows noted on the ground. Another two exploration wells were drilled in 1963. The Tamworth Belt rocks have been mildly deformed, producing a series of north-trending and variably plunging folds that could constitute potential traps. Fluorescence, indicating the presence of hydrocarbons, was recorded in cuttings from wells.

Oil shale has been produced in limited quantities in the Nandewar study area. Total production value is difficult to quantify, as prices and markets have changed substantially, although a figure around A$45 million (2003) is indicated.

Oil shale deposits were discovered in the Werrie Basin approximately 5.5 kilometres north of Murrurundi before 1862 and by 1865 prospecting shafts had been sunk. Mr T. Affleck developed several shafts and adits in the area between 1883 and 1887 and in 1887 dispatched 660 tons of high-grade oil shale to various gas companies. Due to high costs of the extraction mining only continued intermittently. In 1909 British Australian Oil Co reopened the mines and built a retorting plant at Murrurundi. Between 1909 and 1911 the company raised in excess of 11 800 tons of oil shale, however, by 1913 the mines once again fell idle. The only record of further activity in the area was during 1924 when a new syndicate carried out prospecting and experimented with a new American type of retort (Lishmund 1974).

There has been little exploration in recent years in the area, and resources and potential for oil shale are considered to be limited. However, there have been increases in the level of conventional petroleum exploration activity along the western margins of the Nandewar study area in recent years.

## 4.3.2 Industrial Minerals and Construction Materials

### Asbestos and Magnesium

The Woodsreef Asbestos Mine in the Nandewar study area has operated intermittently from 1906 to 1983, however most production occurred from 1971to 1983. Production totals 550 000 tonnes of fibre from 24.2 Mt of ore, at an average grade of about 4% asbestos, and a value of around A$600 million (1970 price, inflation adjusted). The mine closed due to a collapse in demand associated with the recognition of severe health effects associated with asbestos mining and use.

***Photograph 4-D. Tailings dump from the Woodsreef asbestos mine***

Very large resources of magnesium are present in the tailings at the old mine **(Photograph 4-D).** These can be mined safely and constitute a potentially significant long-term resource (see **Appendix 3**). An assessment lease has been granted for a large magnesium project, with capital costs estimated at A$680 million (2003) and full time employment of around 350. The 24.2 Mt tailings dump contains in excess of 5.5 Mt of magnesium, which is equivalent to greater than A$20 billion in resources (2003). These resources could supply an 800 000t per annum refinery for 50 years. However, the long term prospects for magnesium in the Nandewar study area are unclear, partially due to the uncertainty of future global demand for magnesium, and also due to strong competition from similar projects in other states, and internationally.

### Diamonds

The Nandewar study area contains the Bingara Diamond Field located southwest of Bingara, and the northern part of the Copeton Diamond Field south of Inverell. Until recent decades these fields were Australia's largest historical diamond producers. The total value of diamond production within the Nandewar study area is difficult to quantify, due to changing prices and insufficient records, but is estimated to be at least A$25 million, and possibly up to A$50 million. The Bingara Diamond field produced in excess of 34 000 carats between

1872 and 1902, and the Copeton Diamond field produced well over 200 000 carats from 1872 to the 1910's (MacNevin 1977). At both fields diamonds were recovered predominantly from Tertiary age sediments but also from Quaternary age sediments. A few thousand carats have also been produced in recent years from the two fields. A very limited number of diamonds have also been recovered from a few other scattered localities, including areas about the Nandewar Range, and in southeastern parts of the Nandewar study area.

The Bingara diamond field was discovered accidentally by alluvial gold miners in Eagle Hawk Creek in 1872, although diamonds had been known in the area since 1865. A rush ensued with most production occurring intermittently between 1872 to 1887 and from 1892 to 1902. Lack of water plagued the mines and as a result washing operations were intermittent. The field was also inhibited by the unusual hardness of the diamonds, the lack of primary diamond sources, and from overseas competition. However, gem-quality proportions within the leads were reputedly very high. The most productive mine was the Monte Christo, in which up to 2 189 diamonds were reputedly washed from 15 loads of washdirt. Minor production has also occurred from the Monte Christo mine since 1997.

In the Copeton area, diamonds were discovered in 1872 during tin prospecting in Maids Creek near the Gwydir River. Intermittent production continued in the area until about 1905, after which production steadily declined. Most production occurred around the old Boggy Camp Township, (also called Bengonaway and later renamed Copeton), now situated under the waters of Copeton Dam. The most productive mines were within ten kilometres of the old Boggy Camp township, most of which are still accessible, and include the Malacca, Staggy Creek, Oaky Creek, Kirks Hill, Star of the South, and Streak of Luck mines. Kirks Hill was known for its richness, producing up to 1 100 carats of diamonds from four loads of washdirt. Several larger scale operations, such as the Malacca in the late 1890s and early 1900s were very successful (Weiderman 1981), and along with tin, contributed to the formation of a local stockmarket at Inverell. However, like the Bingara diamond field to the west, the unusual hardness of the diamonds, the lack of significant primary diamond sources, and overseas competition plagued the field.

Despite over 125 years of intermittent exploration and production, including the use of sophisticated exploration technology, a primary source or sources for diamonds in the region has never been found. A diamond found in the matrix of a dolerite dyke in 1904 close to the Oaky Creek deep lead has resulted in a great deal of scientific speculation and controversy (Pittman 1905). The reason for this is that the rare primary diamonds in the Nandewar study area do not fit traditional models of diamond formation, particularly those models developed in Africa, Russia, North America and Western Australia. Another five diamonds were recovered from bulk samples of this dyke in 1904 and 1912 (MacNevin 1977).

Formation of diamonds in eastern Australia does not fit into traditional models of diamond formation which are based heavily on the more well known South African diamond deposits. Modern exploration in New South Wales is increasingly using locally developed models such as the subduction-related diamond model recently proposed by the Geological Survey of New South Wales (Barron et al. 1996). More detailed discussion of diamond potential is contained within chapter seven.

Contemporary diamond exploration within the Nandewar study area has been concentrated mostly around the historical alluvial diamond fields at Bingara and Copeton **(Photograph 4-E).**

Modern exploration uses high-resolution geophysical and geological technology to target anomalies and potential primary sources in the broader landscape. This style of exploration was unavailable to traditional explorers. Furthermore, an improved understanding of diamond paragenesis in eastern Australia in recent years has led to an increase in interest in diamond exploration, particularly within the New England region. International discoveries of new diamond sources have not kept pace with rising demand during the second half of the 20th century. Despite the lack of past success within the Nandewar study area, exploration is currently occurring to locate primary diamond sources. In recent years, a few diamonds have been recovered adjacent to diatremes that are also shedding subduction model indicator minerals.

***Photograph 4-E. Rough diamonds from the Copeton area***

### Sapphire

The Glen Innes-Inverell area has been one of the world's most productive sapphire provinces. The field is famous for its abundance of quality dark blue gems, and in 1973 the region supplied about 80% of the world's sapphires (Weiderman 1981). The field straddles the Nandewar study area with most production occurring northeast of Inverell. To date more than A$150 million (2003) of sapphires have been produced within the Nandewar study area, from a total production of at least A$250 million (2003). Recent annual production averages $2 million. The most significant producers within the Nandewar study area include the Kings Plains Creek deposits **(Photograph 4-F)**, Frasers Creek, Weean Creek, and Horse Gully areas.

*Photograph 4-F. Rich sapphire-bearing wash, Kings Plains, Inverell*

In recent years production in the Nandewar study area has declined due to competition from lower cost operations in Kenya, Nigeria, Madagascar and China and depletion of world-class deposits such as Kings Plains. However, large areas of low-grade resources remain, and there is potential for further discovery of higher-grade resources.

Exploration interest and activity has remained relatively high in the last decade, and small to medium scale production has occurred in several areas through to the early 2000's. The Kew Valley Mine, located in the Kings Plain Creek area, was recently put on care and maintenance due to competition from overseas sources. About A$10-15 million (2003) in identified resources remain at the Kew Valley Mine.

Sapphires have been explored extensively since the 1960's northeast of Inverell. The area has produced dominantly mid to dark blue sapphires with lesser quantities of light blue and parti colored stones. Recent mining projects have been able to reduce costs through a better understanding of the local and regional geology, improved exploration technology, and improved local mining techniques (Pecover S., Pan Gem Resources (Aust) Pty Ltd, pers. comm., 2003). Sapphire markets have softened since the middle of 2001 due to the slowdown in world economic growth and have been at their most depressed levels experienced for many years.

Exploration for sapphire traditionally targeted modern streams draining areas of Tertiary basalt in the Inverell area. In 1982 informal observations during inspection of a sapphire mine at Elsmore by senior research geologists from the People's Republic of China provided a new line of thought on the origins of sapphire in New South Wales. A genetic association was proposed between sapphire and primary (and moderately reworked) Tertiary volcaniclastics rock units and a new exploration methodology emerged. Extraordinarily rich sapphire deposits being mined at Kings Plains during the mid 1980's were re-interpreted to be of volcaniclastic origin.

Explorers targeted older buried palaeochannels associated with interpreted eruptive centres for volcaniclastic units and discovered a number of very large deposits in the area during the late 1980s and early 1990s. Additional work by the Geological Survey of New South Wales during this project has shown a clear association between the occurrence of sapphire and the chemistry of the source volcanic rocks (see Chapter 7).

### Limestone

Limestone has been quarried in the Nandewar study area from the 1920s. Total past production is estimated to be in excess of A$150 million (2003). Currently the most significant operating quarries are the Jacksons and Sulcor Quarries located near Attunga. The Riverton Quarry is another major quarry located two kilometres to the north of the Nandewar study area in Queensland.

Demand for limestone has grown steadily over the second half of the 20th century, and this is projected to continue. In addition to specialty calcium carbonate powders, limestone is mined for use in the manufacture of cement, as a flux for local iron and steel manufacture, in the production of quick and hydrated limes, for chemical production and for agricultural purposes.

Limestone at Attunga currently produces burntlime for treating water and stabilising roads, and ground limestone for use as aggregate for roads, agricultural lime and flux for smelting non-ferrous metals.

Limestone exploration and mining has been conducted around Attunga **(Photograph 4-G)** and other areas near Tamworth, Murrurundi in the far south, and around Ashford and Tenterfield in the far north. Exploration for new deposits generally uses geological data to target areas along strike of known deposits. These areas are then tested by drilling and samples are analysed for their calcium and magnesium carbonate content.

There is good potential for further growth in the agricultural lime market because of the increasing problem of soil acidity in eastern New South Wales. Other potential new applications for limestone within the Nandewar study area include:

- as pulverised limestone for the underground coal industry, projected to develop further in the south, to the west and possibly in the far north of the Nandewar study area over the next 25 years;
- for stack scrubbing for coal-fired energy plants near Muswellbrook; and
- as a flux for new steel plants proposed for the Hunter Region (Department of Mineral Resources, 2003).

***Photograph 4-G. Jacksons (limestone) Quarry, Attunga***

### Diatomite

Diatomite is a sedimentary rock essentially composed of the siliceous skeletal remains of microscopic, one-celled, aquatic plants called diatoms, which on death accumulate to form a lightweight chalk-like deposit. The New South Wales deposits predominantly consist of the freshwater species *Melosira granulata.* Diatomite has various industrial applications, which include paint filler, paper filler, general absorbent (including pet litter), loose-fill insulation, fertiliser conditioner, and various ceramic applications. It is also used as a filtering aid, especially for dry cleaning fluids, beverages, sugar, oils, fuels, and in filters in swimming pools and water supplies. Diatomite has also been used as a soil conditioner (due to its trace metal content of Mg, Ca, and P). Like most industrial minerals diatomite competes with various synthetic materials in industrial markets.

Intermittent mining of extensive diatomite deposits of Tertiary age has been undertaken near Barraba from the early 1900's to the present **(Photograph 4-H)**. Recent annual production averages about $3 million. The diatomite is of varying quality with the diatomite at Barraba generally classed as medium to high clay diatomite, and a diatom content around 50-60% (Australian Diatomite Mining Ltd 1995). Diatomite deposits have also been prospected northwest of Barraba towards the Nandewar Range.

Diatomite exploration was significant near Barraba during the 1990's. Extensive resources were identified in the immediate area and production has gradually increased over the last few decades.

***Photograph 4-H. Bells Mountain Diatomite Mine, Barraba***

### Kaolin

Kaolin is a soft, fine, earthy, nonplastic, usually white rock composed essentially of clay minerals of the kaolin group, principally kaolinite. Kaolin is used in the manufacture of ceramics, refractories and paper.

Exploration for kaolin during the 1980's and 1990's identified significant resources near Elsmore in the northern half of the Nandewar study area. The deposit has been close to development in recent years, but has faced strong competition from similar kaolin projects in Queensland. Recent exploration for kaolin has identified resources in the Quirindi and Barraba areas.

### Zeolite

Zeolite has been produced in small to moderate quantities in the Nandewar study area since the late 1980's. One mine is currently operating near Werris Creek and there is exploration interest in the zeolite potential. Annual production averages about A$500 000 (2003). The total value of production of zeolite from the Nandewar study area to date is over A$4 million (2003).

Natural zeolites are a group of complex aluminosilicate minerals that are suitable for many applications in agriculture, pollution control, soil conditioning, as an additive in stockfeed, for odour control and in water treatment. Zeolites have an extraordinary ability to absorb, hold, release, and exchange different chemicals, nutrients, toxins and ions in a range of industrial and agricultural contexts. In New South Wales, zeolite is largely used in water and sewerage treatment projects, and as road base, although there is good potential for its use in a range of other applications, particularly agriculture.

In the Nandewar study area commercial deposits of zeolite occurs as an alteration product within late Early to Early Late Carboniferous volcanic rocks (vitric ash fall tuffs) deposited within lacustrine, fluvial, and shallow marine environments.

### 4.3.3. Metallic Minerals

#### Gold

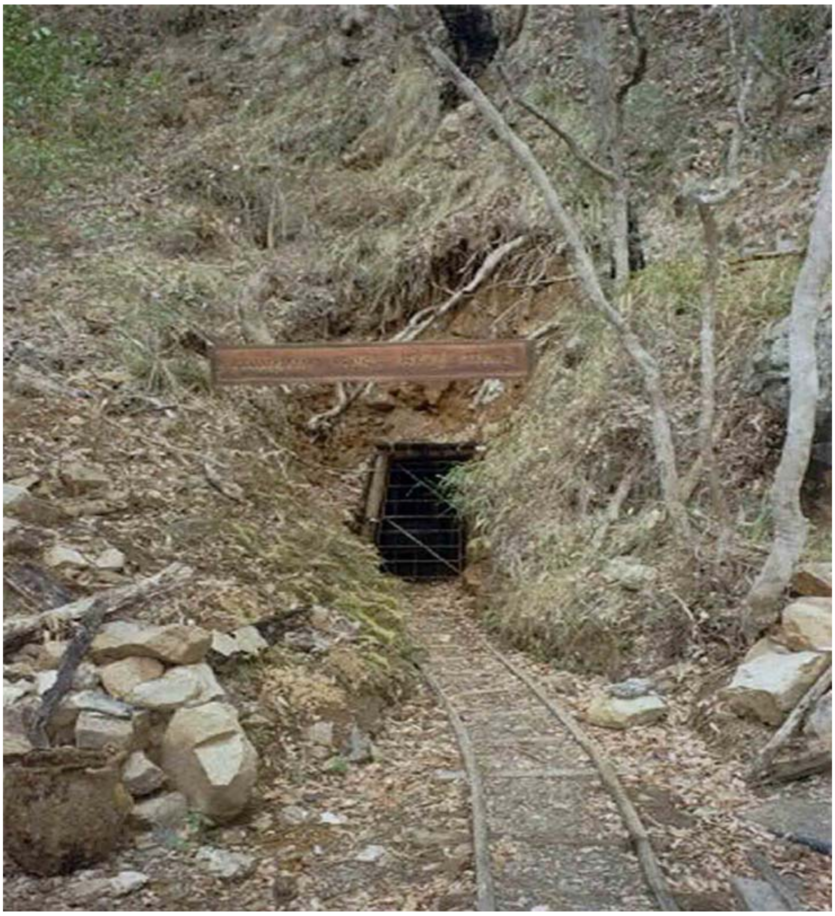
Gold was produced in significant quantities in the Nandewar study area from the early 1850's to the 1890's. The value of past production of gold amounts to over A$230 million (2003). There are several areas of historic gold rushes, particularly around Nundle (production greater than 9.4 t Au), Bingara and Upper Bingara (production greater than 1.3 t Au), Weabonga (production greater than 0.217 t Au), and Woodsreef (estimated production greater than 0.5 t Au).

The Nundle Gold Field was mostly an alluvial field, with production occurring between 1852 and the 1890's. At least 7 tonne of gold was produced from alluvial deposits of the Peel River and its tributaries, and from at least 12 alluvial mines in Tertiary deep leads near Hanging Rock. Over 70 hard rock deposits produced at least 2.4 t Au over an area of about 90 square kilometres near the Nundle township, particularly around Bowling Alley Point and Hanging Rock **(Photograph 4-I)**, during the 1860's to 1880's (Gilligan and Brownlow 1987). Minor gold production has also occurred in recent years from a few mines located near Hanging Rock. Minor antimony and tungsten was also produced from the field.

The Bingara and Upper Bingara Gold Fields produced over 1.3 tonne of gold from the 1850's to the 1890's (Brown and Stroud 1997, Brown et al. 1992). Production in the area was dominantly alluvial, however significant hard-rock producers included several mines southeast of Bingara such as the Hidden Treasure and Spring Creek mines, and around the Upper Bingara township including the Ballarat Mine. A small local operator has been recently active in the Ballarat Mine area (also known as the Three Creeks Gold Mine). Alluvial production occurred around the Upper Bingara township in areas such as Petticoat Flat and the Wet Lead.

The Weabonga Gold Field, located southeast of Tamworth, was mined mainly in the late 19th century with total recorded production of 0.217 t Au. The major producers were the Highland Mary and Little Tichbourne mines (Gilligan and Brownlow 1987).

The Woodsreef area contains several historical gold fields. These include the Baffler Subgroup, the Addison Subgroup, the Crow Mountain field, and the Tea Tree Creek Gold Field. Total production is estimated to be at least 0.5 tonne of gold. Most of the mines were worked in the second half of the 19th century, although some were worked well into the 1930's (Brown et al. 1992).



***Photograph 4-I. Historic Hanging Rock Reef Gold Mine, Nundle***

Since the 1960's, gold exploration within the Nandewar study has focused on areas around Bingara, Woodsreef, Werris Creek and Nundle. Gold exploration was particularly high in the early 1980's and again more recently, coinciding with times of high gold prices. Exploration for gold has also included intermittent exploration for tungsten, molybdenum and copper near Attunga.

Prior to the 1960's, most gold explorers sought small, high-grade deposits that were close to the surface and worked by small teams of miners. Modern exploration companies now target much larger, generally lower grade resources that are more amenable to contemporary mining technology. Exploration is now a global industry and projects compete with other international projects and provinces with similar geological characteristics. Although most gold production within the Nandewar study area has occurred before 1900, high gold prices and improved technology in recent decades has resulted in interest in the areas gold potential.

## Copper

Several small copper mines have been worked in the Nandewar study area, including Gulf Creek, Dungowan, and Attunga. The total value of past production is around A$10 million (2003).

The Gulf Creek Mine near Upper Bingara **(Photograph 4-J)** was discovered in 1889 with intermittent small-scale production through to about 1971. Most of the production occurred between 1894 and 1907. Around 1905 a rare example of spontaneous combustion, or 'chemical firing' of pyritic sulphides occurred at the 50-foot level, through exposure and oxidation of pyrite during mining operations (Carne 1908). Attempts to extinguish the fire were unsuccessful. The fire burned along the line of lode for 75 metres, and also several metres above and below the workings. There has been limited exploration in the immediate area in recent decades, with some small resources identified.

The Dungowan Copper Mine was a small copper mine located south of Tamworth, which was worked around the beginning of the 20th century, and also between 1968 and 1974.

The Attunga Copper Mine was worked between 1904 and 1916, and during the Second World War. Total production is recorded as 1 600 tonnes grading 6.2% copper and 7.75 ppm gold. Small to moderate size copper, tungsten, gold, molybdenum and silver resources have been identified in the area (see **Appendix 3**).

***Photograph 4-J. Historic Gulf Creek Copper Mine.***

### Tin

Tin has been produced in significant quantities in the Nandewar study area, with total production valued at over A$192 million (2003). The Tingha-Gilgai area is a major historic tin field, which straddles the boundary of the Nandewar study area south of Inverell. About half of the recorded total of greater than 70 000 t of tin (that is, greater than A$384 million (2003)) concentrate was recovered from within the Nandewar study area. The area was the first commercial tin field in New South Wales with most production occurring between 1872 and the 1920's, coinciding with high tin prices. Smaller production continued well into the 1970's, mainly by local operators. Minor tin has also been produced from other areas in the Nandewar study area.

The first discovery of economically workable tin deposits in New South Wales is credited to Joseph Wills who in 1870 sold some cassiterite (an ore of tin) he had found at Elsmore, near Inverell. Soon after, numerous workable deposits were found around Elsmore, Inverell and Tingha **(Photograph 4-K)**. During the 1870's to 1880's Australia became the largest producer of tin in the world, and during these years the Tingha-Gilgai division was one of Australia's most significant tin producers. Production peaked in the early 1880's when around 7 000 people worked the flats and gullies in the area. Most of the production was alluvial, with the greatest production from areas such as Copes Creek, Middle Creek, and numerous smaller creeks around Tingha. Dredging operations commenced in the area in the early 1900's and continued intermittently until the 1970's with around 40 dredges working the alluvials.

Tin exploration within the Nandewar study area has been relatively subdued in recent decades, despite the high degree of historical production. This downturn is mostly due to low tin prices, as other metals (particularly aluminium) within industrial markets have replaced tin during the 20th century. However, tin prices have been gradually rising in recent times. The Ardlethan Tin mine in southern New South Wales, another area of historical tin production, reopened in the 1990's and has made steady profits since this time. The low interest in tin exploration within the Nandewar study area may be due to the lack of recognition of the potential for large deposits in the New England region.

Long term opportunities are largely dependent on international tin prices, and being able to compete with large low cost operations overseas, particularly within Southeast Asia.

***Photograph 4-K. Elsmore Tin Mine***

### Molybdenum and Tungsten

Intermittent exploration for molybdenum and tungsten has been undertaken near Attunga since the early 20th century, and particularly since the late 1960s. A detailed review of mineral potential in the Attunga area is contained within **Appendix 3.**

### Miscellaneous

Numerous other commodities have also been mined and quarried in the Nandewar study area. These include chromium, arsenic, rhodonite **(Photograph 4-L)**, dimension stone, jade, olivine, serpentine, loam, mercury, magnesite, antimony, silver, road aggregate, prase, garnet, flint clay, construction sand, river gravel, and kaolin. Further discussion of some of these commodities is contained within chapter seven.

Recent exploration near Quirindi, has identified resources of bentonite and a few small operations have commenced close to the boundary of the Nandewar study area. There is potential for further bentonite exploration and production, especially in association with coal exploration and development, as bentonite and coal often occur within the same geological sequences.

Fossicking for semi-precious and precious minerals continues in the Nandewar study area to the present day, particularly about Inverell, Bingara and Nundle.

***Photograph 4-L. Rhodonite from the Woods manganese (rhodonite) deposit near Bendemeer.***

# 5 Identified Resources

## 5.1 IDENTIFIED RESOURCES

The *Australasian Code for Reporting of Mineral Resources and Ore Reserves* (the JORC Code)(Joint Ore Reserves Committee 1999) sets out minimum standards, recommendations and guidelines for public reporting of exploration results, mineral resources and ore reserves in Australasia. According to the JORC Code, mineral and petroleum 'resources' refer to what has been identified in the ground in such a form and quantity that there are reasonable prospects for eventual economic extraction. The location, quantity, grade, geological characteristics and continuity of a Mineral Resource are known, estimated or interpreted from specific geological evidence and knowledge. Mineral Resources are sub-divided, in order of increasing geological confidence, into Inferred, Indicated and Measured categories.

A Reserve is the economically mineable part of a Measured or Indicated Mineral Resource. Appropriate assessments, which may include feasibility studies, have been carried out, and include consideration and modification by realistically assumed mining, metallurgical, economic, marketing, legal, environmental, social and governmental factors. Reserves are sub-divided in order of increasing confidence into Probable Ore Reserves and Proved Ore Reserves.

What constitutes 'resources' and 'reserves' is by definition dynamic, intimately connected with such factors as international commodity prices, mining technology, and geological understanding. A variety of factors including new exploration technologies, new geological data, depletion of alternative supplies, changes in legislation and new methods of recovery can lead to re-evaluation of areas previously considered uneconomic. Further details on resources and reserves can be found in the Department of Mineral Resource databases for metallic minerals (METMIN, Downes 1999), and industrial minerals (INDMIN, Ray et al. 2003).

**Figure 5-A** shows the location of the identified resources within the Nandewar study area at 1 November 2003.

Resource (and reserve) values for coal, industrial minerals and construction materials, and metallic minerals within the Nandewar study area are shown in **Tables 5-A, 5-B and 5-C**. The values reported represent the best available data and may not necessarily constitute resources as defined by the *Australasian Code for Reporting of Mineral Resources and Ore Reserves*. The resources and reserves values have been derived from a range of sources of varying currency. The sources include company exploration reports, resource assessment studies and environmental impact statements. However, for a variety of reasons the Department of Mineral Resources does not routinely collect or systematically record up-to-date resource data, and therefore the following qualifications need to be applied to the data in these tables:

- some data is pre-mining and the resource may be currently being mined and possibly revised by exploration, therefore reported dates are also included in the tables
- most figures in the tables represent the most recent and 'unmined' resources. Construction material resources are the most uncertain or ambiguous, as these are not always reported to or recorded by the Department of Mineral Resources
- some resources may have been recently mined out or re-evaluated.
- Mineral Claims (MC), Gold Leases, (GL), Assessment Leases (AL), Private Lands Leases (PLL) and Mineral/Mining Leases (ML) for various minerals (and their applications) without reported resources have also been listed
- 'operating' and 'intermittently operating' quarries for various construction materials have been included although the Department of Mineral Resources do not issue titles for these commodities
- some sites contain multiple resource commodities, not always listed or mined
- current mining titles are included, even where operations have recently 'ceased' (for example some sapphire operations) or been placed on care and maintainence

### 5.1.1 Coal Resources

*Table 5-A. Identified coal resources, Nandewar study area*

| Main Commodity | Name | Resource (date) | Markets | Resource Category | Notes |
|---|---|---|---|---|---|
| **Coal** | Ashford Colliery Area | 22 Mt (2003) | Export coking coal | inferred (2003) | Resource, 2003 |
| | Ashford Coal Measures (all areas) | Unknown, potentially very large (100->1000 Mt) (2003) | | unknown | Limited regional data (not shown on figure) |
| | Bickham Coal Proposal | 40 Mt (2003) | Export thermal market | indicated | Propose to bulk sample 25 000 tonnes, 2003 |
| | Creek Resources | 5-10 Mt (2003) | | | Exploration ongoing, 2003 |

### 5.1.2 Petroleum and Coal Seam Methane Resources

There are no petroleum or coal seam methane resources identified in the Nandewar study area.

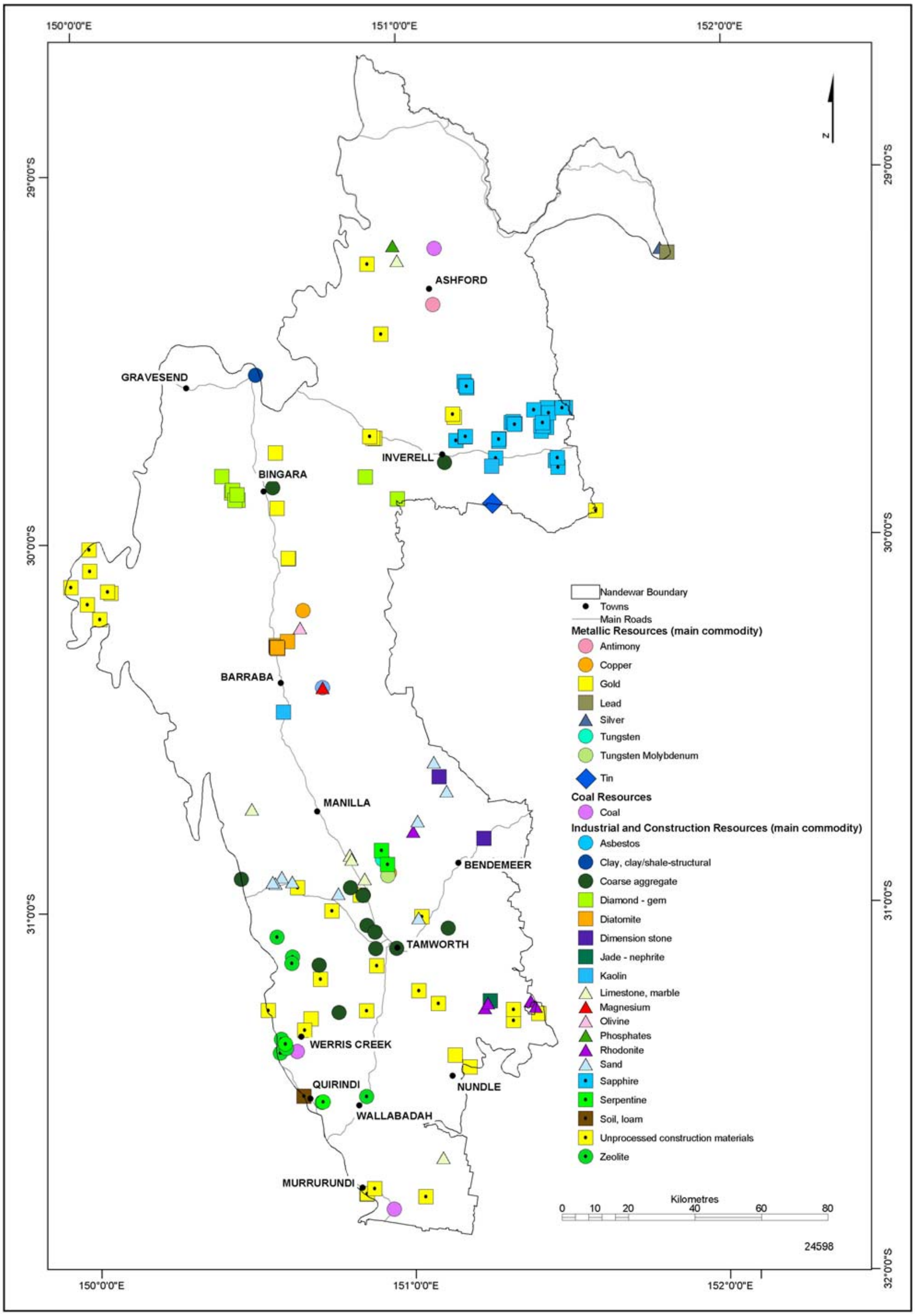



*Figure 5-A. Location of identified resources, Nandewar study area*

### 5.1.3 Industrial Mineral and Construction Material Resources

*Table 5-B. Identified industrial mineral and construction material resources, Nandewar study area*

| Main Commodity | Quarry/ Prospect | Recent Operating Status (date of record, INDMIN) | Long term Status (date of last recorded operation, INDMIN) | Resource (last reviewed/ available date) | Grade | Resource Category | Resource Status |
|---|---|---|---|---|---|---|---|
| **Asbestos** | Woodsreef Asbestos | Not operating (Aug 1996) | Ceased (1983) | 70 Mt (1983) | 4% asbestos | Inferred | Resource |
| **Clay/shale - structural** | Brick Kiln deposit | Not operating (Sep 1988) | Ceased (unknown) | 100 000 tonne (1997) | | Inferred | Resource |
| **Coarse aggregate** | Cockburn River, Pioneer | Not operating (Aug 1997) | Ceased (unknown) | 63 000 $m^3$ (1987) | | Inferred | Pre-mining resource?, production not recorded |
| | Taradale Gravel Deposit | Not operating (Oct 1996) | Prospect/resource | 100 000 $m^3$ (1988) | | Inferred | Pre-mining Resource?, production not recorded |
| | Jeffries Pit | Operating (March 2003) | Intermittent (unknown) | 6 000 $m^3$ (1995) | | Inferred | Pre-mining resource |
| | Peel River, Appleby | not operating (Aug 1997) | Ceased (unknown) | 23 600 $m^3$ (1987) | | Inferred | Pre-mining resource?, production not recorded |
| | Peel River, Wallamore Anabranch | Operating (Mar 1998) | Continuous (June 2000) | 78 000 m3 (1987) | | Inferred | Pre-mining resource |
| | Stangers Road | Not operating (Aug 1997) | Prospect/resource | 9 000 000 tonne (1996) | | Inferred | Resource |
| | Wyalla Mountain | Not operating (Aug 1997) | Prospect/resource | 1 000 000 tonne (1982) | | Inferred | Resource |
| | Inverell Aggregates Quarry | Operating (June 1999) | Continuous (June 2002) | Not available | | | Not available |
| | Scanlons Quarry Tamworth | Operating (Aug 1997) | Intermittent (unknown) | Not available | | | Not available |
| | Peel River Tamworth | Operating (Aug 1996) | Continuous (June 1999) | Not available | | | Not available |
| | Namoi Terrace, Carroll | Operating (Aug 2002) | Continuous (June 1995) | Not available | | | Not available |

| Main Commodity | Quarry/ Prospect | Recent Operating Status (date of record, INDMIN) | Long term Status (date of last recorded operation, INDMIN) | Resource (last reviewed/ available date) | Grade | Resource Category | Resource Status |
|---|---|---|---|---|---|---|---|
| | Betts Quarry, Old Keera Road Bingara | Operating (Aug 1996) | Intermittent (June 1998) | Not available | | | Not available |
| | Suttons Pit, Tamworth | Operating (Aug 1996) | Continuous (June 1999) | Not available | | | Not available |
| **Diamond** | Craddocks Claim | Not operating (March 1997) | Ceased (historical) | 30 800 $m^3$ (Before 1997) | | Inferred | Resource |
| | Eaglehawk Claim | Not operating (Sep 1998) | Ceased (historical) | 72 000 $m^3$ (Before 1997) | 0.14g/t Au, 1.37cts/ $m^3$ | Inferred | Resource |
| | Palmers Deposit | Not operating | Ceased (historical) | 1.346 Mt | | Inferred | Resource |
| | Monte Christo Diamond Mine | Operating (July 2003) | Intermittent (2002) | 80 000 tonne (Before 1997) | | unknown | Pre-mining resource, recent mining, current MC194 |
| | Wilkinson and Legge mine | Not operating (July 2003) | Ceased (historical) | 55 000 $m^3$ (Before 1997) | 0.32cts/ $m^3$ | Inferred | Resource |
| | Surface Hill Alluvials | Not operating (Sep 1998) | Ceased (historical) | 125 000 tonne (Before 1997) | | Inferred | Resource |
| | Staggy Creek | Not operating (Aug 2003) | Intermittent (Approx. 2001) | Confidential | | | Confidential |
| | Malacca | Operating (Sep 1998) | intermittent | Not available | | | Not available, current ML6153 |
| **Diatomite** | Barraba Diatomite | Operating (Dec 2002) | Continuous (June 2000) | 8 056 000 $m^3$ (1997) | 36-60 wt%, $Fe_2O_3$ 1.3-4.7wt% | measured | Resource includes several areas, pre-mining resource (1997), Current ML1096, and ML1195 |
| | Kyooma East Diatomite | Operating (May 2000) | Continuous (not available) | 1 300 000 tonne (1986) | | unknown | Pre-mining resource (1986), Current ML975,and ML976 |

| Main Commodity | Quarry/ Prospect | Recent Operating Status (date of record, INDMIN) | Long term Status (date of last recorded operation, INDMIN) | Resource (last reviewed/ available date) | Grade | Resource Category | Resource Status |
|---|---|---|---|---|---|---|---|
| | Bells Mountain (Site id 2256) | Operating (Dec 2002) | Continuous (not available) | Not available | | | Not available, Current ML1217, and ML1178 |
| | North Bells Mountain (ML1256) | Not operating (ML1256, May 2000) | Ceased (unknown) | Not available | | | Not available Current ML1256 |
| | MC238 (Barraba Diatomite area) | | | Not available | | | Not available, current MC238 |
| | MC239 (Barraba Diatomite area) | | | Not available | | | Not available, current MC239 |
| **Dimension stone - granite** | Gunnalong | Not operating (2002) | Ceased (2001) | 2 600 000 tonne (1995) | | Inferred | Pre-mining resource |
| **Jade - nephrite** | Hosking - ML791 | Operating (Jan 2002) | Intermittent (June 2002) | Not available | | | Not available, current ML791 |
| **Kaolin** | Elsmore Kaolin | Not operating (Mar 2002) | Prospect/resource | 752 400 tonne (1997) | | measured | Consent, not mined (2002) |
| | Elijah Hill Clay Pit | Not operating (June 2001) | Intermittent (June 1996) | Not available | | | Not available, current ML1086, PLL1204 |
| **Limestone** | Jacksons Quarry Attunga | Operating (Oct 2003) | Continuous (June 2001) | 14 000 000 tonne (1988) | | proven | Consent, Pre-mining resource, current ML1394, PLL1297 |
| | Sulcor Limestone Quarry | Operating (May 2002) | Continuous (June 2001) | 1 600 000 tonne (1999) | 97.5%$CaCo_3$, 0.62 $MgCo_3$, 0.87%$SiO_2$, 1.32%$Al_2O_3$+$Fe_2O_3$ | Inferred | Consent, Pre-mining resource, current ML1470 |
| | Woodstock Limestone Proposal (MLA220) | Not operating (June 2002) | Prospect/resource | 282 000 $m^3$ (2002) | | unknown | Resource, current MLA220 |
| | Ashford Limestone | Not operating (May 2002) | Prospect/resource | 40Mt (1995) | | Inferred | Resource |

| Main Commodity | Quarry/ Prospect | Recent Operating Status (date of record, INDMIN) | Long term Status (date of last recorded operation, INDMIN) | Resource (last reviewed/ available date) | Grade | Resource Category | Resource Status |
|---|---|---|---|---|---|---|---|
| | Stearns Ridge Limestone | Not operating (Mar 2003) | Prospect/resource | Confidential | | | Confidential |
| **Magnesium** | Woodsreef Magnesium (Tailings) (ALA28) | Not operating (2003) | Prospect/resource | 24.2 Mt (2002) | 38.3% MgO (1999) (23.1% Mg) | measured | Resource, A$680 million capital cost (2002), ALA28 |
| **Olivine** | Doonba Dunite, (MC156) | Operating (Jan 2002) | Intermittent (June 1997) | 425 000 tonne (1996) | | measured | Pre-mining resource, current MC156 |
| **Phosphates** | Ashford Caves Guano Deposit | Not operating (July 1996) | Ceased (Dec 1952) | 4260 tonne (1952) | 8% $P_2O_5$ | Inferred | Resource (1952) |
| **Rhodonite** | Woods Manganese | Operating (May 2000) | Intermittent (June 2001) | Not available | | | Not available, current ML1004 |
| | Pacey Mine | Operating (2003) | Intermittent (Jan 2003) | Not available | | | Not available, current ML1246 |
| | Spring Creek Rhodonite | Operating (May 2000) | Intermittent (unknown) | Not available | | | Not available, PMA5 |
| | Ogunbil Rhodonite, Whittens | Operating (May 1998) | Intermittent (unknown) | Not available | | | Not available, PMA (1998) |
| | Cooee Creek Manganese | Operating (May 2000) | Intermittent (unknown) | Not available | | | Not available, PMA (2000) |
| | ML1213 (Ivy Ellen) | Not operating (1996) | Ceased (unknown) | Not available | | | Not available, Current ML1213 |
| **Sand** | Retreat, MacDonald River | Not operating (Nov 2003) | Ceased (unknown) | 10 000 $m^3$ (1988) | | Inferred | Unknown, pre-mining resource? |
| | Sunnyside, Betts Lane | Operating (Aug 1997) | Continuous (unknown) | 80 000 $m^3$ (1995) | | Inferred | Pre-mining resource |
| | Campbell/ Matfield | Not operating (Jan 1997) | Prospect/resource (unknown) | 52 000 $m^3$ (1994) | | Inferred | Resource |
| | Peel River Bubbogullian | Not operating (Sep 1997) | Ceased (unknown) | 60 000 $m^3$ (1991) | | Inferred | Pre-mining resource |
| | Woolaston | Not operating (Jan 1997) | Prospect/resource | 29 000 $m^3$ | | Inferred | Resource |

| Main Commodity | Quarry/ Prospect | Recent Operating Status (date of record, INDMIN) | Long term Status (date of last recorded operation, INDMIN) | Resource (last reviewed/ available date) | Grade | Resource Category | Resource Status |
|---|---|---|---|---|---|---|---|
| | | | (unknown) | (1994) | | | |
| | Swanton | Not operating (Jan 1997) | Prospect/resource (unknown) | 45 000 $m^3$ (1994) | | Inferred | Resource |
| | Swanton North | Not operating (Jan 1997) | Prospect/resource (unknown) | 29 000 $m^3$ (1994) | | Inferred | Resource |
| | Watsons Creek Sand Pit | Operating (July 1996) | Intermittent (June 1995) | Not available | | | Not available |
| | Tilmunda Station Bendemeer | Operating (Jan 1997) | Continuous (June 2002) | Not available | | | Not available, current ML1312, (other commodities also) |
| | Sunnyside, Betts Lane | Operating (Aug 1997) | Continuous (not available) | Not available | | | Not available |
| **Sapphire** | Wilson (ML860) | Operating (Aug 2000) | Intermittent (not available) | Not available | | | Current ML860 |
| | Swan Vale, ML1205 | Operating (June 2003) | Intermittent (June 2003) | Not available | | | Current ML1205 |
| | Horse Gully, Wilson, ML240 | Operating (Mar 2003) | Intermittent (not available) | Not available | | | Current ML240 |
| | Horse Gully (Site id 7790) | Operating (Mar 2003) | Intermittent (not available) | Not available | | | Tailings being worked (2003 INDMIN), but no current titles (2003), PMA190 |
| | Frazers Creek, Airlie Brake P/L | Operating (Aug 2000) | Intermittent (not available) | Not available | | | Current ML645, current ML1142 adjoins |
| | Braemar | Operating (April 2003) | Intermittent (not available) | Not available | | | Current ML881 |
| | Kew Sapphire Mine, (ML1492) | Care and Maintenance (June 2003) | Not operating (Nov 2003) | Confidential | | | Confidential, recent mining, current ML1492 |
| | ALA29 (Kew area) | | Not available | | | | Not available, current ALA29 |
| | Narran Vale | Not operating | Ceased (1999) | 120 000 $m^3$ | Not | Inferred | Pre-mining |

| Main Commodity | Quarry/<br><br>Prospect | Recent Operating Status<br><br>(date of record, INDMIN) | Long term Status<br><br>(date of last recorded operation, INDMIN) | Resource<br><br>(last reviewed/<br><br>available date) | Grade | Resource Category | Resource Status |
|---|---|---|---|---|---|---|---|
| | | (June 2003) | | (1994) | stated | | resource, current ML1374 |
| | AL2<br><br>(Yarrandoo) | Not operating (Dec 2002) | Prospect/resource | 134 000 $m^3$<br><br>(1998) | 40g/bcm | indicated | Consent, not mined (2002), current AL2 |
| | Carinya Prospect (MC0182) | Operating (June 2003) | Intermittent (not available) | Confidential | | | Confidential , current MC0182 |
| | Kings Plains (western feeder)<br><br>(Site id 3423) | Operating (April 1997) | Intermittent (not available) | Confidential | | | Confidential |
| | Menari-Swan Vale | Operating (May 2000) | Intermittent (not available) | 24 000 bcm<br><br>(1996) | | Inferred | Pre-mining resource, current ML1505 |
| | Frazers Creek<br><br>(Site id 3583) | Operating (June 2003) | Intermittent (not available) | 80 000 $m^3$<br><br>(1994) | | Inferred | Pre-mining resource, current ML1142, current ML645 adjoins |
| | Red Hill-Frazers Creek | Not operating (June 2003) | Prospect/resource | Confidential | | | Confidential resource, no current title |
| | Weean | Not operating (June 2003) | Prospect/resource | 125 000 bcm<br><br>(2001) | 44.5g/bcm | Inferred | Resource |
| | MC234<br><br>(Apple Tree Gully area) | | | Not available | | | Not available, current MC234, no INDMIN record |
| | MC235<br><br>(Apple tree gully area (2)) | | | Not available | | | Not available, current MC235, no INDMIN record |
| | ML181<br><br>(Horse Gully area) | | | Not available | | | Not available, current ML181, no INDMIN record |
| | ML549<br><br>(Horse Gully | | | Not available | | | Not available, current ML549, no INDMIN |

| Main Commodity | Quarry/ Prospect | Recent Operating Status (date of record, INDMIN) | Long term Status (date of last recorded operation, INDMIN) | Resource (last reviewed/ available date) | Grade | Resource Category | Resource Status |
|---|---|---|---|---|---|---|---|
| | area (2)) | | | | | | record |
| | ML1320 (Swan Vale-Warrawee area) | | | Not available | | | Not available, current ML1320, no INDMIN record |
| | ML1251 (Strathdarr) | Not operating (May 2000) | Ceased (1998) | Not available | | | Not available, recent mining (ceased), but current ML1251 |
| | MC111 (Walkers area) | | | Not available | | | Not available, current MC111, no INDMIN record |
| | MC112 (Walkers area) | | | Not available | | | Not available, current MC112, no INDMIN record |
| | PLL1393 (Swan Brook area) | | | Not available | | | Not available, current PLL1393, no INDMIN record |
| | PLL3859 (Swan Brook area (2)) | | | Not available | | | Not available, current PLL3859, no INDMIN record |
| | ALA19 (Kings Plains area) | | | Not available | | | Not available, current ALA19 |
| **Serpentine** | Tundi Serpentinite Mine | Operating (Aug 1997) | Intermittent (June 2001) | Not available | | | Not available, current MC143, PMA30 |
| | Abras Serpentine | Operating (May 2000) | Intermittent (June 1999) | Not available | | | Not available, current ML1310 |
| **Soil, loam** | Manuka | Operating (March 1994) | Intermittent (not available) | Not available | | | Unknown status, (No current title 2003, but not an industrial mineral) |

| Main Commodity | Quarry/ Prospect | Recent Operating Status (date of record, INDMIN) | Long term Status (date of last recorded operation, INDMIN) | Resource (last reviewed/ available date) | Grade | Resource Category | Resource Status |
|---|---|---|---|---|---|---|---|
| **Unprocessed Construction materials** | Wattle Park Pit | Operating (July 2003) | Intermittent (not available) | Not available | | | Not available |
| | Waters'-J23 | Operating (Jan 1994) | Intermittent (not available) | Not available | | | Not available |
| | Wanderra Pit, Ashford Road | Operating (June 2000) | Intermittent (June 1999) | Not available | | | Not available |
| | Wandera Lane, Inverell | Operating (Dec 1996) | Intermittent (June 1996) | Not available | | | Not available |
| | Parker's-O24 | Operating (Jan 1994) | Intermittent (not available) | Not available | | | Not available |
| | Mcnall's-K25 | Operating (Jan 1994) | Intermittent (not available) | Not available | | | Not available |
| | Little Plain Pit 2 | Operating (July 2003) | Intermittent (not available) | Not available | | | Not available |
| | Little Plain Pit 1 | Operating (July 2003) | Intermittent (not available) | Not available | | | Not available |
| | Horgmans Pit, Milbrodale | Operating (Oct 2002) | Intermittent (not available) | Not available | | | Not available |
| | Glencairn-I21 | Operating (Jan 1994) | Intermittent (not available) | Not available | | | Not available |
| | Everys | Operating (Sep 1999) | Intermittent (not available) | Not available | | | Not available |
| | Coburn | Operating (May 2000) | Intermittent (not available) | Not available | | | Not available |
| | Cascades-I24 | Operating (Jan 1994) | Intermittent (not available) | Not available | | | Not available |
| | Campbells Creek West | Operating (Mar 1994) | Intermittent (not available) | Not available | | | Not available |
| | Campbells Creek East | Operating (Mar 1994) | Intermittent (not available) | Not available | | | Not available |
| | Betts Lane, RTA | Operating (Aug 1997) | Intermittent (not available) | Not available | | | Not available |
| | Benhams Quarry | Operating (Aug 2000) | Intermittent (not available) | Not available | | | Not available |
| | Banool-G23 | Operating (Jan 2004) | Intermittent (not available) | Not available | | | Not available |
| | Amberley-I25 | Operating (Jan 2004) | Intermittent (not available) | Not available | | | Not available |
| | Ponto Pit | Operating (Aug 1997) | Intermittent (not available) | 5 400 $m^3$ | | Inferred | Pre-mining resource |

| Main Commodity | Quarry/ Prospect | Recent Operating Status (date of record, INDMIN) | Long term Status (date of last recorded operation, INDMIN) | Resource (last reviewed/ available date) | Grade | Resource Category | Resource Status |
|---|---|---|---|---|---|---|---|
| | | | | (1995) | | | |
| | Kennedy Pit | Operating (Aug 1997) | Intermittent (not available) | 3 000 $m^3$ (1995) | | Inferred | Pre-mining resource |
| | Kevin Tongue Pit | Operating (Aug 1997) | Intermittent (not available) | 4 000 $m^3$ (1995) | | Inferred | Pre-mining Resource |
| | McCulloch Pit | Operating (Aug 1997) | Intermittent (not available) | 3 500 $m^3$ (1995) | | Inferred | Pre-mining resource |
| | Mills Pit | Operating (Aug 1997) | Intermittent (not available) | 20 000 $m^3$ (1995) | | Inferred | Pre-mining resource |
| | Oslands Pit 1 | Operating (Aug 2000) | Intermittent (not available) | 8 000 $m^3$ (1995) | | Inferred | Pre-mining resource |
| | Oslands Pit 2 | Operating (Aug 1997) | Intermittent (not available) | 4 000 $m^3$ (1995) | | Inferred | Pre-mining resource |
| | Rostry Pit | Operating (Aug 1997) | Intermittent (not available) | 65 500 $m^3$ (1995) | | Inferred | Pre-mining resource |
| | Saw Pit Gully Pit | Operating (May 2000) | Intermittent (not available) | 200 000 $m^3$ (1996) | | Inferred | Consent, Pre-mining resource |
| | Wallangra Gravel Pit | Operating (May 2000) | Intermittent (not available) | 25 000 $m^3$ (1996) | | Inferred | Consent, Pre-mining resource |
| | Werris Creek Tip Pit | Operating (Aug 1997) | Intermittent (not available) | 25 000 $m^3$ (1995) | | Inferred | Pre-mining resource |
| | Somerton Common | Operating (Aug 1997) | Intermittent (not available) | 15 000 $m^3$ (1995) | | Inferred | Pre-mining resource |
| | Spains Lane Tamworth | Operating (Aug 1997) | Intermittent (not available) | 179 000 $m^3$ (not available) | | Inferred | Pre-mining resource |
| **Zeolite** | Bindawalla Zeolite Mine | Operating (Mar 2001) | Continuous (June 2001) | 2 500 000 tonne (1995) | | indicated | Consent, Pre-mining resource, current ML1395 |
| | AL3 (Bindawalla area) | | | Not available | | | Not available, current AL3 |
| | | | | | | | |

| Main Commodity | Quarry/ Prospect | Recent Operating Status (date of record, INDMIN) | Long term Status (date of last recorded operation, INDMIN) | Resource (last reviewed/ available date) | Grade | Resource Category | Resource Status |
|---|---|---|---|---|---|---|---|
| | Currabubula Zeolite Prospect | Not operating (June 2003) | Prospect/resource | 250 000 tonne (1993) | 135 meq/100 g | Inferred | Resource |
| | Escott Zeolite Mine | Operating (March 2001), not operating? (2003) | Continuous (June 2000) | 500 000 tonne (1999) | | proven | Consent, Pre-mining resource, current ML1356 |
| | AL7 (Werris Creek area) | | | Not available | | | Not available, current AL7 |
| | Turiwala Zeolite Deposit | Not operating (March 2001) | Prospect/resource | Confidential | | | Confidential |
| | Oaky Creek Zeolite Prospect | Not operating (Nov 1998) | never worked | 122 000 tonne (1998) | CEC 85, AEC 83 | Inferred | Resource |
| | Sheedys Zeolite | Not operating (June 2003) | Prospect/resource | 400 000 tonne (1991) | | Inferred | Resource |
| | Gaspard Creek Zeolite Prospect | Not operating | Prospect/ resource | 300 000 tonne (1993) | | Inferred | Resource |
| | The Gap Zeolite | Not operating (May 2000) | Prospect/resource | 50 000 tonne (1993) | | indicated | Resource |

### 5.1.4 Metallic Minerals

***Table 5-C. Identified metallic mineral resources, Nandewar study area***

| Main Commodity | Name | All Commodities | Resource (last reviewed date) | Grade | Resource Category |
|---|---|---|---|---|---|
| **Antimony** | Frasers Creek Antimony Deposit | Sb | 1 000 tonne (1997) | | Inferred |
| **Copper** | Attunga Copper-Gold Mine | Cu, Au, Ag, Mo | 20 000 tonne (2003) | 4-10% Cu, 0.6-15ppm Au, 100-200ppm Ag, 0.1-1.0% Mo, 0.2% Bi | Inferred, includes current ML204, PLL3683 |
| **Gold** | Hidden Treasure mine | Au | 260 000 tonne (1997) | 2ppm Au | Inferred |
| | Hillside Prospect | Au (Ag, Zn, Cu) | 132 000 tonne (1993) | 7.8ppm Au | Inferred |
| | Gulf Creek Copper Mine | Cu, Ag, Pb, Zn | 50 000 tonne (1952) | unknown | Inferred |
| | Folly Prospect (Rowdy Gully) | Au | 336 000 tonne (1987) | 4.75ppm Au | Inferred |
| | Marquis of Lorne | Au | 336 000 tonne (1991) | 4.75ppm Au | Inferred |
| | MC181 (Bobby Whitlow area) | Au | Not available | | Not available, current MC181 |
| | MC165 (Lady Jersey area) | Au | Not available | | Not available, current MC165 |
| | MC133 (Three Creeks Gold Mine area) | Au | Not available | | Not available, current MC133 |
| | MC134 (Three Creeks Gold Mine area) | Au | Not available | | Not available, current MC134 |
| | GL5890 (Three Creeks Gold Mine area) | Au | Not available | | Not available, current GL5890 |
| **Lead** | Torny Mine | Ag,Pb | 51 000 tonne (unknown) | 466ppm Ag, 0.1% Cu, 11.9% Pb, 0.2% Sn, 2.3% Zn | Inferred |
| **Silver** | Burra Silver Mine | Pb,Ag,Zn | 60 000 tonne (1997) | 933ppm Ag, 20% Zn | Inferred |

| Main Commodity | Name | All Commodities | Resource<br><br>(last reviewed date) | Grade | Resource Category |
|---|---|---|---|---|---|
| **Tin** | Tingha Tin Field (all deposits, about half in Nandewar study area) | Sn | 32 Mt<br><br>(2002) | 0.27% Sn | Inferred |
| **Tungsten** | Kensington Prospect | W | 4.2 Mt<br><br>(2003) | 0.17% $WO_3$. | Inferred |
| **Tungsten, Molybdenum** | Attunga Scheelite Deposit (Southern Skarn) | W, Mo | 1.25 Mt<br><br>(2003) | 0.82% $WO_3$, 0.14% Mo | Inferred |

# 6 Current Mining and Exploration

## 6.1 TITLES AND APPLICATIONS (SEPTEMBER 2003)

### 6.1.1 Introduction

Exploration and mining in New South Wales for minerals (including coal) is principally governed by the *Mining Act 1992*, administered by the Department of Mineral Resources, and by the associated regulations and conditions. Under the *Mining Act 1992*, there are three principal forms of title**,** Exploration Licence (EL), Assessment Lease (AL) and Mining Lease (ML). The Mineral Claim (MC) is a title that can be granted to cater for smaller operations, prospecting and mining in areas up to two hectares in size. Some current coal exploration licences were granted prior to the 1992 Act and are referred to as Authorisations (AUTH). Some Gold Leases (GL) and Private Lands Leases (PLL) were also granted prior to the 1992 Act in the Nandewar study area.

Construction material extraction is controlled by a number of State and Local Government agencies. Some materials, like clay and shale used for brick making, are prescribed as minerals under the *Mining Act 1992* and can be extracted under mining titles issued by the Department of Mineral Resources. Most construction materials are not prescribed minerals under the *Mining Act 1992* and hence a mining title is not required to explore for, or extract these materials. Materials that are not prescribed minerals are owned by the landowner where they occur on freehold land, and by the Crown in the case of Crown land. Where such materials occur on Crown land, a Crown Lands Licence to extract them must be obtained from the Department of Lands. Where such materials occur in State forests, a forest materials licence to extract them must be obtained from State Forests of New South Wales.

The Department of Mineral Resources has a recognised and accepted role in assessing the State's resources of construction materials and providing advice on their management and extraction.

The ownership of petroleum in New South Wales is vested in the Crown. Exploration and production of petroleum (including conventional petroleum, natural gas and coal seam methane gas) is treated separately to minerals. Petroleum is regulated by the *Petroleum (Onshore) Act 1991* and the associated regulations.

There are three titles that are relevant to the exploration for, and evaluation of, oil and gas. They are the Petroleum Exploration Licence (PEL), the Assessment Lease (AL) and the Special Prospecting Authority (SPA). These titles are to be distinguished from a Production Licence (PL) which is a separate title permitting the extraction and sale of oil and gas.

**Figure 6-A** shows the location of all the extant (24 September 2003) titles and applications issued by the Department of Mineral Resources. Details of the Title Holder, Date of Grant etc are shown in **Appendix 4** or can be derived by enquiring on the shapefile entitled 'ntitles030924.shp' located on the data disk.

### 6.1.2 Mining Titles and Applications

The following mining titles and applications were extant in the Nandewar study area on 24 September 2003:

***Table 6A. Mining titles and applications 24 September 2003, Nandewar study area.***

| Title | No of Titles | Commodity | Area |
|---|---|---|---|
| Mining Leases | 7 | Diatomite | Barraba |
| Mining Leases | 2 | Limestone | Attunga |
| Mining Leases | 12 | Sapphire/corundum/zircon | Inverell |
| Mining Leases | 3 | Rhodonite | Manilla, Nundle |
| Mining Leases | 1 | Serpentine | Manilla |
| Mining Leases | 1 | Jade/nephrite | Nundle |
| Mining Leases | 1 | Diamond/tin | Inverell |
| Mining Leases | 2 | Zeolite | Quirindi |
| Mining Leases | 1 | Kaolin plus ten minerals | Barraba |
| Mining Leases | 1 | Tin plus seven minerals | Watsons Creek |
| Mining Leases | 1 | Sapphire plus six minerals | Inverell |
| Mining Leases | 1 | Rhodonite plus seven minerals | Nundle |
| Mining Leases | 1 | Copper/gold plus ten minerals | Attunga |
| Minerals Claims | 4 | Gold | Bingara, Nundle |
| Minerals Claims | 2 | Diatomite | Barraba |
| Minerals Claims | 1 | Diamond/gold | Bingara |
| Minerals Claims | 5 | Sapphire/corundum/zircon | Inverell |
| Minerals Claims | 2 | Serpentine | Barraba, Tamworth |
| Gold Lease | 1 | Gold | Bingara |
| Private Lands Leases | 1 | Kaolin plus three minerals | Barraba |
| Private Lands Leases | 2 | Sapphire | Inverell |
| Private Lands Leases | 1 | Copper/gold plus 12 minerals | Attunga |
| Mining Lease Application | 1 | Coal | Murrurundi |
| Assessment Lease Applications | 1 | Serpentine | Barraba |
| Assessment Lease Applications | 1 | Sapphire/corundum | Inverell |
| Assessment Lease Applications | 1 | Sapphire/corundum/diamond | Inverell |

The Department of Mineral Resources also administers construction material resources but does not issue titles for construction materials. Local councils and various other agencies issue these. At 24 September 2003, there were 7 operating and intermittently operating quarries for coarse aggregate, 1 for sand and 32 for unprocessed construction materials.

### 6.1.3 Exploration Titles and Applications

The following exploration titles and applications were extant in the Nandewar study area on 24 September 2003:

***Table 6-B. Exploration titles and applications 24 September 2003, Nandewar study area.***

| Title | No of Titles | Group/Commodity |
|---|---|---|
| Exploration Licences | 12 | Metallic minerals |
| Exploration Licences | 4 | Metallic minerals; gemstones |
| Exploration Licences | 7 | Non metallic minerals |
| Exploration Licences | 7 | Gemstones |
| Exploration Licences | 3 | Coal |
| Coal Authorisation | 1 | Coal |
| Petroleum Exploration Licence | 4 | Petroleum |
| Exploration Licence Applications | 1 | Metallic minerals |
| Exploration Licence Applications | 1 | Metallic minerals; clay minerals; gemstones |
| Exploration Licence Applications | 2 | Semi precious stones |
| Exploration Licence Applications | 5 | Gemstones |
| Exploration Licence Applications | 1 | Coal |

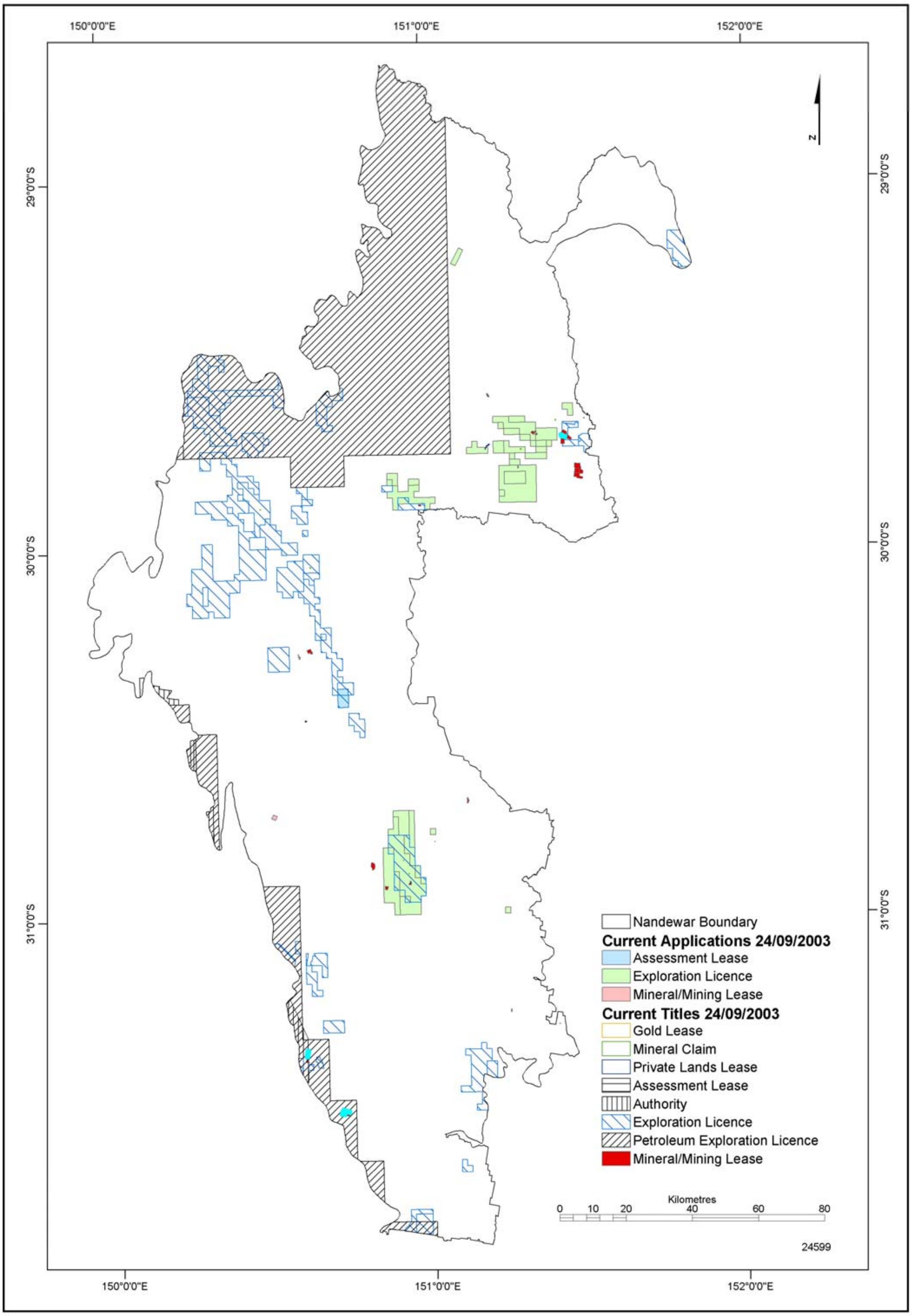



*Figure 6-A. Current titles and applications (September 2003), Nandewar study area*

## 6.2 CURRENT MINING (SEPTEMBER 2003)

### 6.2.1 Coal and Petroleum

There is no record of production of coal, coal seam methane or petroleum from the Nandewar study area in the 2002-2003 financial year, and no production is recorded within the previous five years. Coal deposits with significant development potential are located within the Werrie Basin and in the Ashford area. These deposits are currently at various stages of assessment.

### 6.2.2 Industrial Minerals and Construction Materials

During the first quarter of the 2002-2003 financial year there were 57 operating quarries or mines producing a range of industrial minerals and construction materials in the study area. The number of quarries or mines for each commodity together with their recent average annual production is shown in **Table 6-C**. The location of the operating industrial mineral and construction material quarries and mines is shown on **Figure 6-B**.

*Table 6-C. Industrial mineral and construction materials produced in the Nandewar study area[1]*

| Commodity | Number of Quarries or Mines | Average Annual Production |
|---|---|---|
| Limestone/Agricultural Lime | 2 | $8 000 000 |
| Sapphire[2] | 7 | $2 000 000 |
| Diatomite | 2 | $3 000 000 |
| Zeolite | 1 | $500 000 |
| Diamond[3] | 1 | $50 000 |
| Serpentinite | 1 | $10 000 |
| Rhodonite[2] | 2 | $7 000 |
| Jade-nephrite | 1 | $30 000 |
| Unprocessed construction materials | 32 | $750 000 |
| Coarse aggregate inc. river gravel | 7 | $1 050 000 |
| Construction sand | 1 | $350 000 |
| | | |
| **TOTAL PRODUCTION** | | **$15 747 000** |

[1]Figures given for industrial minerals are averaged for the last reported year of the licences. Production figures for construction materials are for the 2001-2002 financial year. (2002-2003 financial year production figures for construction materials are not yet available). Production figures for construction materials and some industrial minerals is under-recorded, as some construction material and industrial mineral quarries do not provide data to the Department of Mineral Resources.

[2] Small scale fossicking not recorded, but minor.

[3] Estimated from limited mining details.

Based on these figures, the total of the recent average value of production for the Nandewar study area is $15,747,000 of which $13,597,000 was derived from industrial minerals (limestone, sapphire, diatomite, zeolite, diamond, serpentinite, rhodonite, jade) and $2,150,000 was from construction materials (unprocessed construction materials, crushed and broken stone and gravel, and sand). However the actual production figures for the study area is higher because production figures for some construction materials and industrial minerals are under-recorded or not provided to the Department of Mineral Resources.

### 6.2.3 Metallic Minerals

The only metallic mineral produced within the Nandewar study during the last financial year was gold. The value of this gold production was approximately $1 600. Small scale fossicking for gold is not recorded, but is estimated to be less than $10 000. The location of the operating gold mine (near Bingara) is shown on **Figure 6-B**.

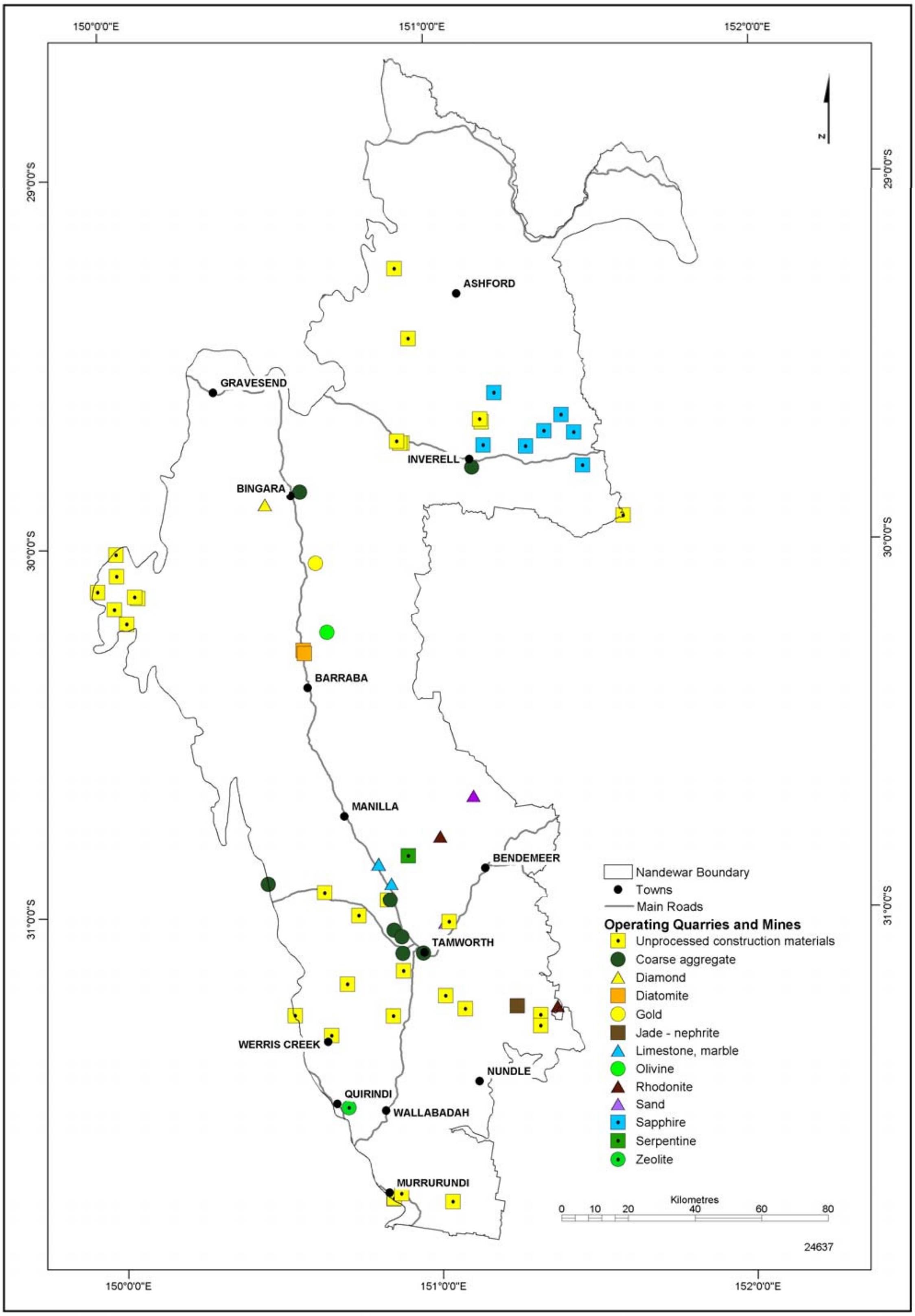



*Figure 6-B. Operating quarries and mines (September 2003), Nandewar study area.*

## 6.3 CURRENT EXPLORATION (SEPTEMBER 2003)

The Department of Mineral Resources keeps detailed records of exploration expenditure undertaken by exploration licence holders. Annual exploration expenditure for various minerals and construction materials in the Nandewar study area has averaged around A$2 million (2003) over the last decade. Actual figures vary considerably from year to year. The variation relates to prevailing economic conditions, commodity prices, the development of new geological and mineral deposit models, accessibility, and the availability of new data such as detailed geophysical or geological data.

Commodities that are being explored for and assessed include limestone, zeolite, sapphire, diatomite, gold, silver, tungsten, molybdenum, copper, diamond, magnesium, coal, coal seam methane, petroleum and kaolin.

### 6.3.1 Coal and Petroleum Exploration

#### Coal

Authorisation A-216 and EL 5833 are both held by the Department of Mineral Resources for ongoing assessment and research on coal in the Gunnedah Basin. Small areas of both titles extend across the western boundary of the Nandewar study area.

EL 5993 is held by Creek Resources Pty Ltd and includes the old Werris Creek Colliery. Earlier mining worked the Tunnel (Lower) Seam and the Black (Upper) Seams. Coal resources in the area are understood to be five to ten million tonnes plus possible minor remnant coal from earlier mining. The coal resource is suitable for open cut extraction. Exploration is ongoing.

EL 5306 and EL 5888 were granted to Bickham Coal in 1996. Exploration is continuing for both open cut and underground coal resources. Potential open cut resources of about 40 million tonnes and underground/highwall resources of the order of tens of millions of tonnes have been identified to date.

ELA 2077 has recently been received from Renison Bell Holdings Pty Ltd to explore for coal in the Ashford area adjacent to the old open cut coal mine.

#### Petroleum

PEL 437 covers a large part of the study area northwest of Inverell. It was granted to Pangaea Oil & Gas Pty Ltd to explore the area where shallow Surat Basin and Warialda Trough sediments onlap onto the adjacent New England Fold Belt.

PEL 1 is located along the southwestern boundary of the Nandewar study area. It was granted to Australian Coalbed Methane Pty Limited to assess the Permian coal measure sequences for their potential to yield commercial quantities of coal seam methane gas. The area contains significant coal resources within the Black Jack Formation mostly within the Maules Creek Sub-Basin. PEL 286, located to the south of PEL 1, was also granted to

Australian Coal Bed Methane Pty Limited to explore for coal seam methane. The company will test the Permian Coal measures sequences in two scenarios: (i) in a zone of structural imbrication adjacent to the Hunter Thrust and (ii) in the postulated Murrurundi Trough whose axis is interpreted to transect the central part of the area.

PEL 6 was granted to Eastern Energy Australia Pty Ltd to test the prospectivity of the thick good quality reservoir sandstones within the Permian Back Creek Group which are expected to be present over large anticlines and faulted blocks in the area. Only a very small part of this licence comes into the study area northwest of Bingara.

### 6.3.2 Industrial Minerals and Construction Materials Exploration

#### Introduction

Exploration for industrial minerals is at a moderate to high level throughout the Nandewar study area. Recent highlights include the discovery of a large resource of magnesium contained in the tailings of the former Woodsreef Asbestos Mine, on-going evaluation of limestone resources near Nundle and on-going evaluation of zeolite potential at Werris Creek and sapphire potential northeast of Inverell. Interest in exploration for diamonds remins moderate to high in the Bingara and Copeton areas.

Because most construction materials are not classified as minerals under the *Mining Act (1992),* exploration licences for these materials are not issued by the Department of Mineral Resources. Except in the case of Crown land where a licence to explore or extract construction materials from the Department of Lands is required, exploration activities are undertaken by agreement between the explorer and individual landowners. As a consequence, information on exploration for construction materials is not readily available, except where it may have been documented in Environmental Impact Statements prepared for quarrying proposals.

The Department has no records of any existing crown land licences to explore for construction materials within the study area, or other records of any exploration currently being undertaken for construction materials.

#### Gemstones

Recent exploration in the Copeton Diamond Field by Cluff Minerals (Aust) Pty Ltd has recovered diamonds from several areas including the Staggy Creek mine area, (now covered by EL 6073) with several areas proposed for further exploration. Other exploration highlights include the recovery of several diamonds by Rimfire Pacific Mining NL southwest of Bingara (now covered by EL 6106), including from bulk samples near diatremes shedding subduction model indicators in the Horton area. Cluff Minerals (Aust) Pty Ltd and and Rimfire Pacific Mining NL are also exploring for diamonds in the Bingara area on EL's 3325 and 5880 respectively.

Exploration for additional resources of sapphire are continuing in the Inverell area by Pan Gem Resources (Aust) Pty Ltd (EL 5927), Pan Gem Aust Pty Ltd and Judith Patricia

Cosgrove (EL 5352) and Sapphire Mines NL, Great Northern Mining Ltd, Jesasu Pty Ltd, and Sapphires NL (EL 4278).

In addition to the above licences, there are several recently granted exploration licences for both diamond and/or sapphire, for which the first annual exploration reports have not yet been submitted.

### Non-metallic minerals

Pacific Magnesium Pty Ltd is evaluating the magnesium potential of the former Woodsreef Asbestos Mine tailings near Barraba on EL 5490. They have identified a resource of 24.2Mt of 23.1% magnesium from 15 vertical air-core drillholes and have applied to the Department of Mineral Resources for an Assessment Lease (ALA 28) to continue the evaluation.

P W English and Associates Pty Ltd are evaluating the potential for olivine on EL 4642 located northeast of Barraba. They have identified a resource of 425 000 tonnes of olivine at the Doonba Dunite Prospect.

Exploration is also underway by Snowmist Pty Ltd and Alamo Limestone Pty Ltd for additional resources of limestone at the Stearns Ridge Limestone Prospect near Nundle (EL 5635) and for zeolite at Werris Creek on EL 5400 (Zeolite Australia Ltd and J M Stephens Pty Ltd); EL 5549 (Zeomin Technologies) and EL 5978 (Rimfire Pacific Mining NL).

Supersorb Minerals NL are evaluating the non-metallic mineral potential in the Barraba area in EL 5944.

## 6.3.3 Metallic Minerals Exploration

Exploration for metallic minerals is at a low to moderate level within the Nandewar study area. Exploration licences for gold are current in the Bingara, Upper Bingara, Nundle, Crow Mountain, Werris Creek and Woodsreef areas. Exploration progress on the active licences is discussed below. However, there are several recently granted licences for which the first annual exploration reports have not yet been received.

Rimfire Pacific Mining NL has been granted EL5550 over the Spring Creek (Hidden Treasure) gold resource and the Lone Hand Prospect. A gold resource of 260 000 tonnes at 2ppm Au at Spring Creek was outlined by previous exploration.

Hibernia Gold Pty Ltd hold EL 6118 located over the Rowdy Gully (Follys Prospect) near Nundle. This prospect has returned encouraging results from previous exploration.

Exploration is continuing in the Mount Terrible area near Werris Creek under EL5855 (Alphadale Pty Ltd and Werrie Gold Pty Ltd) where a resource of 132 000 tonnes at 7.8ppm Au was previously identified.

Exploration for additional resources of metallic minerals is also underway at Attunga on EL 5869 (Goldrap Pty Ltd), at Woodsreef on EL 5551 (Rimfire Pacific Mining NL) and near Torrington on EL 6114 (Mount Conqueror Minerals NL).

# 7 Resource Potential

## 7.1 ASSESSMENT METHODOLOGY

The mineral, construction material, and petroleum potential of the Nandewar study area has been assessed by determining the types of deposits likely to be found within the geological framework known or interpreted to be present. Marsh et al. (1984), Taylor and Steven (1983), and Dewitt et al. (1986) describe a summary of the qualitative assessment methodology. The approach identifies geological areas (tracts) which are known to contain, or have the potential to contain, particular types of deposits.

A qualitative assessment of the potential resources of an area is an estimate of the likelihood of occurrence of deposits that may be of sufficient size and grade to constitute a resource. Only the deposit types judged to be most likely to constitute significant resources in the region have been assessed in detail.

Resource assessment of an area combines knowledge of its geology, geophysics, geochemistry, and deposit occurrences, with current theories of deposit genesis and results of previous exploration. The assessment process requires a study of available geoscientific data to determine the history of geologic processes and environments. Geological environments judged to have characteristics that are known to be associated with specific types of deposits are then identified. In particular, the assessment draws on regional and local characteristics of deposit models to establish whether or not specific types of deposits are likely to occur, and whether they occur in economic grades and sizes.

The potential of an area is its likelihood of having a particular type of deposit, based on expert judgments of geoscientists involved in the assessment. Such areas are usually subdivided according to differing levels of potential, for a particular size of deposit. There may be up to five mineral deposit 'levels' or 'tracts' of varying potential for each type of deposit. Each tract may be ranked as high (H), moderate to high (M-H), moderate (M), low to moderate (L-M), or low (L) for a particular size of that deposit. Each tract within a particular deposit type is listed in order from highest to lowest potential (A to E) with each of these tracts also assigned a certainty level to reflect the differing amounts of information available for each tract. The letters A to D denote increasing the levels of certainty **(Table 7-A).** (For a more detailed explanation of the terminology used for the assessment of mineral potential, see Appendix 5).

*Table 7-A. Relationship between levels of resource potential and levels of certainty*

Decreasing level of potential ↓

<table>
<tr><td>H/D<br>HIGH POTENTIAL</td><td>H/C<br>HIGH POTENTIAL</td><td>H/B<br>HIGH POTENTIAL</td><td rowspan="4">U/A<br>UNKNOWN POTENTIAL</td></tr>
<tr><td>M/D<br>MODERATE POTENTIAL</td><td>M/C<br>MODERATE POTENTIAL</td><td>M/B<br>MODERATE POTENTIAL</td></tr>
<tr><td>L/D<br>LOW POTENTIAL</td><td rowspan="2">L/C<br>LOW POTENTIAL</td><td rowspan="2">L/B<br>LOW POTENTIAL</td></tr>
<tr><td>N/D<br>NO POTENTIAL</td></tr>
<tr><td>D</td><td>C</td><td>B</td><td>A</td></tr>
</table>

Decreasing level of certainty →

*Example of tract labelling method (Coal)*

| | |
|---|---|
| Tract COAL A/H/C-D | A – first and highest potential coal tract |
| | H – level of potential is high |
| | C-D – level of certainty is moderate to high |

Tracts in the Nandewar study area judged to contain potential for the formation of specific types of deposits are listed with their potential in **Table 7-B**. This table also shows the ‘Deposit Index’, which is the socio-economic ranking of the deposit.

It is important to note 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, construction material and petroleum resources at any given time. The resource potential needs to be monitored and reassessed periodically to take account of new data and advances in geological understanding including relevant new discoveries. Advances in exploration,

*Table 7-B. Deposit types, Deposit Index and Weighted Potential Scores, Nandewar study area*

| | | LEVELS OF POTENTIAL & STANDARD POTENTIAL SCORES ) | | | | |
|---|---|---|---|---|---|---|
| | | **High** | **M-H** | **Moderate** | **L-M** | **Low** |
| | | 18 | 12 | 6 | 2 | 1 |
| **DEPOSIT** | **DEPOSIT INDEX** | **WEIGHTED POTENTIAL SCORE (a x b)** | | | | |
| **COAL AND PETROLEUM** | | | | | | |
| Coal | 12 | 216 | 144 | 72 | | 12 |
| Coal Seam Methane (CSM) | 12 | | | 72 | | |
| Petroleum (includes Conventional Gas) | 12 | 216 | | 72 | | 12 |
| **INDUSTRIAL MINERALS AND CONSTRUCTION MATERIALS** | | | | | | |
| Magnesium | 12 | | | 72 | | |
| Primary Diamond | 6 | 108 | 72 | 36 | | 6 |
| Sapphire | 5 | 90 | 60 | 30 | 10 | 5 |
| Limestone | 5 | 90 | 60 | 30 | 10 | 5 |
| Construction Materials | 4 | 72 | | 24 | | 4 |
| Diatomite | 4 | 72 | | 24 | | 4 |
| Alluvial Diamond | 3 | 54 | | | 6 | 3 |
| Serpentinite-Related Deposits | 3 | 54 | | | | |
| Kaolin | 3 | | 36 | 18 | 6 | |
| Zeolite | 2 | 36 | | | | 2 |
| **METALLIC MINERALS** | | | | | | |
| Orogenic Gold | 7 | | 84 | 42 | | 7 |
| Porphyry Copper-Gold | 7 | | | 42 | 14 | 7 |
| Epithermal Gold-Silver | 7 | | 84 | 42 | 14 | 7 |
| Tin (Greisen and Vein) | 5 | | 60 | | 10 | 5 |
| Tungsten-Molybdenum and Copper-Gold Skarn | 4 | 72 | | | | |
| Tungsten-Molybdenum Pipes, Veins and Disseminations | 3 | | | 18 | | 3 |
| Besshi-Cyprus (VHMS) | 3 | | 36 | 18 | 6 | 3 |
| Secondary Tin | 3 | | 36 | 18 | | |
| Alluvial Gold | 3 | | 36 | | | |
| Silver-Bearing Polymetallic Vein | 2 | | | 12 | 4 | 2 |

mining, production and quarrying technologies, and changes in commodity prices and new growth markets are other factors that may change the resource potential of an area.

Detailed descriptive models for the qualitative broad scale assessments of the Nandewar study area are presented in **Appendix 2**.

## 7.2 COAL AND PETROLEUM POTENTIAL

### 7.2.1 Coal

Within the Nandewar study area, coal is present in the Werrie Basin in the south, in the Ashford area in the north, and in small areas of the Maules Creek Sub-basin within the bioregion in the west. The following discussion details the potential of these areas, which have then been integrated into a unified coal potential tract for the bioregion. Minor occurrences of coal in the Surat Basin and Warialda Trough sequences in the northwest have not been assigned a potential.

#### Ashford area

In the Ashford area, outcrop of the Ashford Coal Measures form part of a north-northeasterly trending, uniformly west-dipping, narrow, discontinuous strip of Early Permian strata that extend some 60 kilometres from the Bonshaw area in the north to the Arthurs Seat-Arrawatta area in the south. At the subsurface level, the Ashford Coal Measures may also extend some distance to the west. The sequence occupies part of the floor of a broad valley, which runs for some 25 kilometres north-northeast to approximately 12 kilometres south of Ashford. Beyond these limits the coal measures may persist under a cover of soil and alluvium.

The distribution of the coal measures within this broad valley suggests that the present-day coal-bearing strata were once part of a more widely distributed coal sequence. The post depositional events of uplift, deformation and erosion associated with faulting along the Severn Thrust have now reduced the distribution of coal measures to a series of isolated erosional basal remnants (Brown and James, 1987).

The Severn Thrust is a major structural feature, some 32 kilometres long. The average vertical displacement along the fault over its total length is about 300 metres (Owen & Burton, 1954) but only 170 metres at the old colliery site, where several cross-faults also occur. Early models of the fault suggested dips of 45 to 70 degrees for the fault. This interpretation severely limited the resources of the Ashford Coal Measures, as a steeply dipping fault would cut off the shallow dipping coal seam around 100 metres below the surface **(Figure 7-Aa**). The dip of the fault can be seen in the number nine open cut in the old colliery area, where the granite is overthrusting the coal measures.

However, Bekker (1977) concluded that the Severn Thrust was likely to have a moderately low angle dip. During the 1987 drilling program (White Industries Limited 1987), several boreholes penetrated through the overthrusting rocks and intersected the underlying coal measures. Borehole DDH6, drilled near the western boundary of the mining lease, provides evidence that the Severn Thrust is a reverse fault with the granite thrust to the east, at low angle, over the coal measures and sub-parallel to the Ashford seam (**Figure 7-Ab**). The drilling provided evidence that the Ashford seam extended down dip to the west beyond the open cut highwall boundary and underneath the granite for at least 1.5 kilometres, and along strike for almost two kilometres.

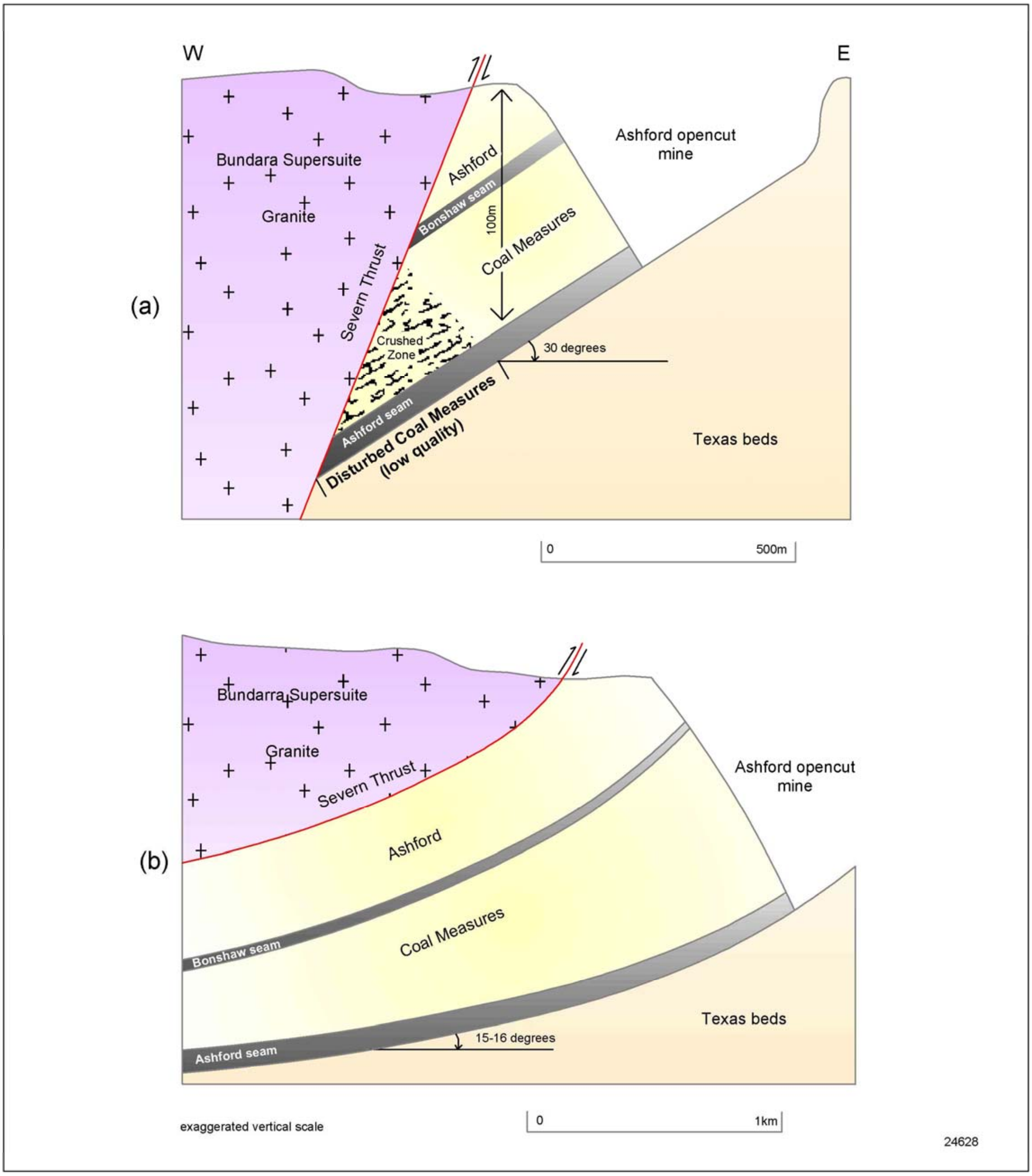



***Figure 7-Aa. An early model showing a steeply dipping Severn Thrust limiting extent of the Ashford seam (after White Industries 1987).***

***Figure 7-Ab. The current model showing a shallow dipping Severn Thrust sub parallel to the Ashford seam (after White Industries 1987).***

The area for which coal resources have been estimated with reasonable confidence is centred around the Ashford Colliery (herein referred to as Ashford Coal Resource Block A) **(Figure 7-B)**. Projection of data and geological information to the west of this area allows delineation of Ashford Coal Resource Block B.

### *Ashford Coal Resource Block A*

Ashford Coal Resource Block A is situated west of the highwall of the open cuts of the old Ashford Colliery. Block A is defined by the maximum area of influence of seam intersections for which coal seam quality data are available. The Ashford seam is the only seam with economic potential in the Ashford Coal Resource Block A. Other seams are not considered to have economic potential due to their inferior thickness and/or quality.

The Ashford seam ranges in thickness from 2.8 metres to approximately 17 metres and is particularly variable in thickness within the Numbers 7, 8 and 9 old open cuts, largely due to small-scale step faulting in sympathy with the Severn Fault. The seam thins to the south of the mine but is shallowly underlain by a lower seam, or bottom split, 1.19 to 1.37 metres thick.

The Ashford seam in the open cut dips at about 25 to 35 degrees. However, computer modelling by White Industries Limited (1987) indicated a change of dip westwards in the subsurface to a dip of 15 to 16 degrees **(Figure 7-Ab)**. The coal resources of the Ashford seam, therefore, are continuous at shallow depths for some distance west of the Severn Fault, as shallowing dips indicate that the seam does not become to deep to be mined.

West of the highwall, the Ashford seam is thickest in the central-eastern part of Block A, ranging from eight metres to approximately 17 metres. In the central-western part of Block A, the seam maintains a thickness range of six metres to eight metres over much of the area. The seam is 6.06 metres thick in the westernmost hole, DD-3, which is about one kilometre west of the Severn Fault. The seam is less than six metres thick in the remaining parts in the northeastern and southeastern corners of Block A **(Figure 7-B)**.

Coal in the open cuts was generally fragmented and core recovery in early drilling was low. Raw coal ash of the seam ranges from as low as 10% to more than 35%, averaging 15% to 20%. Raw coal ash is highest in the southeastern corner reaching 37.38% but is generally low over much of the Block A **(Figure 7-C)**.

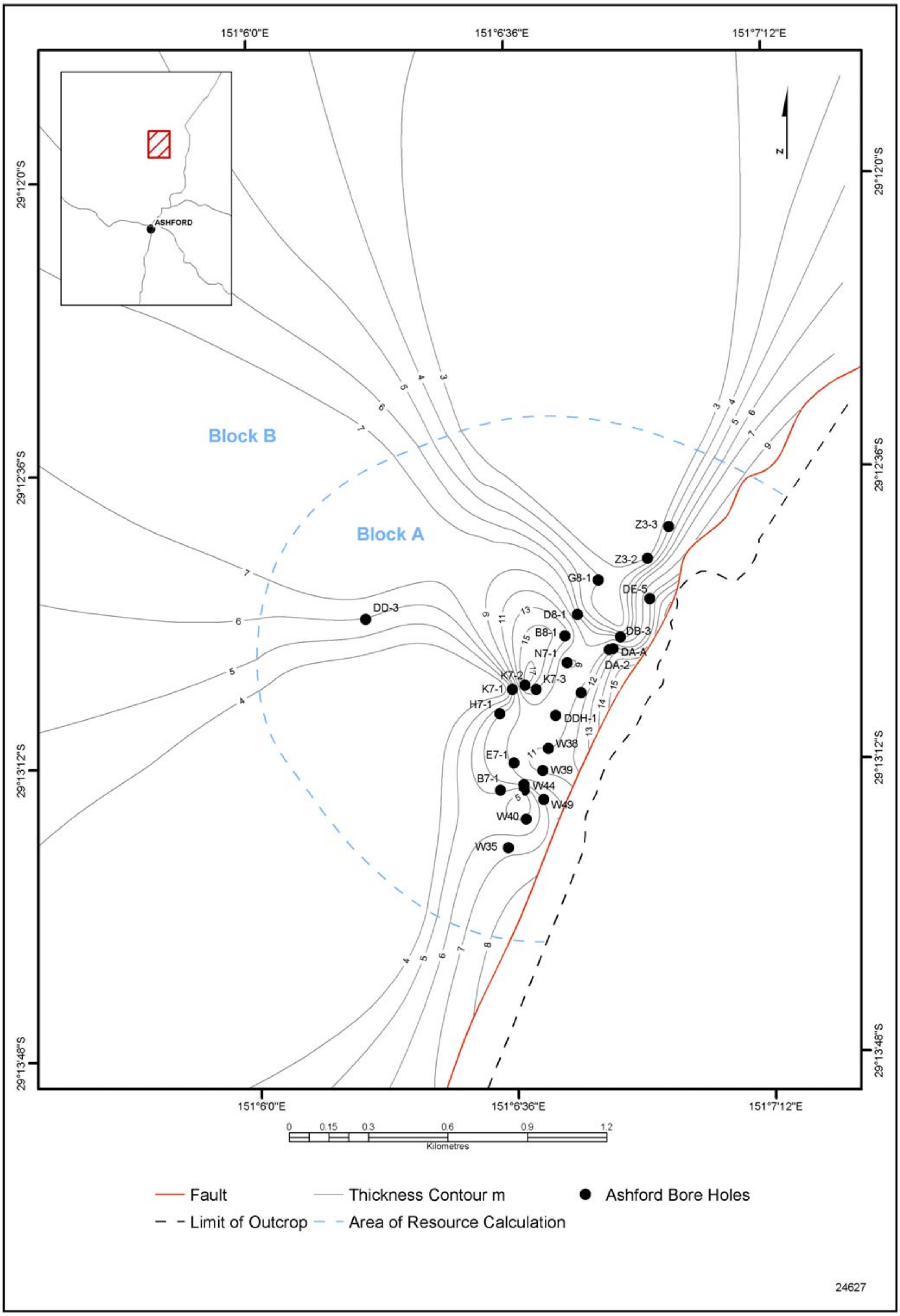



*Figure 7-B. Borehole locations and projected seam thickness contours for the Ashford coal seam*

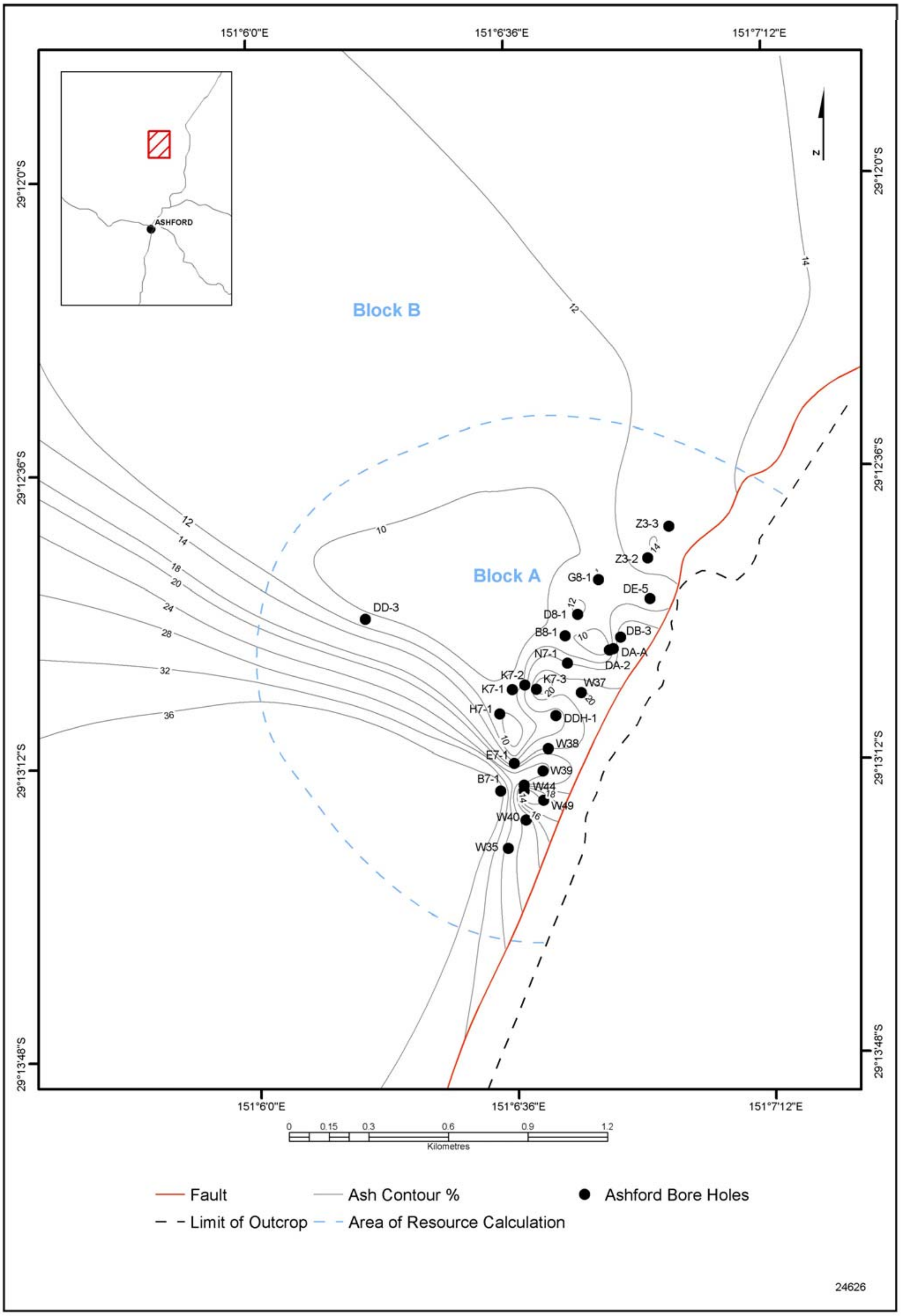



*Figure 7-C. Borehole locations and projected ash contours for the Ashford coal seam.*

Indicative analyses of the Ashford seam in Coal Resource Block A are shown in **Table 7-C** below:

***Table 7-C. Indicative analyses of the Ashford Seam***

| | |
|---|---|
| Inherent Moisture % | 0.8 |
| Ash % | 15.87 |
| Volatile Matter % | 24.00 |
| Fixed Carbon % | 58.95 |
| Total Sulphur % | 0.38 |
| Specific Energy MJ/kg | 25.0 |

A high quality section of the Ashford seam, with less than 15% raw coal ash, is present within the central-eastern part of Block A where thickness of the seam ranges from 8 metres to 13.6 metres **(Figures 7-B, 7-C).** This low ash section of the Ashford seam in the westernmost hole, DD-3, is equivalent to the total seam thickness of 6.06 metres. This seam section is less than six metres thick in the northeastern part of the block.

Analytical data for some of the boreholes in the south of Block A are available for the total seam only and are generally higher than 15% raw coal ash, reaching 26.7% in the southernmost borehole - W35. Raw coal ash for the selected best seam section is generally low over much of Block A ranging from 8% to 12%. Raw coal ash in the westernmost seam intersection in DD-3 is 10.5%. In the north, where the seam is thin, raw coal ash is around 13.7%.

It was not until the late 1970's, after some 20 years of mining that the coking properties of the Ashford coal were found to be attractive which led to research into the coal's cokeability. Bekker (1977) described the Ashford coal as a bituminous, medium volatile, high rank coking coal with the quality parameters shown in **Table 7-D.**

***Table 7-D. Ashford coking coal parameters***

| | |
|---|---|
| Total moisture % | 8 |
| Inherent moisture % | 2 |
| Volatile matter (a.d.) % | 24.5 |
| Ash (a.d.) % | 8.5 - 10.5 |
| S, P and Cl % | very low |
| Grindability index | 70 - 80 |
| Free swelling index | 5 - 6 |
| Gray-king coke type | G - G6 |
| Japanese drum index | 94.3 |

However, over most of its history, the Ashford seam was only mined as thermal coal to supply the local power station.

In situ resources of the Ashford seam in Block A are estimated to be 22 million tonnes. The seam thickness ranges from 2.8 metres to 16.94 metres averaging around seven metres. Sulphur rarely exceeds 0.4%.

**Table 7-E** shows the in situ resources in the Ashford Coal Resource Block A calculated for the whole seam.

***Table 7-E. In situ resources in Ashford Coal Resource Block A***

| | Thickness Range (m) | Average Thickness (m) | Average Relative Density | Average Ash (%) | Resource Mt |
|---|---|---|---|---|---|
| Total Ashford seam | 2.80 - 16.94 | 6.99 | 1.43 | 15.87 | **21.93** |

### *Ashford Coal Resource Block B*

Ashford Coal Resource Block B encompasses the remaining Ashford Colliery Coal Resource area. The coal resource potential of Block B is based on an interpretation of available geological data, particularly structural, and its implications for the northern, southern and western continuity of the Ashford seam. Coal Resource Block B remains open to the north and south and down dip to the west.

Trends in seam thickness in Block B suggest a range between three metres and seven metres. Based on the minimum seam thickness, Block B could potentially contain a few hundred million tonnes of Inferred resource with a raw coal ash ranging from 12% to 35%. This resource could be mineable by underground methods, except in areas where block faulting might have uplifted coal close to the surface.

### *Ashford North (Spring Creek Area to Severn River)*

White Industries Limited (1979) excavated an oxidised coal seam, 1.2 metres thick with 24.7% raw coal ash, on the bank of Spring Gully (a tributary of Spring Creek). The seam is overlain by about 0.6 metres of carbonaceous matter. A sample from a nearby shaft collar analysed 8.9% raw coal ash. The area is affected by faulting that produces variable strikes and dips.

The North West County Council and Joint Coal Board drilled about 12 holes (open to the top of the Ashford seam) in the area and proved several hundred thousand tonnes of coal under relatively thin overburden. The Ashford seam ranges in thickness from 5.37 metres and 37.5% raw coal ash, to 6.23 metres and 24.6% raw coal ash with swelling 2½ -7. In addition, there are several thinner seams below the Ashford seam ranging from 1.3 to 2.44 metres with highest raw coal ash of 23.7%. Drilling has also indicated the presence of coal resources between Myall Creek and the Ashford colliery.

### *Ashford South (*Arthurs Seat)

Permian rocks in the Arthurs Seat area consist of alternating beds of shale, conglomerate and sandstone with carbonaceous layers, occupying the floor of a four kilometre south-trending valley. The beds are commonly masked by a thick mantle of alluvium but are locally exposed in the stream channels.

Thin uncorrelatable coal seams are present to the south of Ashford. Faulting in the synclinal area in the southern end of Arthurs Seat further complicates correlation.

White Industries Limited (1979) drilled a series of 38 holes in areas where the coal measures outcrop. That drilling indicated the area had no economic potential, as the seams are thin and extensively faulted.

### *Arrawatta*

A coal seam, three metres thick and dipping westerly at 55 to 60 degrees occurs in the bed of the MacIntyre River at Arrawatta, 16 kilometres north of Inverell. Booker (1939) reported that the lower 1.80 metre section, exposed in a shallow shaft, was oxidised (4.02% hygroscopic moisture) and devolatalised (10.14% Volatile Matter) but was relatively low in raw coal ash (15.04%). This analysis indicates that the coal was of excellent quality. However, the extent of coal bearing strata within the area is uncertain and further work is needed to assess its coal resource potential.

### *Other Areas*

White Industries Limited (1979) drilled 35 boreholes in the Bonshaw area, to the north of Ashford during 1978-79. Most of the boreholes encountered Early Carboniferous rocks, coarse-grained granite sand (most likely derived from underlying granite) and/or a thick mantle of lithified post-Permian sediments. Boreholes drilled in the only known occurrence of Permian rocks in the Bonshaw area intersected non coal-bearing sequences. White Industries Limited (1979) concluded that much of the Permian sequence was probably faulted out.

There are several other locations in the general Ashford area that have potential for coal bearing units. These locations have been reported by local residents or derived from research of regional geological surveys and water well exploration (Brown and James 1987). Most of these locations are shown as areas of low potential on **Figure 7-D.** The extent of coal bearing strata within all of these areas is uncertain and the areas remain as sites for future exploration.

In the Warialda-Ashford area some water boles have intersected coal intervals within the Jurassic Walloon Coal Measures, and also in some overlying Cretaceous sediments. Minor coal is also reported from the Gunnee Formation within the Warialda Trough. The water boreholes are of only limited assistance because of the very basic geological descriptions, presumably recorded by the driller. The most significant intersection recorded in this area is a three metre section of 'black coal' reported from water bore WRC No. 4866, presumably within the Walloon Coal Measures, 10 kilometres north-east of Warialda at about 91 metres depth (Hawke & Cramsie 1984). However the available analyses, whilst very limited, suggest that the prospects of significant Jurassic coal deposits within the Walloon Coal Measures in this area is relatively low. However it must be noted, that most water bores have the overlying Pilliga Sandstone as their target, and because the underlying Walloon Coal Measures seldom crop out, it is clear that the Walloon Coal Measures in this area remain largely unexplored (Hawke & Cramsie, 1984). There are also several coal mines within the Walloon Coal Measures over the state border in Queensland.

#### *Summary of Potential of the Ashford Coal Measures*

Ashford Coal Resource Block A constitutes a small but important part of the area covered by the Ashford Colliery Resource Area. Coal Resource Block A, west of the open cuts, has the highest potential of all the areas within the Ashford Coal Measures with exploration to date indicating good quality, high value coal suitable for the export coking market. The resource delineated in Coal Resource Block A is probably too small to warrant a major capital expenditure for a large new mine. However, the area is open-ended in all directions except to the east where coal has been mined by open cut. Therefore, it is highly probable that the Ashford Coal Measures contain potentially mineable coal resources in areas not covered by exploration, particularly farther west of the Severn Fault in the area herein defined as Ashford Coal Resource Block B.

The focus of small mining operations in the Ashford area in the past was on extracting coal cheaply for the local power plant, despite its coking properties, thus locking the mining company into the area of shallow coal suitable for low cost extraction by open cut. Shallow coal east of the Severn Fault was fraught by faulting and variation in coal seam thickness. In addition, it appears that the coal was also of low quality in the east. However, there is a remarkable improvement in coal quality progressively west away from the area of the open cuts. The coal resource in the Coal Resource Blocks A and B is present at depths suitable only for underground mining methods, under Carboniferous metasediments and granite.

An inhibiting factor in the development of coal in the Ashford area is the distance to New South Wales's markets. However potential for mining is good as the resource is mainly high value coking coal in an area proximal to active coal mines and associated infrastructure in Queensland. The distance to the port of Brisbane is about 350 kilometres, or about the same as the distance of the Gunnedah Coalfield from the port of Newcastle.

### Werrie Basin

The Werrie Basin is located in the south of the Nandewar study area. The basin extends from south of Murrurundi to north of Werris Creek. Coal deposits in the Werrie Basin have been known since the 1890's when coal beds were intersected in the basal unit (Temi Formation) of the basin in water bores between Werris Creek and Quirindi.

In 1924, exploration was concentrated on coal seams higher up in the basin sequence in the Willow Tree Formation with underground mining at the Werris Creek Colliery commencing as a small operation in 1925. Mining ceased in 1963 due to the cancellation of railway contracts for coal.

Mining in the southern part of the Werrie Basin commenced around the early part of the 20th century. Coal was won by underground mining from an area northeast of Wingen, southwest of the current Bickham proposal. The mine extracted coal from the lowest of seven seams in the Koogah Formation, however the steep dip of seams, flooding of the mine and finally the onset of the Great Depression contributed to the closure of the mine in the 1930s.

### *Werris Creek Area*

Located five kilometres south west of Werris Creek, EL 5993 covers an area of 531 hectares and includes the now closed Werris Creek Colliery. The title, held by Creek Resources was granted in 2002.

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

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

The deposit is contained within a synclinal structure that contains nine coal seams in the Willow Tree Formation. The area also contains several faults with a maximum displacement of less than two metres and several igneous intrusions.

The Werris Creek coal seams, if selectively mined should be capable of producing a very low sulphur export thermal coal. A small quantity of low quality coal requiring washing could be sold as domestic power station fuel.

### *Bickham Area*

The Bickham open cut coal resource is located east of the New England Highway between the townships of Wingen and Blandford. The area includes an old coal mine that operated between the early 1900's and 1930's and the Commercial Minerals Chamotte Mine (six 6 pits) that extracted flint clay between 1970 and 1994. There are two exploration licences over the area, EL 5888 and EL5306 held by the Bickham Coal Company Pty Ltd.

The economic seams in the Bickham area are contained within the Koogah Formation. There are seven potentially economic coal seams that vary in thickness from 0.5 metres to 11.5 metres with the lowest 3 seams containing 75% of the resources. Ash (a.d.) varies from 4% to 9% in the 3 lowest seams and 15.5% to greater than 30% in the upper seams. A higher than average iron content in the ash of the Bickham coal may prove to be problematic. Total sulphur (a.d.) varies between 0.29% to 0.52% in all but the top seam with 8.8% sulphur (a.d.). Total measured resources at Bickham are 125 Mt at 7% ash. The coal is export quality thermal coal.

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

The Bickham Coal Company Pty Ltd is proposing to extract approximately 25 000 ROM tonnes of coal from a bulk sampling site located within EL 5306. The bulk sample will allow a better understanding of the performance of the coal during extraction, the practicalities of physical separation of ‘problem horizons’ and the efficiencies of beneficiation in reducing sulphur and iron in ash. A Review of Environmental Effects for the bulk sample proposal was placed on public display during October and November 2002.

### Gunnedah Basin

*Maules Creek Sub-basin*

The eastern boundary of the Maules Creek Sub-basin overlaps with a small part of the western boundary of the Nandewar study area, to the south of the Mount Kaputar National Park. An interpreted deep seismic line through this area **(Figures 3-F, 7-E)** shows the Maules Creek Sub-basin continues at depth below the east-dipping Hunter-Mooki Fault.

There is a large amount of data on the Maules Creek Sub-basin in the Brigalow Belt South Bioregion study area to the west (Barnes et al. 2002). Here, high quality coal crops out in and around the Leard and Vickery State Forest areas near Boggabri.

However, data on coal within the part of the Sub-basin within the Nandewar study area and in the area below the Hunter-Mooki Fault is limited. The area considered to have potential has been shown as the area within a two kilometres buffer of units of the Maules Creek Sub-basin that fall within the Nandewar study area.

### Coal Tracts (Figure 7-D)

*Tract COAL A/H/C-D*

The Ashford Coal Resource Block A situated west of the highwall of the open cuts of the Old Ashford Colliery has a high potential for coal mining.

The tract also includes potential open cut coal resources from nine coal seams in the Willow Tree Formation (Werris Creek area) and from seven coal seams in the Koogah Formation (Bickham area). In the Bickham area, the mapped extent of the Koogah Formation has been buffered to two kilometres.

*Tract COAL B/M-H/B-D*

The Ashford Coal Resource Block B (west of Block A), the Ashford North (Spring Creek to Severn River) area and the Arrawatta area have moderate to high potential for future coal mining.

### *Tract COAL C/M/B-C*

This tract includes the mapped extent of the Temi Formation in the Werrie Basin buffered to one kilometre.

### *Tract COAL D/L-M/B-C*

This tract includes a terrestrial coal bearing sequence (Murulla Beds) that crop out in the western part of the Werrie Basin (south).

### *Tract COAL E/L/B-C*

The areas included in this tract are the buffered part of the Maules Creek Sub-basin within the study area and several small potentially coal-bearing areas surrounding Ashford.

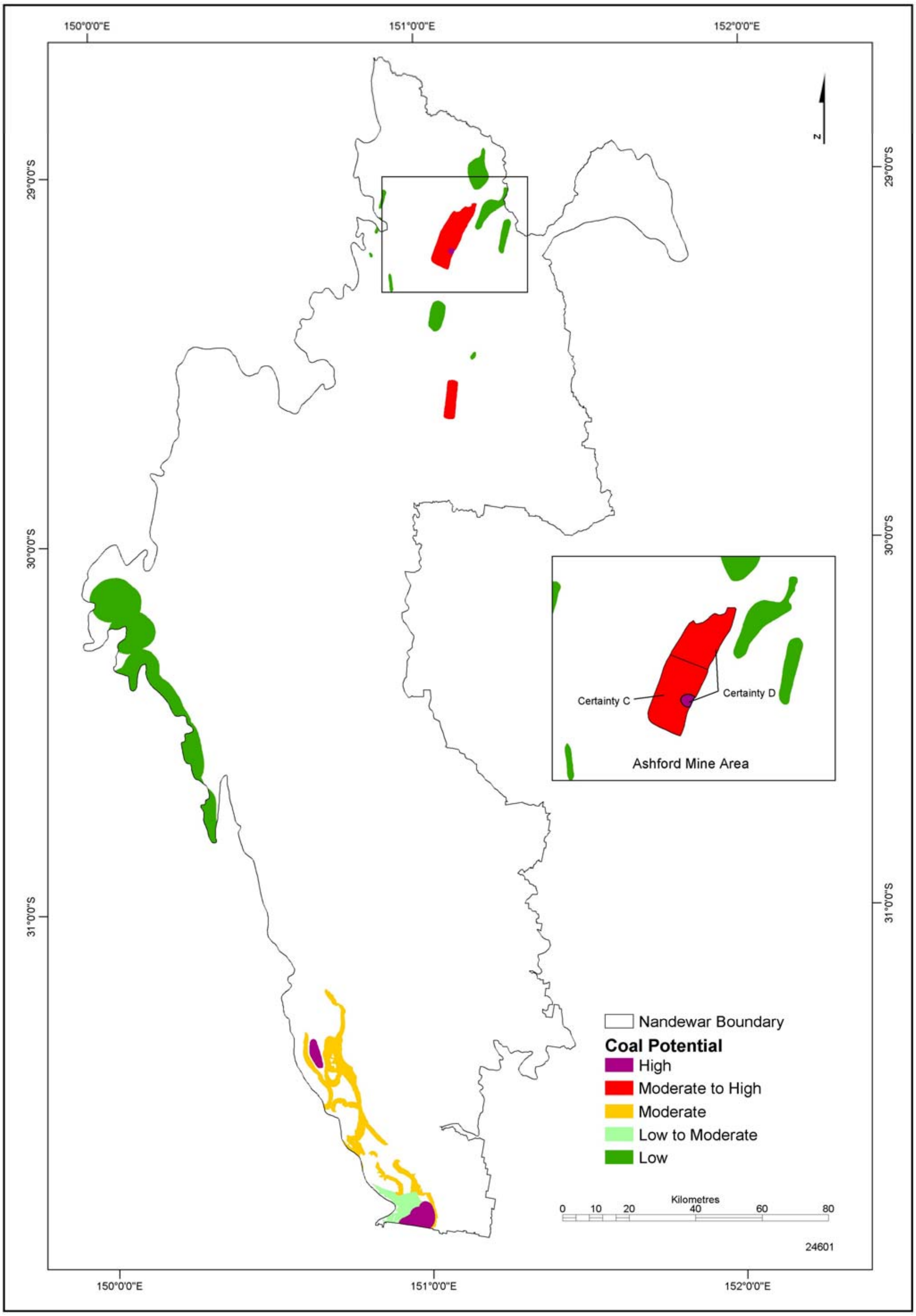



*Figure 7-D. Coal potential tracts, Nandewar study area*

### 7.2.2 Coal Seam Methane (CSM)

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

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

Recoverable reserves of CSM are controlled by many factors and it is first necessary to quantify the critical coal reservoir properties. These factors are coal thickness, gas contents, permeability and reservoir pressure. In New South Wales, exploration for CSM has been carried out for some years in the Gunnedah Basin and in the Sydney Basin, further to the south. In the Gunnedah Basin, the focus of exploration has been in the Narrabri area where pilot plants at the Coonarah, Bohena and Wilga Park sites are currently producing CSM from Permian coal measures. The Permian coal is thick, very gassy, highly fractured with little or no mineralisation, highly permeable and over-pressured.

The Gunnedah Basin is located on the western side of the Nandewar study area and is bounded on the east by the east dipping Mooki Thrust where the older New England Fold Belt rocks have been thrust over Gunnedah Basin strata. This relationship is shown on the interpretation of the Deep Seismic Line BMR91 **(Figure 7-E)** that follows the road east from Boggabri to Manilla. In this area, the interpretation shows the Boggabri Ridge and the Maules Creek Sub-basin as the parts of the Gunnedah Basin that are overthrust by the New England Fold Belt (Tamworth Belt). However, the Boggabri Ridge closes off just south of Gunnedah and here the Murrurundi Trough of the Mullaley Sub-basin becomes the part of the Gunnedah Basin that is overthrust.

The CSM potential of the Nandewar study area relates to the potential developed where the coal-bearing sequences of the Gunnedah Basin are overthrust by the western part of the Tamworth Belt. There is also potential associated with coal-bearing units in the Werrie Basin.

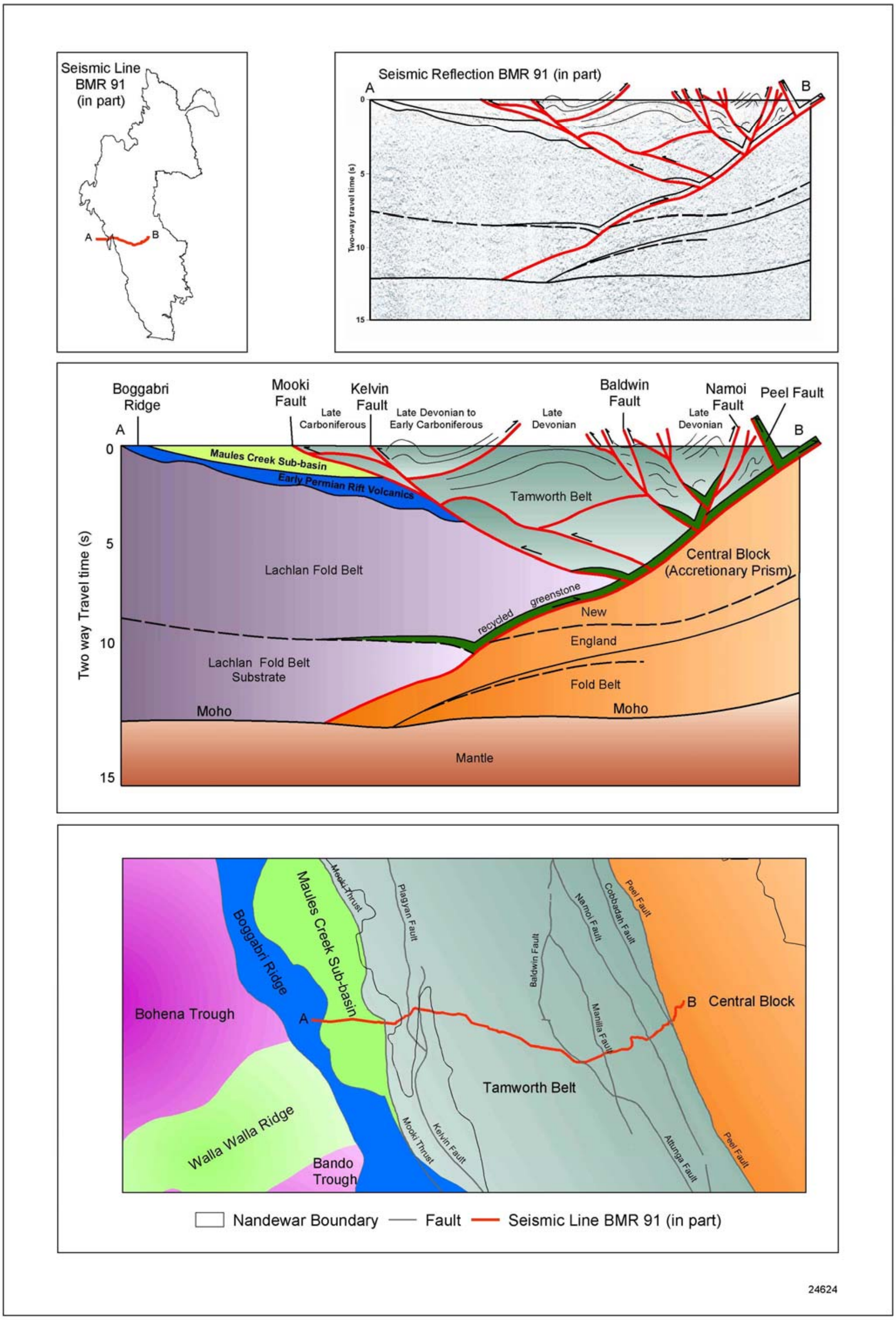



***Figure7-E. Structural model based on Deep Seimic Line BMR-91 (modified after Korsch et al. 1995)***

### Maules Creek Sub-Basin

The Early Permian Maules Creek Formation onlaps the Boggabri Ridge in the west of the Sub-basin and shows a progressive and relatively uniform thickening to the east-northeast towards and under the Mooki Fault. A projected maximum thickness of 1200 metres is expected at the deepest part of the Sub-basin. Deposition in a braided stream environment and cyclic fining-upwards sequences has resulted in a monotonous and almost regularly rhythmical series of conglomerate, sandstone, mudstone and coal, the provenance of which is largely from the west (Boggabri Ridge).

Structures show a relatively uniform NNW strike with dips to the ENE. A NE-SW conjugate fracture system is also developed that is related to a stress regime associated with the Mooki Fault. These structures may represent fairways of potentially enhanced coal seam permeability but may also represent active degassing to the surface.

Coal quality throughout the sequence is generally excellent. Coals are vitrinite rich and are characterised by generally very low ash contents. Maules Creek Sub-basin coals show mean maximum vitrinite reflectances ($R_o$ (max)) ranging from 0.5% to 0.9%, largely being depth dependent.

The relatively uniform distribution of seams throughout the sequence, and the fact that individual seam thicknesses decrease basinwards detracts from specific target zones in areas where cover may be adequate for potentially commercial gas retention. However, areas where cover is greater than 300 metres have relatively few seams in excess of 1.5 metres thick. On the other hand, it appears unlikely that significant CSM potential will be encountered beneath cover of less than about 500 metres.

The CSM potential beneath the Mooki Fault is largely conjectural but the coal quality is predicted to be excellent, as observed in the greater western margin of the Maules Creek Sub-basin.

### Werrie Basin

In the Werrie Basin, the Willow Tree Formation is a coal-bearing unit equivalent to the Early Permian, Maules Creek Formation. Although it is anticipated that where this formation occurs at depths of 200 metres or less it is likely to be largely degassed, CSM potential may be present within a number of small synclinal areas identified largely as a result of coal measure mapping (Maloney, 2002). Greatest potential is anticipated within synclines such as the Fairfield and Quirindi.

### Murrurundi Trough

During 1995, AMOCO drilled a number of wells adjacent to the southwestern parts of the Nandewar study area, (East Dunlop – TD 1092 metres. Adder Hill 1 - TD 655 metres, Wybong 1 - TD 763 metres, Goulburn River - TD 609 metres, and Doolans Creek 1 - TD945 metres) in the Murrurundi Trough. Regional mapping had identified areas containing thick Late Permian coal measures, developed within the depocentre of the Murrurundi Trough and its western coalfields equivalents. Because of the plunging nature of the Murrurundi Trough to the south it was generally considered that only the Late Permian coals would be at depths where suitable permeabilities for CSM may be retained. Interest was in the Late Permian Wittingham Coal Measures, equivalent to the Black Jack Formation, and in particular the Bayswater Seam which is equivalent to the Hoskissons Seam of the Gunnedah Basin stratigraphy.

Drillhole Wybong-1 confirmed the presence of thick net coals, encountering over 60 metres of coal between 90 and 728 metres. The Bayswater Coal Seam was over 18 metres thick. Unfortunately the coal was sparsely cleated and fractured. Permeabilities ranged from only .0055mD up to .65mD. Moreover, the diagenetic history of the region was complex and resulted in mineralisation within the cleat spacings. This, and other wells, also established that the levels of carbon dioxide were very high. Methane percentages varied from 35 to 96%.

#### Coal Seam Methane Tracts (Figure 7-F)

*Tract CSM A/M/B-C*

This tract covers the elements of the Gunnedah Basin overthrust by the Tamworth Belt such as the Boggabri Ridge, the Maules Creek Sub-basin and the Murrurundi Trough.

The Boggabri Ridge and the Maules Creek Sub-basin are underthrust to a point just east of the Nandewar Volcanic Complex. Here, the Maules Creek Sub-basin contains up to 1200 metres of units of the Maules Creek and Black Jack Formations.

Elements of the Gunnedah Basin (Maules Creek Sub-basin and Murrurundi Trough) are interpreted to continue east below the Mooki Fault to a line, that when projected to the surface, is equivalent to the eastern edge of the Carboniferous overlap assemblage of the Tamworth Belt. The CSM tract therefore continues east to this edge.

The tract also includes the coal bearing units of the Werrie Basin. The proximity of the Werrie Basin to the Mooki Fault may have increased permeability of the coal and provide greater gas production. However the risk of gas leakage here is high.

### 7.2.3 Petroleum (Oil and Conventional Gas)

Most sedimentary rocks contain some organic material, although not all rocks are capable of generating petroleum. Typically, rocks capable of generating conventional petroleum have at least 0.5% and preferably more than 1.0%, total organic carbon content.

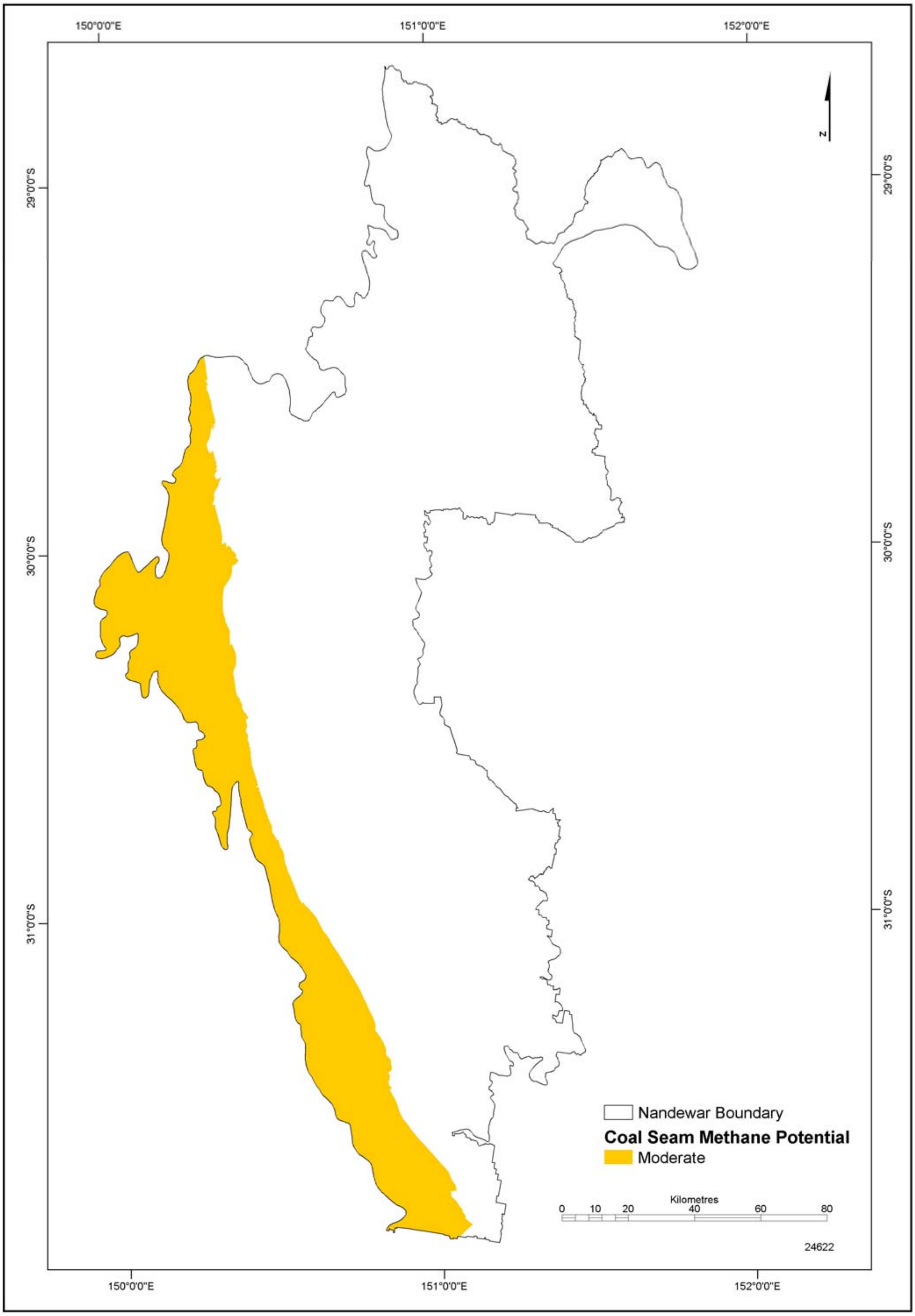



*Figure 7-F. CSM potential tracts, Nandewar study area*

Coals and fine-grained sedimentary rocks, such as shales and siltstones, are the most common rock types containing sufficient organic material to constitute potential petroleum source rocks.

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

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

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

In the Nandewar study area, five exploratory wells were drilled in the vicinity of Tamworth to test the petroleum potential of the Tamworth Belt sedimentary rocks. The wells were apparently drilled to test the validity of sketchy reports of oil and gas shows noted on the ground. The Tamworth Belt rocks have been mildly deformed, producing a series of north-trending and variably plunging folds that could constitute potential traps.

However, a more significant potential petroleum system has now been recognised from the interpretation of the Deep Seismic Line BMR91 **(Figure 7-E).** The interpretation shows the Tamworth Belt overthrusting the eastern part of the Gunnedah Basin. This seismic line follows the road east from Boggabri to Manilla and hence the interpretation shows the Boggabri Ridge and the Maules Creek Sub-basin as the parts of the Gunnedah Basin that in this area are overthrust by the Tamworth Belt. However, the Boggabri Ridge closes off just south of Gunnedah and here the Murrurundi Trough of the Mullaley Sub-basin becomes the part of the Gunnedah Basin that is overthrust.

The Maules Creek Sub-basin, the Boggabri Ridge and the Murrurundi Trough therefore comprise the three elements or principal controls on depositional style, structuring and lithofacies development, all of which are important for understanding the distribution of source, seal, reservoir, and trapping mechanisms for conventional oil and gas generation. A brief description of each follows.

### Maules Creek Sub-basin

The Maules Creek Sub-basin is bounded by the east dipping Mooki Fault in the east, and the Boggabri Ridge to the west. Deformation associated with crustal shortening, during the Permian and Triassic, has produced thrust faults that have deformed and faulted the basin sediments and thrust the western edge of the New England Fold Belt over the eastern side of the Maules Creek Sub-basin for distances of up to 15 kilometres. This has resulted in Tamworth Belt rocks of the New England Fold Belt covering at least the eastern third of the Maules Creek Sub-basin.

### Boggabri Ridge

This structural high separates the Maules Creek Sub-basin from the Mullaley Sub-basin to the west. The ridge was a high during the Early Permian, and Early Permian sediments on-lap both the eastern and western flanks. The ridge consists of the Boggabri Volcanics in the south and centre, and the Werrie Basalt to the north.

### Murrurundi Trough

Exploration drilling and regional mapping during the 1990's identified areas containing thick Late Permian coal measures, developed within the depocentre of the Murrurundi Trough and its western coalfields equivalents. Interest was in the CSM potential of the Late Permian Wittingham Coal Measures, equivalent to the Black Jack Formation, and in particular the Bayswater Seam which is equivalent to the Hoskissons Seam of the Gunnedah Basin stratigraphy.

### Petroleum Tracts (Figure 7-G)

#### *Tract PETROL A/H/B*

This tract encompasses the north-south trending part of the Boggabri Ridge within the Nandewar study area. With the Mullaley Sub-basin situated to the west and the deepest part of the Maules Creek Sub-basin located to the east, the Boggabri Ridge has served as a focal point for hydrocarbon migration from these kitchen areas. Argillaceous sequences within the Maules Creek Sub-basin, which have reached optimum depth of burial (within oil and gas windows), are perceived as the main source of hydrocarbons.

#### *Tract PETROL B/M/B-C*

This tract comprises the area east from the eastern flank of the Boggabri Ridge to a 20-kilometre buffer on the eastern side of the Mooki Fault.

On the eastern flank of the Boggabri Ridge, the tract comprises a narrow belt where stratigraphic pinch-out of reservoir sands against the ridge is highly likely. The shallowing basement acts as depositional margin where lateral facies variations in sandstone reservoirs could provide a series of wedge-out stratigraphic traps. The equivalent Maules Creek Formation and older lacustrine shales are within optimum depth of burial at the deepest part of Maules Creek Sub-basin to generate hydrocarbons that preferentially migrate westward towards the Boggabri Ridge.

East of the Mooki Fault, the overthrust part of the Maules Creek Sub-basin and (to the south) the Mullaley Sub-basin, are within a structural setting that generates tightly folded imbricate sheets that provides further enhancement of porosity and permeability of the reservoir rocks. Compressional stresses along the fault zone create buckling and drag that promotes structural rollover to generate possible structural traps.

The petroleum systems present in this tract involve the source-seal and reservoir components within the Maules Creek Sub-basin and Mullaley Sub-basin. Reservoir sands can also be sealed to the east when in contact with the basement of the New England Fold Belt.

### *Tract PETROL C/L/C*

This tract is defined by the areal extent of the Tamworth Belt. This belt is considered to have low potential based on the presence of a thick succession of sedimentary rocks that have been faulted and gently folded to produce a series of north-trending and variably plunging folds that could constitute potential petroleum traps.

Traces of a ‘mineral oil’ substance and gas bubbles were reported from water bores and ‘natural artesian springs’ near Tamworth in 1922 (Kenny 1923a,b). Shallow artesian bores in a local artesian basin at times gave off considerable quantities of gas bubbles. The outrush of gas was reputedly more pronounced after the bores had been plugged partially for some time. Oil films on water bores were collected and analysed, along with a black greasy material from one bore, both of which revealed traces of petroleum. It was concluded at the time that the oil “may have formed by the destructive distillation of the soft parts of (the) vegetable and animal representatives” from the surrounding (Tamworth Belt) strata (Kenny, 1923b).

Five exploratory wells were drilled in the vicinity of Tamworth to test the petroleum potential of the Tamworth Belt sedimentary rocks. Fluorescence (indicating the presence of hydrocarbons) was recorded in cuttings from wells.

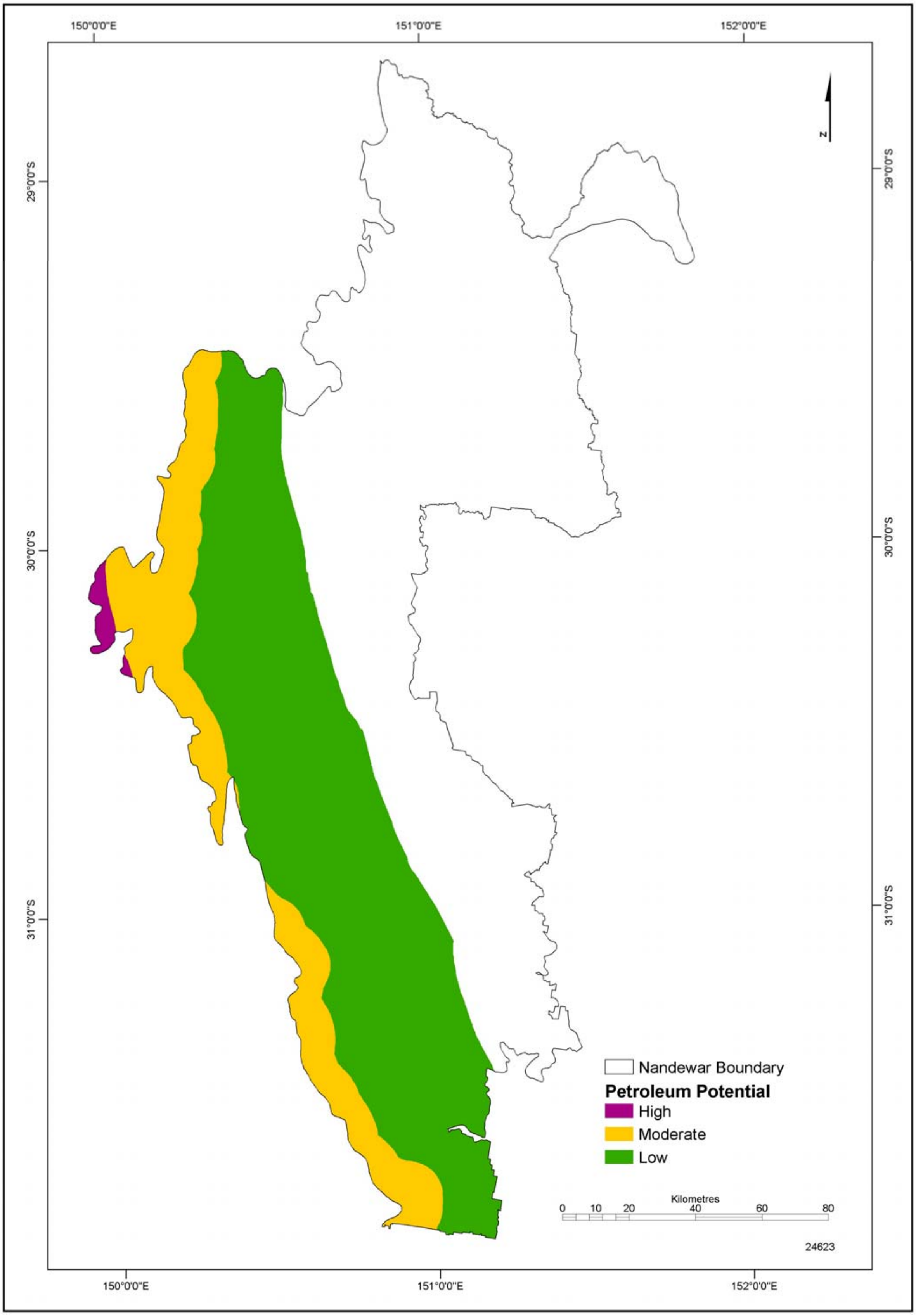



*Figure 7-G. Petroleum potential tracts, Nandewar study area*

## 7.3 INDUSTRIAL MINERALS AND CONSTRUCTION MATERIALS

### 7.3.1 Magnesium

Magnesium is present in high concentrations in mine tailings at the Woodsreef Asbestos Mine. The magnesium can be extracted safely using modern mining techniques. Magnesuim demand is projected to increase in coming decades, mainly because of its increasing use in the automobile industry, but also in a range of applications including computers, mobile phones, power tools and sporting and leisure equipment.

The location of magnesium resources within the Nandewar study area are localised and known, and therefore a mineral potential tract has been compiled only for the tailings dump area. However, potential infrastructure requirements would extend beyond this area. The magnesium resource at Woodsreef comprises an Inferred 24.2 Mt at an average 23.1% Mg (38.3% MgO). This equates to about a A$20 billion (2003) resource.

Further discussion of the potential for magnesium in the Nandewar study area is contained within **Appendix 3**.

#### Magnesium Tract (Figure 7-H)

*Tract Mg: A/H/D*

This tract consists of the known resources of magnesium within the tailings dump at the former Woodsreef Asbestos Mine buffered to one kilometre.

### 7.3.2 Primary Diamond

Diamond is a high-pressure form of carbon, formed at depths of up to 250 kilometres in the earth, and brought to the surface during eruptive events to form primary sources of diamonds.

Despite more than 236 000 carats of alluvial diamonds having been recovered in the Nandewar study area, and intermittent exploration for about 130 years, no significant primary source for the diamonds has been found. Scientific debate has ensued over the significance of a single diamond found in dolerite matrix near Copeton in the early 1900’s (Pittman 1905). It is a significant loss that this scientific specimen went missing in the 1960’s from the Armidale Council Safe (MacNevin 1977). However, diamonds have been recovered from bulk sampling adjacent to diatremes near Walcha in the southern New England region.

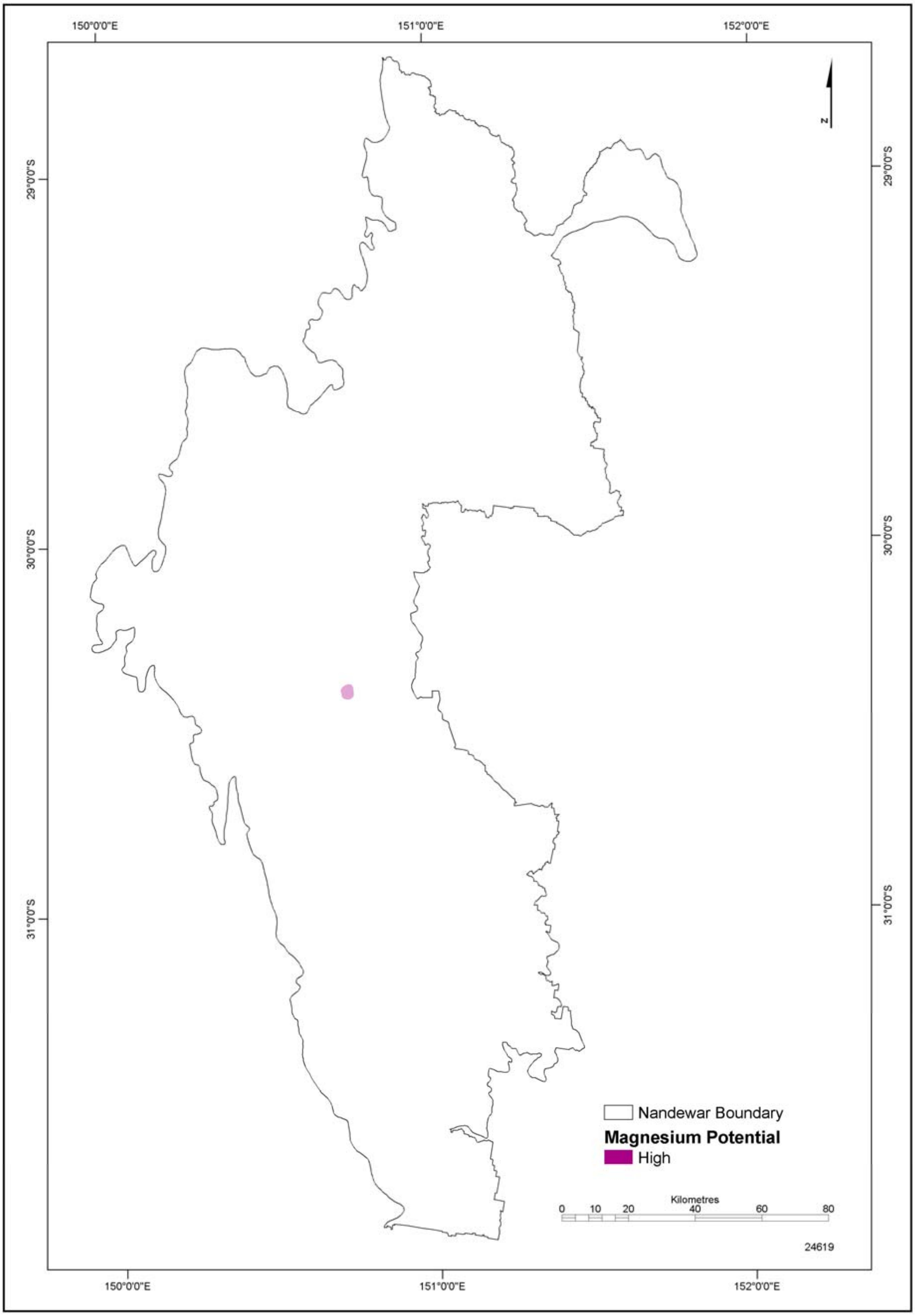



*Figure 7-H. Magnesium potential, Nandewar study area*

In eastern Australia, primary diamond deposits can be amongst the most difficult of all mineral deposits to locate, or to effectively model. There are several main reasons for this, which include the following:

- although the host rocks to diamond deposits are usually very particular, these rock types can occur almost anywhere in the regional landscape
- typical host rocks to diamond deposits are soft and easily eroded. This may result in both their non-preservation in the landscape, and/or masking by overlying units and sediments
- although hard-rock diamond deposits may produce very high returns, they are not usually areally very large (typically 50-500 metres wide), and may exhibit little or no geophysical anomalies, and/or few geochemical ‘halos’

Primary diamonds found in eastern Australia do not appear to fit into traditional models for diamond formation. A relatively new model of diamond formation has been proposed for Eastern Australia, which advocates a subduction related origin (Barron et al. 1996**, Figure A-C, Appendix 2).** Exploration companies using this model are currently active in the Nandewar study area.

Diatremes, or intrusive pipes, in the greater New England region contain breccia which includes rock fragments of alkali basaltic composition that show characteristics of the deep-seated origin required to access diamonds from deep crustal subduction zones (Barron et al. 1996). They intrude along major deep-seated structures and may carry diamond to higher levels in the crust or to the surface. Lineaments in the surface topography often mark these structures and it is the intersection of one or more lineaments that can provide a particularly favourable site for diatreme emplacement, clusters of diatremes, and dyke swarms.

A northeast trending lineament passes through the junction of the Gilgai and Bundarra granites in the Copeton area. The western portions of the Gilgai Granite also exhibits zones of hydrothermally altered granite which, together with faulting, have been preferentially eroded, and which now partially forms basement for the Maids Creek channel near Copeton. Spatial and other analyses in this area suggest that a palaeochannel adjacent to the current alluvial bed of Maids Creek and the Gwydir River, most likely sourced diamonds from this area, before trending west towards the Bingara diamond field, as the current Maids Creek/Gwydir River also now trend. In this interpretation, the area of greatest prospectivity for primary diamonds occurs in the area of the junction of the Gilgai and Bundarra granites, as also suggested by MacNevin (1977).

The difficulties in formulating a viable tract for primary diamonds in the Nandewar study area include the extreme uncertainty of delineating diamond parametres in the broader landscape, the paucity of detailed mapping in key areas, general difficulties with model formulation specific to eastern Australia, and the relatively unexplored and traditionally poor understanding of diamond paragenesis in eastern Australia.

### Primary Diamond Tracts (figure 7-I)

*Tract DIA A/H/B*

Primary diamond sources often occur in clusters so the tract delineates units within 30 kilometres of the Copeton diamond field interpreted primary source area.

*Tract B/M-H/A-B*

This tract consists of interpreted magnetic anomalies within the Tamworth Belt in the vicinity of the Bingara diamond field. A few diamonds have been found in sediments adjacent to some of these magnetic anomalies. It also includes interpreted dyke units/faults in the vicinity of the Bingara diamond field. It is a distinct possibility that the Bingara diamonds are sourced from the same field as the Copeton area to the east, although a more local source(s) is also possible.

*Tract C/M/A-B*

The tract consists of extensions to units hosting diamond fields, favourable structures and magnetic anomalies within the Tamworth Belt and Central Block.

*Tract D/L/A-B*

The tract consists of all other units in the Nandewar study area not included in the above tract.

## 7.3.3 Sapphire

Sapphire is the gem variety of the mineral corundum, with various colours formed by traces of metals in the crystal lattice. The majority of the sapphire is dark blue in colour but parti coloured (yellow, blue and green) stones are also common in the Inverell area. Deposits of sapphires are often associated with alkaline volcanic provinces (especially in New South Wales).

A strong spatial association exists between alluvial sapphire deposits and some Tertiary basalts in New South Wales. Within the Nandewar study area, sapphire is associated with Tertiary basalts of the Central Province and with undifferentiated Tertiary basalts near Nundle.

In the Central Province, volcanism commenced in the east as multiple shallow explosive eruptions from flat-floored craters initially producing volcaniclastic rocks which progressed to lava dominated volcanism. Volcaniclastic rocks are fragmental aggregates of volcanic material formed by explosive volcanic activity. They are thin and poorly exposed, and are often altered to iron rich clays. Sapphires did not crystallise from these volcaniclastic rocks but were already formed at depth, and were brought to the surface by this volcanism.

Volcaniclastic rocks, and to a lesser extent alkali basaltic lavas, were recognised as the host rocks for the sapphires after a comparison was made between the New

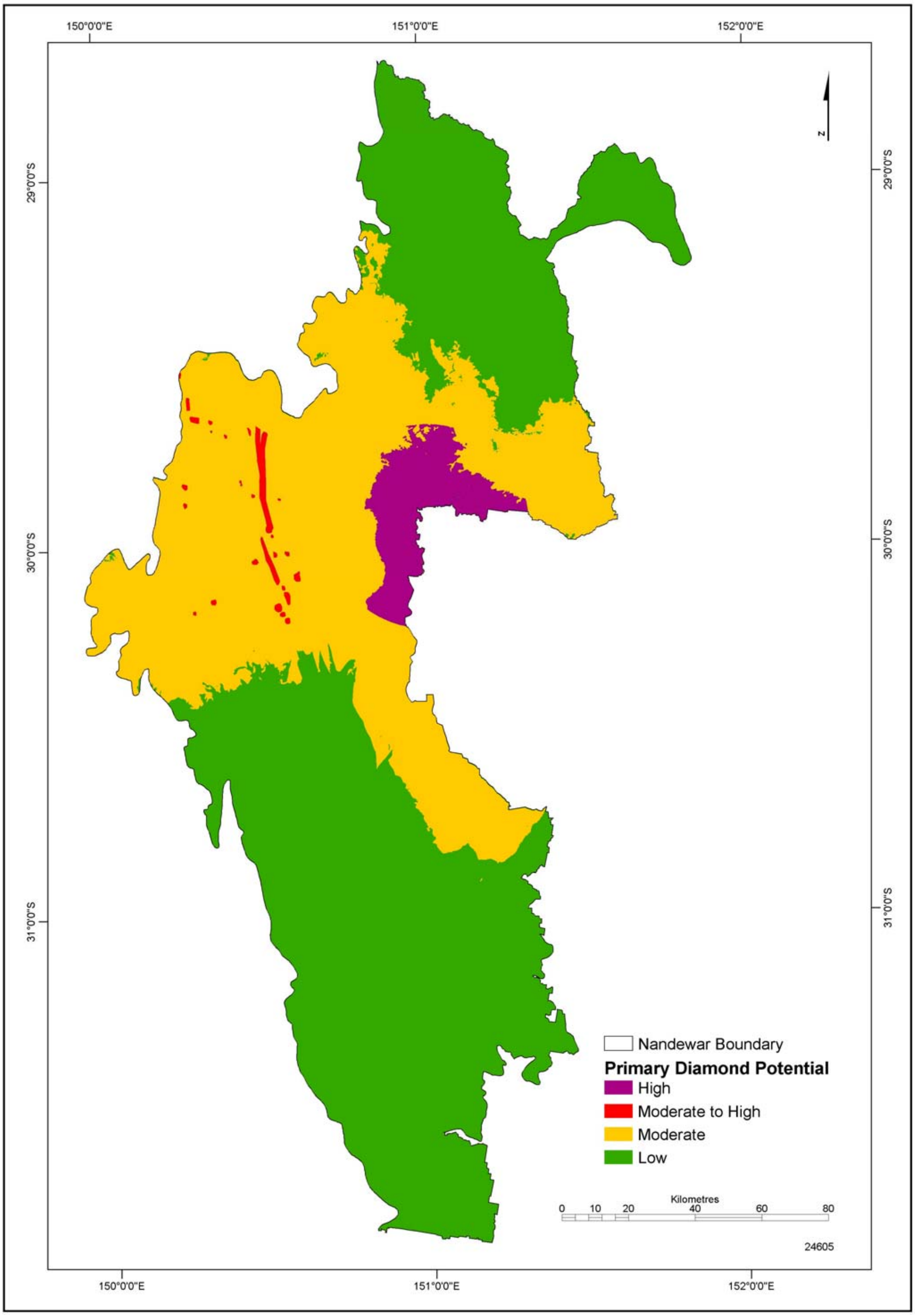



*Figure 7-I. Primary diamond potential, Nandewar study area*

England deposits of the easternmost Central Province and those in China (Lishmund and Oakes 1983). Similar sapphire deposits related to alkali basaltic volcanism are recognised throughout southeast Asia including Thailand, Cambodia, Laos and Vietnam.

In places, the volcaniclastic rocks have been deposited into and immediately reworked by rivers and lakes to form concentrated bands of heavy minerals, including sapphires. These volcano-fluvial and fluvial geological settings have produced the highest grades of sapphire, with examples at the 'Braemar' property near Elsmore, and the Kings Plains (Brown and Pecover 1988a, 1988b; Pecover and Coenraads 1989; Pecover 1994). Reworking of volcaniclastic rocks can concentrate sapphire into grades greater than 200 grams per bank cubic metre, and some grades can be as high as several kilograms per bank cubic metre. The Kings Plains deposits are thought to be the world's richest deposits associated with basalts (Pecover 1994).

Erosion and weathering of the primary and reworked volcaniclastic source rocks has formed Tertiary and Quaternary alluvial deposits. Local geomorphology of current and palaeo river valley systems plays an important role in concentrating the sapphires and an understanding of these processes is necessary in order to locate the deposits. Tertiary lavas flowed down river channels commonly diverting river systems, inverting topography and covering reworked sapphire-bearing volcaniclastics, forming deep leads (Coenraads 1991).

Newly acquired geochemical data and geological mapping completed for the Nandewar geology project (NAND04 – Geology Integration and Upgrade) over the Central Province has enabled the differentiation and mapping of the Tertiary basalts which had previously only been accomplished at localised scales (for example Duggan 1972; Oakes et al. 1996). The province can now be divided into two geochemical groups, those of alkali basalt composition associated with sapphires, and the sapphire-barren tholeiitic association. The alkali basalts occur in the eastern part of the Central Province corresponding to the distribution of the majority of the alluvial sapphire deposits. The basalts of tholeiitic composition occur in the western part of the province and have only a low potential to host or cover deposits of sapphire.

The alkali basalts and volcaniclastic rock association contains several identified vent complexes. The two most dominant are the Maybole Volcano and the vent complex in the Swans Brook-Kings Plains area. The vents have formed at or near the intersections of basement structures (Coenraads 1990). The erosion of these vent complexes has led to the development of a radial drainage patterns. Virtually all the streams draining the Maybole Volcano are sapphire-bearing (Pecover 1992).

Alluvial sapphire deposits also occur to the east of Nundle, in creeks draining Tertiary basalts. These basalts are undifferentiated but are most likely to be of alkali basalt origin. Large resources of sapphire and rubies are associated with the Barrington Tops volcanic complex, southeast of the Nandewar study area.

### Sapphire Tracts (Figure 7-J)

*Tract Sapp A/H/C-D*

This tract consists of proximal volcaniclastic rocks with an alkali basalt geochemical affinity, that have been moderately sorted by palaeodrainage to form reworked volcaniclastic rocks with concentrated bands of sapphire. These deposits now form palaeochannels that include some of the richest concentrations of sapphire and have been worked at 'Braemar' near Elsmore and in the Kings Plains area. The Kings Plains valley has been buffered using the updated geology, geophysics and digital terrain data. A three kilometre buffer has been placed around the 'Braemar' deposit to include palaeochannel deposits in the vicinity.

*Tract Sapp B/M-H/B-C*

This tract consists of major rivers and creeks draining the alkali basalts of the Central Province, buffered out to five kilometres from these basalts to include any distal alluvial deposits. The rivers themselves are buffered to 500 metres to include any palaeochannels. However, it is recognised that palaeochannels may not follow current stream orientations, decreasing certainty.

*Tract Sapp C/M/C*

This tract consists of primary and reworked volcaniclastic rocks with an alkali basalt geochemical affinity in the Central Province. Volcaniclastic rocks are known hosts of sapphire and it is possible this tract includes reworked volcaniclastic rocks with economic concentrations of sapphire. These volcaniclastic rocks have been differentiated in the field and have a corresponding dark green radiometric signature.

*Tract Sapp D/L-M/B-C*

This tract contains the alkali basalts of the Central Province. The basalts are buffered to five kilometres to cover any alluvial sapphire deposits in minor rivers, deep leads and palaeochannels.

This tract also includes undifferentiated Tertiary basalts to the south of the study area tentatively included in the Barrington Volcanic Province (informal). These basalts are most likely associated with the alluvial sapphire deposits near Nundle and are associated with the sapphire and ruby deposits at Barrington Tops and Gloucester. The basalts are buffered to five kilometres to include alluvial sapphire deposits.

*Tract Sapp E/L/C*

The tract is comprised of basalts and volcaniclastic rocks of the Central Province with a tholeiitic geochemical affinity. The basalts have been buffered to five kilometres to include any alluvial sapphire deposits, however because of their thoelitic geochemistry, they are not considered to be likely sources of sapphire.

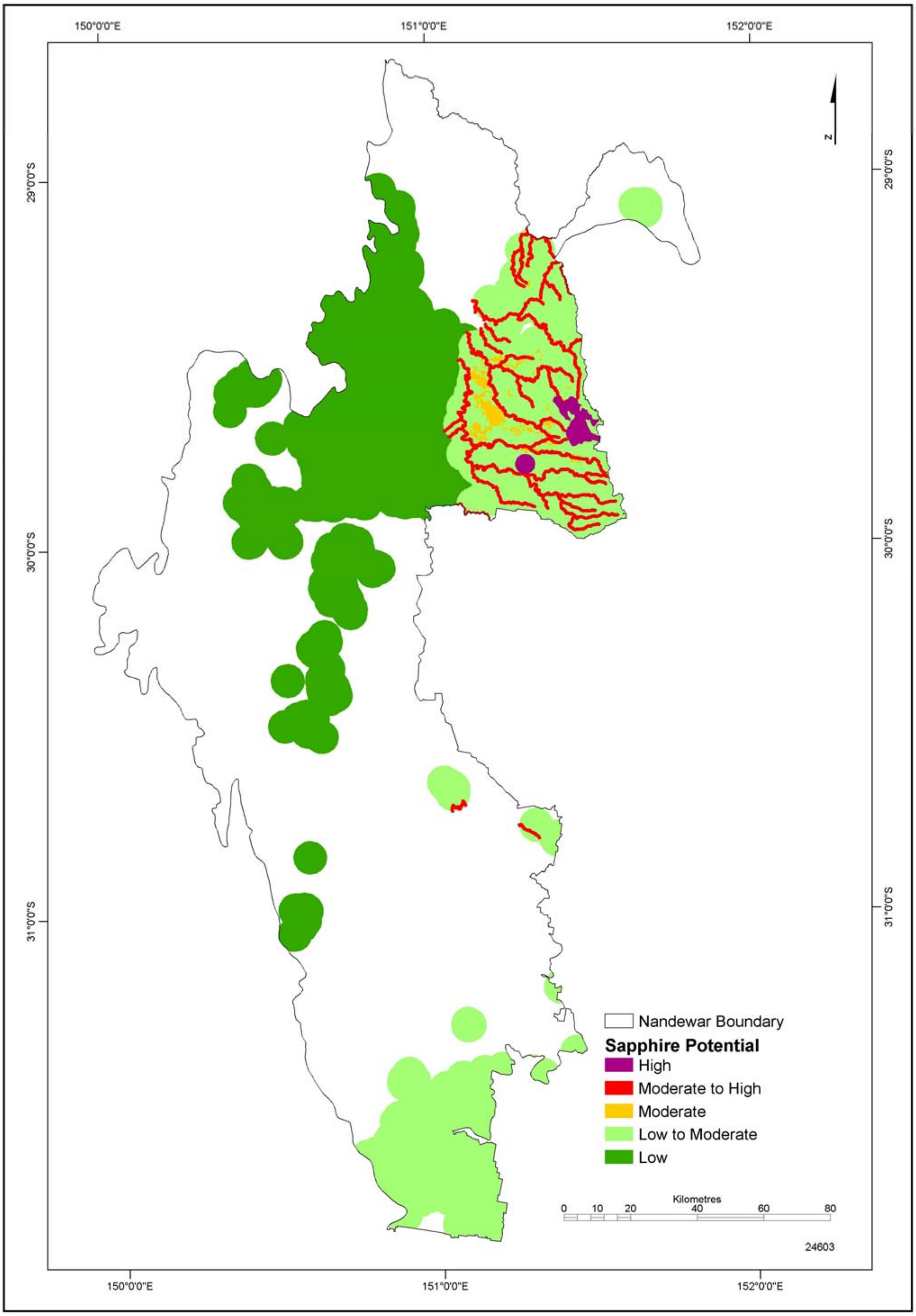



*Figure 7-J. Sapphire potential, Nandewar study area*

They may, in some cases, cover older palaeochannel deposits associated with alkali basaltic volcanism. In areas of thinner, younger tholeiitic sequences, economic extraction of sapphire-bearing palaeochannels may be viable in the future.

### 7.3.4 Limestone

Limestone is a sedimentary rock composed principally of calcium carbonate ($CaCo_3$), usually as the mineral calcite. Limestone forms largely in shallow marine environments.

Limestone is only a low to moderate cost material, and transport costs are a large proportion of final product costs. The main consuming industries must therefore obtain their raw materials as close as possible to the manufacturing or processing plants to reduce costs (Lishmund et al. 1986). The largest deposits in New South Wales supply processing plants within economic haulage distance of these markets.

In the Nandewar study area, limestone is currently being quarried from two deposits north of Attunga, Jacksons Quarry and the Sulcor Quarry. Recent annual production from both quarries averages about 200 000 tonnes per year. Exploration has defined a further 1.6 million tonne resource of high purity limestone north of the Sulcor Quarry.

The Attunga limestone deposits are located within the Early to Middle Devonian Tamworth Group. Folding and faulting of these once continuous beds has isolated the limestone into blocks surrounded by deep-water sediments. Limestone in the Tamworth Group near Murrurundi is presently undergoing evaluation.

Near Ashford, limestone deposits crop out over a strike length of ten kilometres. The limestone deposits are thought to be the remains of a seamount within sandstone of the Texas Beds. An Inferred resource in excess of 40 Mt of very pure (greater than 98.5% $CaCO_3$) low iron limestone was calculated down to a depth of 20 metres (Stephen and Arkland Pty Ltd, Final exploration report, EL 4020, Ashford area 1995).

The long term outlook for limestone for use as a flux may be enhanced in the Nandewar study area by expansion of the coal industry in the Gunnedah Basin, the Werrie Basin, and in the Ashford area.

#### Limestone Tracts (Figure 7-K)

*Tract LST: A/H/C-D*

The mapped limestone units of the forearc sedimentary sequences of the Early Devonian Tamworth Group define this tract, which include the Sulcor, Moore Creek, Neminga, Timor, Loomberah and Crawney Limestone Members.

Included in this tract are four limestone deposits to the south of Warialda, which have been buffered out to two kilometres. Brown and Stroud (1997) have suggested that these deposits are also limestones of the Tamworth Group. Some of these deposits have been worked historically.

*Tract LST: B/M-H/B*

This tract comprises the undifferentiated units of the Tamworth Group, which may also have potential to host economic deposits of limestone.

*Tract LST: C/M/C*

The tract includes the mapped Ashford Limestone units within the Texas Beds. The limestone is interpreted to be a seamount incorporated into the Texas Beds. These seamounts host limestones of high purity (greater than 98%) (Lishmund et al. 1986).

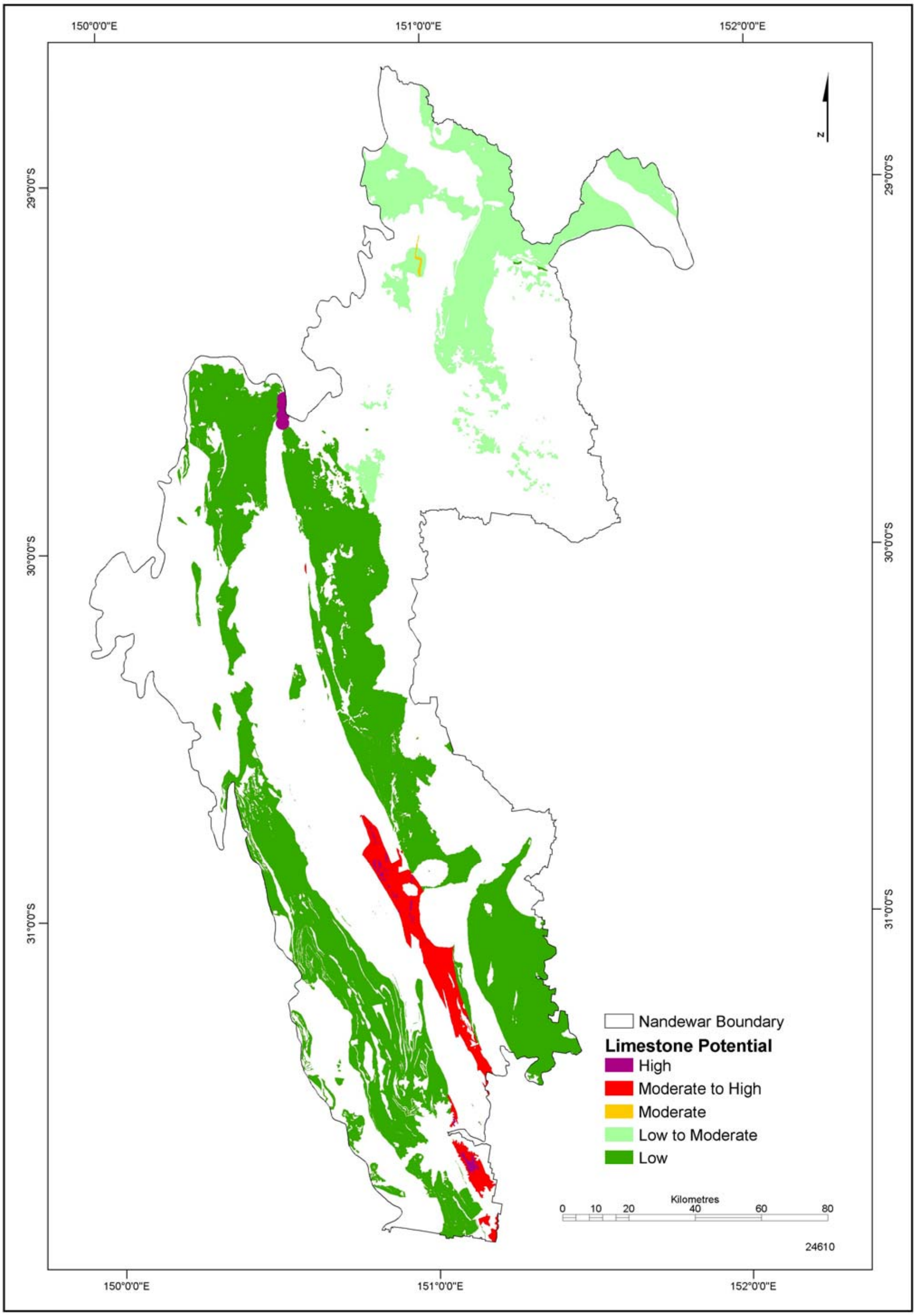
*Tract LST: D/L-M/B*

The tract includes undifferentiated Texas beds units that have the potential to host further economic deposits of limestone. Limestone within the Texas Beds is recorded to the north and northwest of Torrington but not mapped (for example Tenterfield Limestone, Ray et al. 2003). The limestone deposits are not continuous, however, they are in greater abundance near the New South Wales-Queensland border with an operating quarry (Riverton) in southern Queensland.

*Tract LST: E/L/B*

The tract includes small discontinuous limestone lenses that are hosted by the Woolomin Beds and the Whitlow, Cara and Wisemans Arm Formations of the Central Block. Limestones, fault-bounded and associated with serpentinite within the Woolomin Beds are thought to be derived from seamounts scraped off a subducting slab (Lishmund et al. 1986). Limestone occurs in the Cara and Wisemans Arm Formations as minor olistoliths, although not all these are mapped. Deposits are small and remote from markets, downgrading their economic importance.

This tract also includes the Glenmore Formation, the basal member of the Wandsworth Volcanic Group (containing clastic sediments with rare interbeds of massive fine-grained limestone (Stroud 1992)) and the Parry Group and Caroda, Currabubula and Merlewood Formations of the Tamworth Belt (containing extensive but thin and impure beds of limestone).




*Igure 7-K. Limestone potential, Nandewar study area*

### 7.3.5 Construction Materials

The term *construction materials* is used to denote all low-cost minerals and rocks which are extracted in bulk, and used for construction purposes.

Quarrying operations for construction materials in the Nandewar study area are spatially associated with major markets and transport routes. Eightyone per cent of the operating quarries and pits within the Nandewar study area occur within 60 kilometres of the two main centres of Inverell and Tamworth. Distance from markets is an important criterion in assessing the development potential of a particular site. Transport to markets is generally by truck and therefore requires road linkage from the quarry to the market. Gaining transport access to a site, and appropriate development consent for any road upgrading are preconditions to developing suitable access roads to quarries. Therefore, proximity of roads to quarry sites is an important consideration and can be used to model potential.

Within the Nandewar study area, several small quarries for dimension stone have been developed mainly for granite in the southern part of the Bundarra Supersuite. Historically, basalt has been quarried near Inverell for dimension stone. Near Attunga, minor amounts of

limestone and serpentinite have been crushed for use as a decorative aggregate (Brown et al. 1992) and limestone and marble have been quarried for use as decorative stone.

Quarries producing unprocessed construction materials are developed in a wide variety of rock units throughout the Nandewar study area, particularly in proximity to the two major towns. Pits are also developed by councils for use as road base, generally in close proximity to the sites being upgraded or maintained. Lower quality limestone extracted from the Jacksons Quarry is crushed and also used as road base.

Coarse aggregate and sand for construction purposes have been extracted from river channels, especially those located in close proximity to Tamworth including the Cockburn and Peel Rivers, and Quirindi Creek. Thick and extensive alluvial deposits occur along the banks of the Gwydir River and Copes Creek. Several small pits are developed within these deposits with potential for further sand and gravel extraction.

Several quarries in the Nandewar study area have been developed locally to supply construction material for dams, for example the Split Rock and Copeton Dam quarries.

The AUSLIG Geodata road data set has been used for modelling potential. This road data set is classified and buffered as shown in **Table 7-F:**

***Table 7-F. AUSLIG Geodata road data***

| Class | Description | Explanation | Buffered distance each side of road (metres) |
|---|---|---|---|
| **1** | Dual carriageway | Freeway, tollway or other major road with lanes in different directions separated | N/a |
| **2** | Principal road | Highway, regional and through road | 3200 |
| **3** | Secondary road | Connector and distributor road | 1600 |
| **4** | Minor road | Access, residential, local road | 800 |
| **5** | Track | Public or private roadway of minimum or no construction, not necessarily maintained | 400 |

Note: there are no Class 1 roads in the Nandewar study area

### Construction Material Tracts (Figure 7-L)

*Tract Conmat A/H/C*

The tract includes areas within 3200 metres from principal roads, class 2. There are no class 1 roads in the Nandewar study area.

*Tract Conmat B/M/C*

The tract includes areas within 1600 metres from secondary roads, class 3.

*Tract Conmat C/L/C*

The tract includes areas within 800 metres from minor roads, class 4 and areas within 400 metres of tracks, class 5.

Subsequent to the above modelling, some known locations of construction materials and dimension stone were still present outside of the buffers because of the lack of sufficient detail on roads, or because local use required little transport (for exampled quarries excavated for dam construction). These known quarries were buffered to 500 metres to indicate that additional resources of construction materials and/or dimension stone may be present.

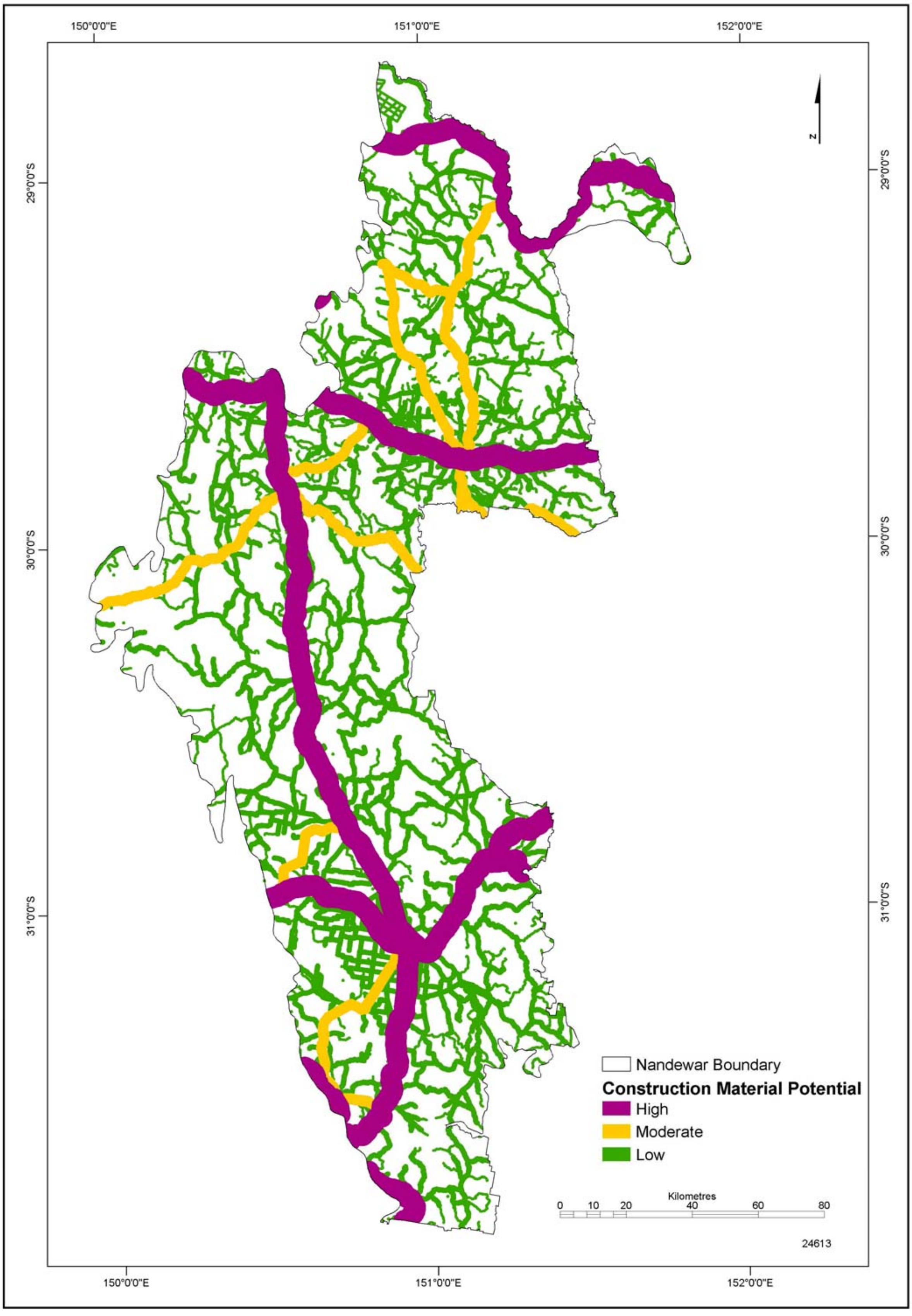



*Figure 7-L. Construction material potential, Nandewar study area*

### 7.3.6 Diatomite

Diatomite is a sedimentary rock essentially composed of the siliceous skeletal remains of microscopic, one-celled, aquatic plants called diatoms, which on death accumulate to form a lightweight chalk-like deposit. Diatomite has various industrial applications, which include paint filler, paper filler and as a general absorbent (including pet litter).

Deposits of high quality diatomite have been mined in the Nandewar study area since the 1930's, particularly in the Barraba area. Remaining resources at Barraba are substantial with current production valued at around A$3 million per year. The Barraba deposits are associated with 18 Ma basaltic and trachytic lava flows and pyroclastic tuffs of the Nandewar Volcanic Complex. Alternating bands of diatomite and/or tuffs and clays overlie thick beds of clay-altered trachytic tuffs. A capping of Tertiary basalt (Holmes et al. 1989) has preserved these deposits. The deposits are thought to have formed by the impounding of the palaeodrainage by lava flows forming freshwater lakes in which diatoms could thrive. Abundant silica, for diatom formation, was supplied from volcanic ash. The diatomite at Barraba is found in four main seams that range from less than 0.5 metres to 7.5 metres in thickness (Australian Diatomite Mining Ltd 1995).

Within the rest of the study area, the Tertiary sediments have not been delineated sufficiently to target prospective horizons associated with Tertiary volcanics, such as the Central Province and the Nandewar Volcanic Complex. Diatomite-bearing sequences have been mapped with associated volcanics in the western Nandewar Volcanic Complex, but exploration has not been undertaken.

#### Diatomite Tracts (Figure 7-M)

*Tract Diat A/H/C-D*

This tract includes all known diatomite deposits and prospects at Barraba associated with the Nandewar Volcanic Complex.

*Tract Diat B/M/B*

This tract contains all mapped Tertiary sediments that are reported to contain diatomite within five kilometres of early Miocene age volcanic rocks. All of New South Wales diatomite deposits contain a species of early to mid Miocene freshwater diatom, constraining the age of the deposits.

*Tract Diat C/L/B*

This tract comprises all Tertiary volcanic rocks younger than early Miocene. These volcanic rocks have potential to host further Tertiary sediments including diatomite.

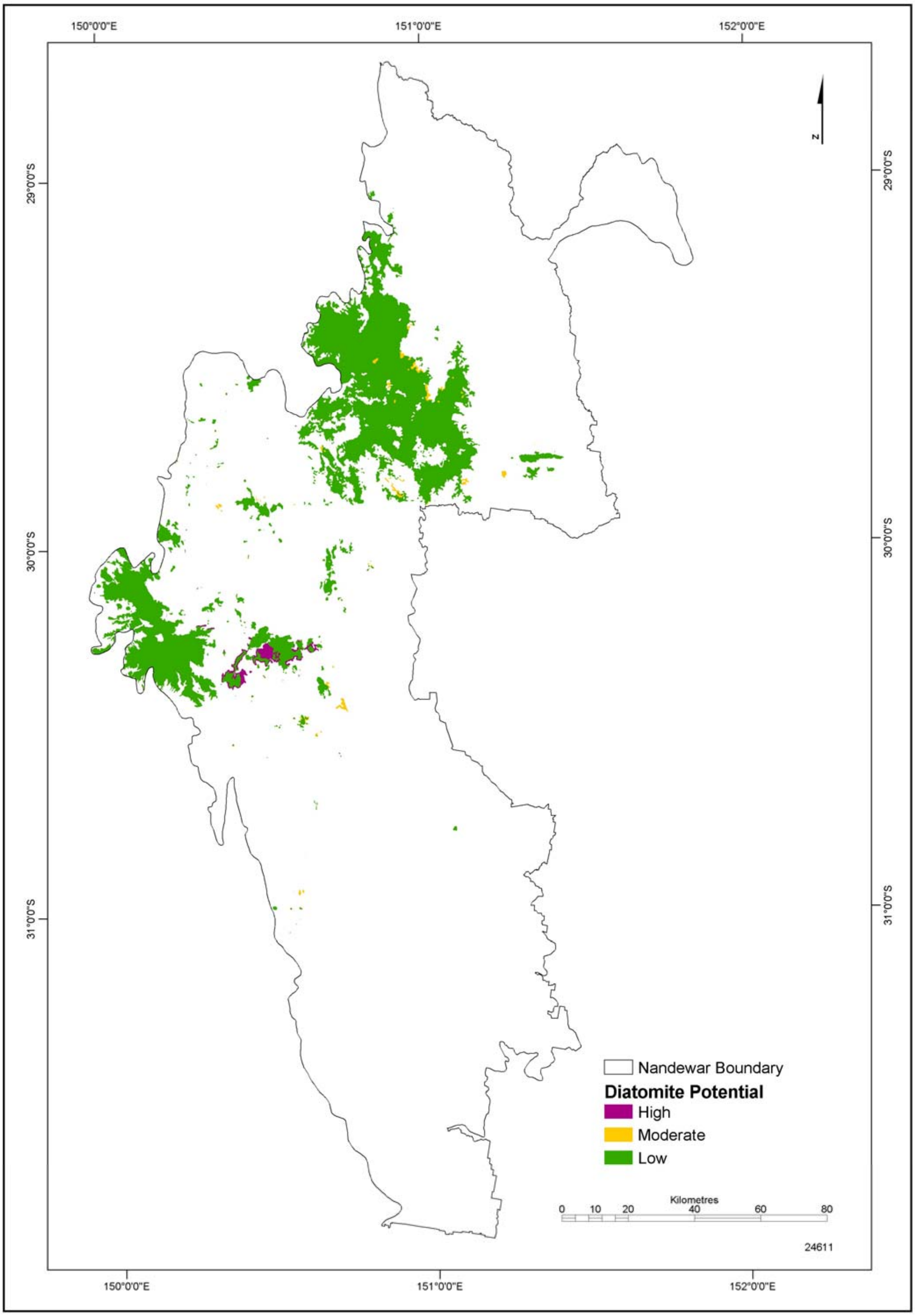



*Figure 7-M. Diatomite potential, Nandewar study area.*

### 7.3.7 Alluvial Diamond

Alluvial diamond deposits are secondary deposits formed from the erosion and deposition of diamonds from primary sources by alluvial processes.

Significant alluvial diamond production has occurred at the Bingara Diamond Field, within the Nandewar study area, and the Copeton Diamond Field that partly overlaps the Nandewar study area. Recorded historical production of diamonds from these fields is in excess of 236 000 carats (MacNevin 1977, Brown and Stroud 1997), but is most probably over 500 000 carats (Barron et al. 1996). Small-scale intermittent open cut mining of resources at old mine sites at Copeton such as Streak of Luck, Doctors Workings, Round Mount and Mount Ross on the east side of the Copeton Dam commenced in 1996 (Cluff Resources Pacific NL 1997). Minor production has also occurred at the Monte Christo mine at Bingara, with production since 1998 of the order of several thousand carats.

The Bingara Diamond Field has a recorded production of at least 34 000 carats between 1872 and 1904 (Brown and Stroud 1997). Alluvial gold was also present in payable quantities in some areas, notably in reworked Holocene alluvial flats and stream beds derived from the Tertiary leads. The host units for the diamonds includes Tertiary deep leads, unroofed Tertiary gravels and minor volumes of redistributed alluvials. Average size of the diamonds is small (0.20 carat), however the proportion of gem quality stones is high (Brown and Stroud 1997). An independent diamond valuation on the diamonds recovered (+1mm) from the 1995 bulk sampling program at Monte Christo has yielded US$61/carat, and 98% gem quality (*Minfo Quarterly Journal No. 63*, April 1999). Corundum, zircon, and tourmaline are also present in varying concentrations in the Tertiary leads. Clast compositions and heavy mineral analyses suggest that the Central Block was the provenance of the Bingara diamond-bearing gravels. Some recent analyses suggest the source could be the same as that of the Copeton diamond field, being part of the same palaeochannel system, although local sources for the Bingara diamonds are still possible.

The Copeton diamond field contained rich (3.3 to 12 carats per cubic metre of gravel, Brown and Stroud 1997) diamond deposits which were discovered in 1872 and mined in association with tin between 1872 and 1922. Recorded diamond production was over 200 000 carats but mining was generally not very profitable (MacNevin 1975). A high proportion (approximately 90%) of the diamonds is apparently of gem quality (Cluff Resources Pacific NL 1991, 1996a; *Minfo Quarterly Journal No. 63*, April 1999) but they are relatively small. The diamonds are found in Tertiary boulder beds, gravels and sands, and Quaternary river and creek gravels in areas southwest of Inverell (Brown and Stroud 1997). There is some suggestion of proximal or in-situ material also being mined for diamonds in the Copeton area. The spatial distribution of palaeochannels within the region support the idea that the source(s) of the diamonds lies close to the junction of the Gilgai and Bundarra granites in the Copeton area (MacNevin 1977). The diamonds at Bingara may also be sourced from the Copeton area. Several surveys conducted during the late 19th century also suggested that the diamonds at Bingara were sourced from south of Inverell (Stonier 1895).

Small-scale open cut mining of remaining resources at old mine sites such as Streak of Luck, Doctors Workings, Round Mount and Mount Ross on the east side of the Copeton Dam commenced in 1996 and have continued intermittently (Cluff Resources Pacific NL 1997).

Diamond grades are estimated at 0.5 carats per tonne underground at Mount Ross and 0.05 to 0.07 carats per tonne in open cut resources at Streak of Luck and Round Mount (Cluff Resources Pacific NL 1996b). Numerous old workings on the northern side of the Copeton Dam offer potential for small mineable resources, such as at Wonderland, Staggy Creek and Oaky Creek.

### Alluvial Diamond Tracts (Figure 7-N)

*Tract ADia A/H/A-B*

This tract consists of Tertiary units which host known diamond occurrences, or are in the vicinity of known alluvial diamond fields.

*Tract ADia C/L-M/A-B*

This tract consists of other Tertiary units within the vicinity of known diamond occurrences. Quaternary units are not included, as the number of diamonds currently being shed into Quaternary stream systems appears to be limited. Those that contain diamonds are thought to be shedding from Tertiary or previous units, with a few possible exceptions.

*Tract ADia C/L/A-B*

This tract consists of all other Tertiary units within the Nandewar study area, streams draining diamond fields buffered to 100 metres, and Quaternary units in the vicinity of known diamond fields.

Diamonds have not been recorded in streams draining most of the Tertiary units within the Nandewar study area, and it is considered that the potential for either the presence or discovery of economic deposits of alluvial diamonds within many of these areas is low. Extensive testing and mining of alluvial sediments in the Nundle region, for example, has recovered sapphire and zircon, (and rubies outside the Nandewar study area), but no diamonds.

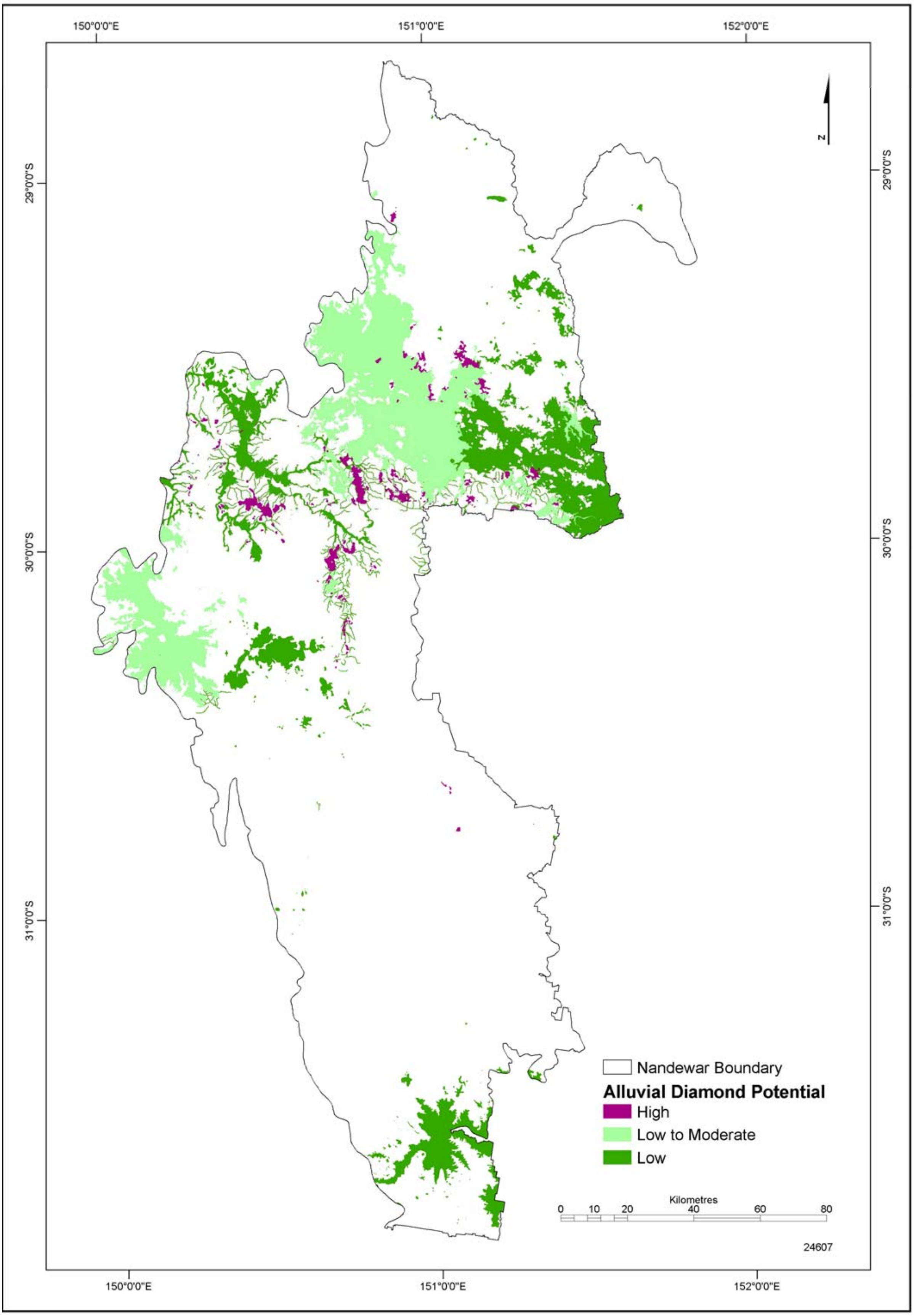



*Figure 7-N. Alluvial diamond potential, Nandewar study area*

### 7.3.8 Serpentinite-Related Deposits

Serpentinite is an unusually reactive, pearly lustered green-black rock that oftens forms in collisional environments, such as along the Peel Fault in the central part of the Nandewar study area. Serpentinite belts can host a range of deposit types but they have all been grouped together for modelling purposes. This class of deposits includes podiform chromite, sediment-hosted and hydrothermal magnesite, ultramafic-hosted asbestos, serpentine, olivine (dunite), and nickel-copper deposits. The tract overlaps with orogenic gold within the Nandewar study area.

Examples of all these types of deposits are known within the Nandewar study area. Several occurrences of sediment-hosted magnesite have been recorded in the Warialda, Attunga and Woodsreef areas, and hydrothermal magnesite is known around Woodsreef. Large deposits (greater than A$600 million in production, 2003) of asbestos have been mined at Woodsreef near Barraba. Pods of chromitite are distributed throughout much of the Great Serpentinite Belt and some of its satellite bodies. Most of the chromitite bodies are lenticular and elongate parallel to the strike of the ultramafic belt. A gabbro associated nickel-copper (model Cox and Singer 7A 1986) occurrence occurs at Upper Bingara at the Harrisons mine. An olivine (dunite) deposit is currently under assessment near Barraba, and bodies of industrial serpentine are widespread.

There are large resources of industrial serpentine in the Nandewar study area, with minor current production. Its major use in New South Wales is as a flux in steel making. There may be long term potential for increased serpentine production within the Nandewar study area with the proposed development of three steel making projects in the Hunter Valley. The proposed steel projects total A$4.3 billion (2002) in capital costs, and have gained development consent or are at an advanced feasibility stage.

Nickel is a commodity commonly associated with serpentinite belts, and in which international demand has grown significantly over the second half of the 20th century. It is used mostly in stainless steel production. Demand is projected to increase further over coming decades, potentially raising prices to very attractive levels. Although the potential for nickel within the Nandewar study area is considered limited, it is perhaps true to say that systematic research and exploration has thus far been quite limited. An example is the widespread presence of anomalous nickel in the Upper Bingara area, which has hardly been investigated since the 1960’s. Samples of nickel carbonate on the dumps and up to 30 metres from Harrisons Mine shaft have recorded up to 10% nickel.

#### Serpentinite-Related Deposit Tracts (Figure 7-O)

*Tract Serp A/H/C*

The tract includes all outcropping units of serpentinite. It should be noted that there are probably areas of outcropping and subcropping serpentinite or serpentinite-related rocks that have not been defined by mapping or exploration to date.

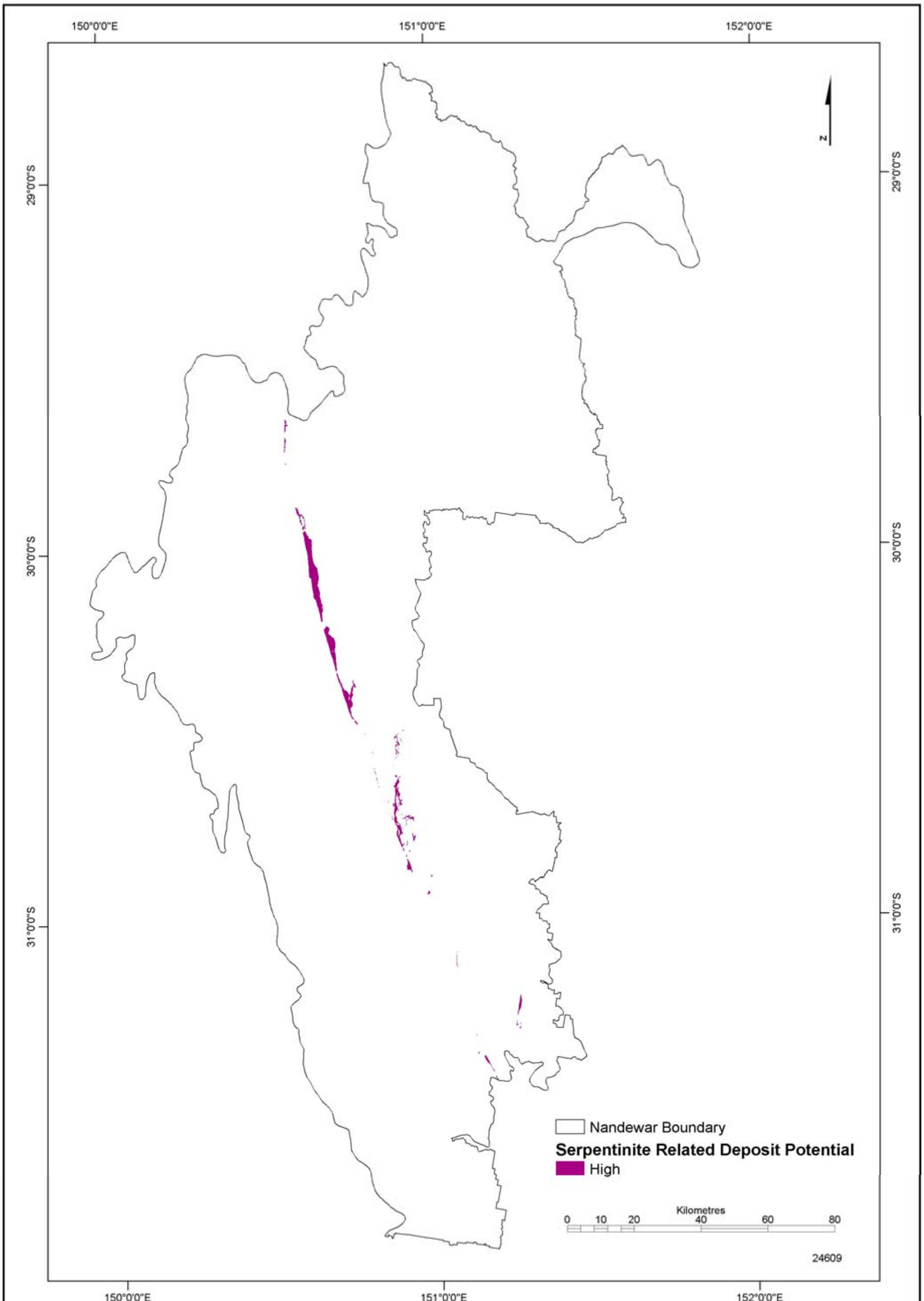



*Figure 7-O. Serpentinite-related deposit potential, Nandewar study area*

### 7.3.9 Kaolin

Kaolin is a soft, fine, earthy, nonplastic, usually white rock composed essentially of clay minerals of the kaolin group, principally kaolinite. Kaolin is used in the manufacture of ceramics, refractories and paper.

Kaolin deposits are broadly classified as primary (or residual) and secondary (or transported). Primary deposits form *in situ* by weathering and/or hydrothermal alteration of certain rock constituents. Secondary deposits comprise detrital clay derived from primary deposits and transported (generally by water) to the site of deposition.

In New South Wales, most known kaolin deposits formed in the Tertiary period during humid climatic conditions which formed deeply weathered/leached regolith profiles.

Hydrothermal alteration of a leucogranite at Elsmore has produced a primary kaolin deposit. Hoynes et al. (1996) calculated reserves of 752 400 tonnes of which 320 000 tonnes of kaolin can be produced. Mining of the deposit in recent years has been curtailed largely due to strong competition from similar sources in Queensland. The Gum Flat Kaolin deposit also formed as a result of alteration of granite.

Many of the secondary kaolin deposits have been derived from a variety of source rocks including slates, granites, basalt and tuffs. The deposits are commonly less than ten metres thick and were formed in a variety of environments. Kaolinisation of the Sandon Beds resulted in the Wades Brickworks deposit, which produced some 41 000 tonnes of clay between 1956 and 1973 (Baker and Uren 1982).

Kaolin deposits north and south of Barraba occur within the Tertiary sequence as transported kaolin derived chiefly from altered trachytic tuffs (Baker & Uren 1982). In places kaolinitic clays are associated with large, currently mined diatomite deposits and are capped by Tertiary basalt. The clays have been used as flint clay for the manufacture of refractories and cream house bricks during the 1970’s (Baker & Uren 1982) and again in recent years.

The Permian Koogah Formation contains kaolinitic clays partly calcinised by the Burning Mountain burning coal seam (Baker & Uren 1982). The clays were derived from the nearby weathered Werrie Basalt and transported and deposited as an alluvial fan (Loughnan 1973). The calcined kaolin has properties suitable for use in the manufacturing of refractories. Gilligan and Brownlow (1987) however noted that identified reserves of calcined kaolin were virtually exhausted.

#### Kaolin Tracts (Figur 7-P)

*Tract Kao A/M-H/C*

Baker and Uren (1982) suggested that the most prospective areas for kaolin deposits in New South Wales are those where Tertiary sediments are still preserved. This tract includes known primary and secondary deposits, especially those preserved by Tertiary sediments or basalt (for example Barraba deposits and some near Inverell).

*Tract Kao B/M/B*

The highest quality kaolin deposits are derived from either the hydrothermal alteration and/or weathering of high silica granites or felsic volcanic units. The kaolin deposit can be either of a primary or secondary nature.

This tract consists of the buffering of high silica granites and felsic volcanic units. It includes leucogranites at Elsmore in addition to the Dumboy-Gragin, Gilgai, Webbs Consol and Mole granites. The felsic Late Permian Emmaville Volcanics are included in this tract, where clay deposits derived from rhyodacite have been reported east of Inverell.

*Tract Kao C/L-M/C*

This tract consists of Permian, Triassic and Jurassic age terrestrial sedimentary rocks that have the potential to host transported lower grade kaolin deposits (Baker & Uren 1982). Included in the tract is the Permian Koogah Formation, which may have potential for further resources.

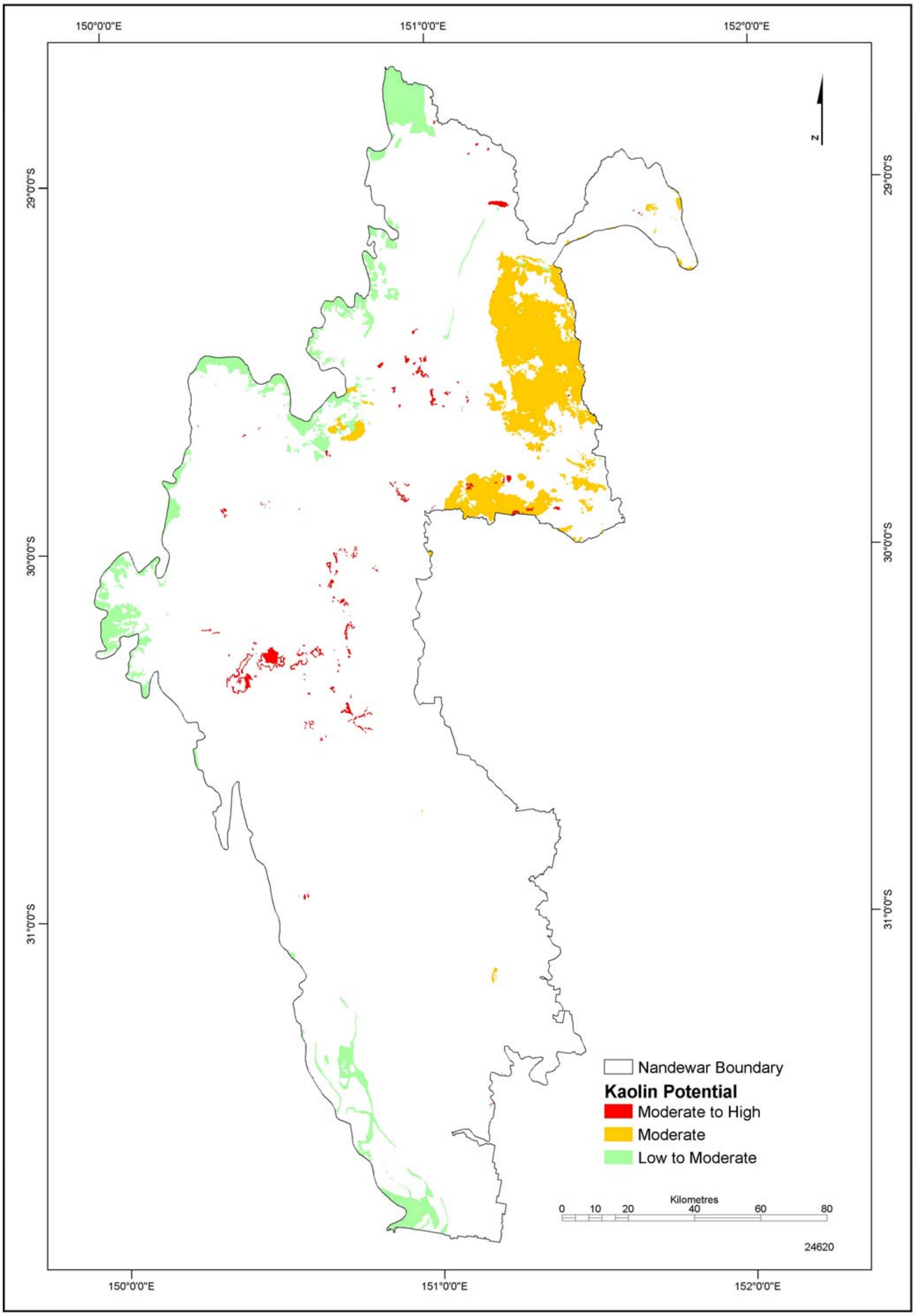



*Figure 7-P. Kaolin potential, Nandewar study area*

### 7.3.10 Zeolite

Zeolites are a group of hydrated aluminosilicates of the alkali and alkaline earth metals, particularly sodium, potassium, and calcium. They are industrially useful because their cation exchange and atomic structure make them suitable for many applications in agriculture, pollution control, soil conditioning, as an additive in stockfeed, for odour control and in water treatment.

Large resources of zeolite are known to occur in the western portions of the Nandewar study area, hosted by Permo-Carboniferous volcanic rocks in the Tamworth Belt. Recently operating mines occur near Werris Creek, (the Escott Mine), and at Bindawalla near Quirindi.

The Currabubula Formation, and its various facies equivalents, have the highest prospectivity for zeolite deposits in the study area. Subsurface extensions of these prospective rock units have not been included in the assessment, due to their lower economic viability. Prospects include The Gap, Wingen Mountain, and Z4.

#### Zeolite Tracts (Figure 7-Q)

*Tract Zeo A/H/C*

This tract contains all Currabubula Formation facies equivalents, and late Early Carboniferous units in the Tamworth Belt which were deposited in either a marine or a transitional marine-terrestrial depositional setting.

*Tract Zeo B/L/C*

This tract contains all other outcropping and subcropping formations considered prospective for zeolite. This includes all remaining Carboniferous volcano-sedimentary units in the Tamworth Belt which were deposited in either a marine or a transitional marine-terrestrial depositional setting.

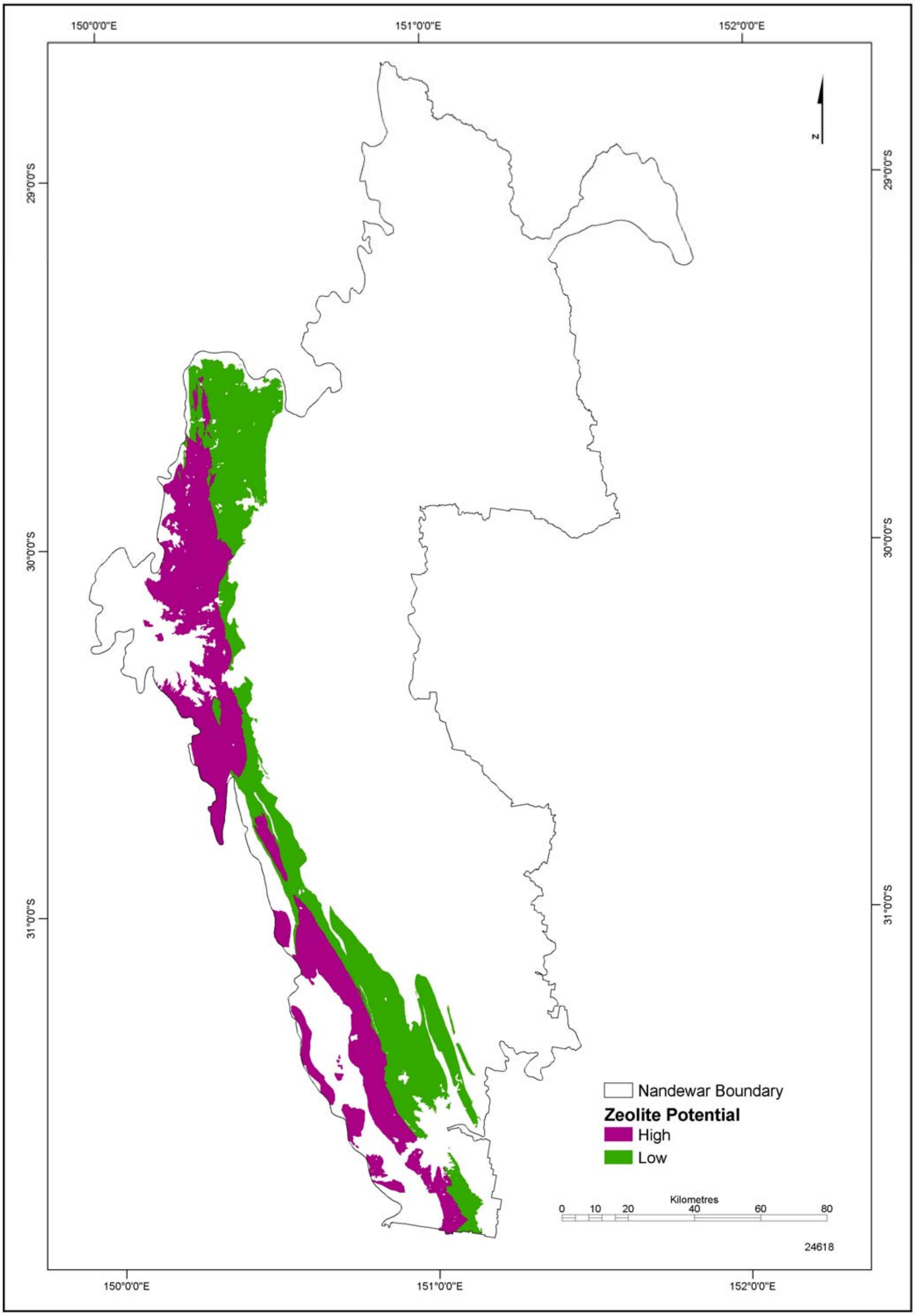



*Figure 7-Q. Zeolite potential, Nandewar study area*

## 7.4 METALLIC MINERALS

### 7.4.1 Orogenic Gold

Orogenic gold deposits are formed within geological structures from a variety of processes during orogenic (tectonic) processes. Worldwide, they are relatively common, but may vary significantly in size. Most orogenic gold deposits are spatially related to well-defined major fault zones, although usually locally situated in second and third order structures (Groves et al. 1998). Major faults are large penetrating structural zones that potentially provide greater access to mineralising fluids from deeper in the earth's crust. The Peel Fault Zone represents the near-surface splay of an interpreted major west-dipping fault (Korsch et al. 1995)(**Figure 7-E**), which is thought to be a major control on most of the orogenic gold deposits in the Nandewar study area. Buffering the Peel Fault Zone and associated subsidiary structures to three kilometres covers all the interpreted orogenic style gold fields along the Peel Fault Zone.

Gold fields within the Nandewar study area classified as orogenic include the Tea Tree, Crow Mountain, Bingara, Upper Bingara, and Nundle Gold Fields. A small Inferred gold resource of 260 000 tonnes at 2ppm Au has been identified at the Hidden Treasure Prospect near Bingara, and similar size resources have been identified in the Nundle area.

#### Orogenic Gold Tracts (Figure 7-R)

*Tract Oro A/M-H/C*

Units in this tract:

- are within three kilometres of the Peel Fault Zone, or;
- within three kilometres of secondary and tertiary structures adjacent to the Peel Fault Zone, or;
- within three kilometres of inferred subsurface extensions of the Peel Fault Zone, or;
- within three kilometres of the Namoi, Cobbodah and Sandy Creek Faults.

This tract includes all of the interpreted orogenic gold fields within the Nandewar study area.

There is a close relationship between regional major structures and the size of orogenic gold deposits worldwide, and to a lesser extent favourable reservoirs and the number of tectonic events. Therefore many of the smaller faults or fault zones in the Nandewar study area have not been included in this tract.

*Tract Oro B/M/A_B*

This tract consists of inferred extensions of the Peel Fault Zone in the Attunga area, and some inferred major faults southeast of Tamworth, where there are several historic gold fields.

The lack of major mapped crustal-scale boundaries or fault zones and the lack of suitable source reservoirs suggest that the potential for major orogenic gold deposits in these areas is no greater than moderate.

### *Tract Oro C/L/A_B*

This tract consists of all the various smaller structures, and/or other unmapped major structures within the Tamworth Belt and Central Blocks. Most of these structures are considered to be too small to host major orogenic style gold deposits in the context of the Nandewar study area, and have therefore been assigned a low potential.

Post-Triassic rocks have been excluded from this tract because they have formed after the major orogenic (tectonic) events. The potential for blind, economic-size orogenic gold deposits beneath post-Triassic cover is considered unlikely and/or impractical in the exploration sense, especially in the absence of known gold fields or mapped major structures.

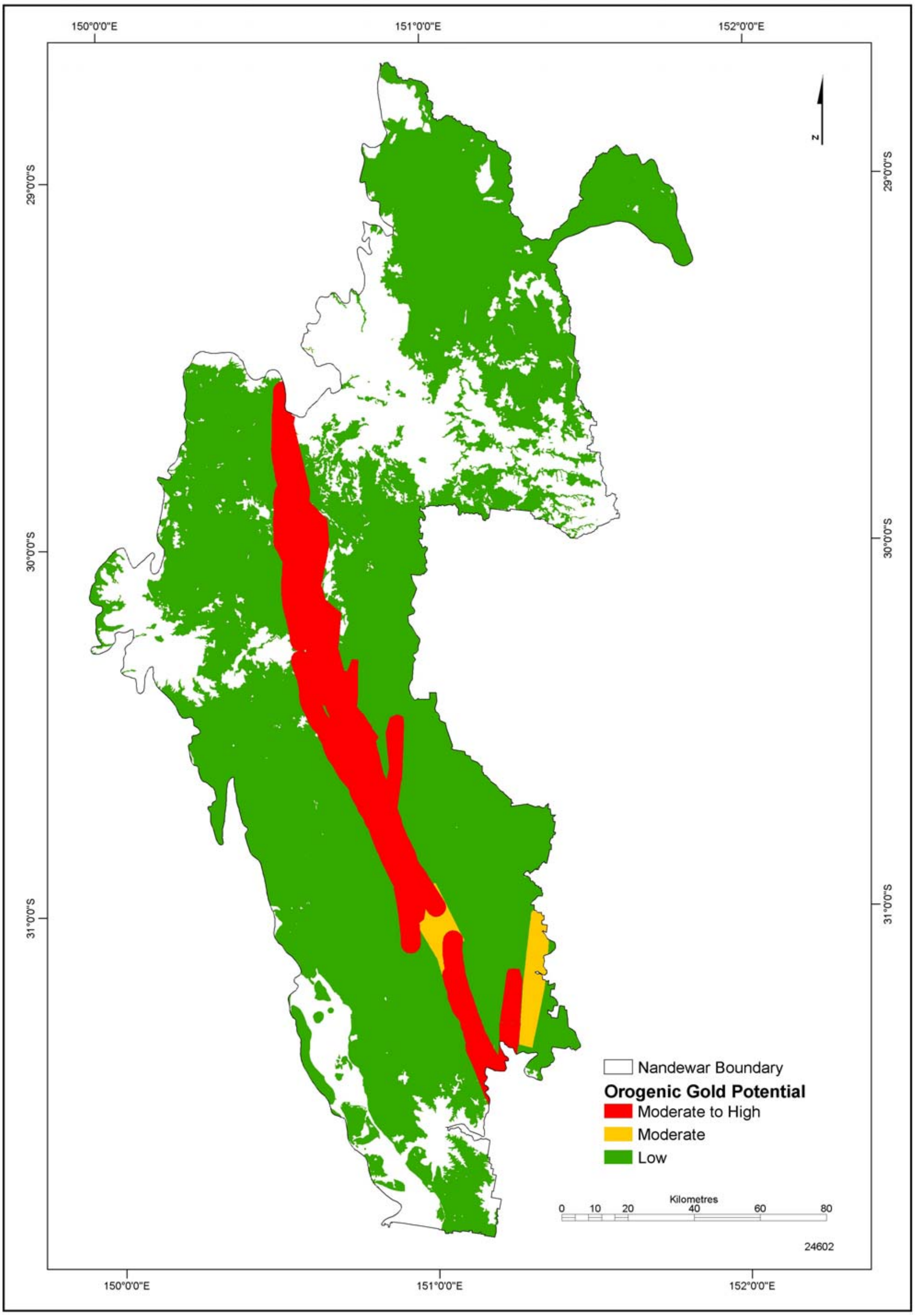



*Figure 7-R. Orogenic gold potential, Nandewar study area*

### 7.4.2 Porphyry Copper-Gold

The term porphyry copper-gold refers to large, relatively low grade, intrusion-related copper-gold deposits that can be mined using mass mining techniques. The deposits are genetically and spatially related to igneous intrusions which are generally felsic but can range widely in composition. The intrusions are invariably porphyritic multiple intrusive events however their most impressive feature is the size of the related metal deposits.

In the Nandewar study area the Moonbi and the Clarence River Supersuite granites are considered variably favourable for development of porphyry copper-gold or porphyry-related gold only deposits and have been buffered to five kilometres. However there is no consistent relationship with overall mineral potential and increasing distance from magmatic sources in this deposit class, and examples of world-class porphyry-related deposits are known (or inferred) up to and exceeding five kilometres from their known and/or inferred magmatic sources. There is a copper-gold-molybdenum occurrence associated with the Duncan's Creek Trondjemite, and a copper-gold vein occurrence west of Nundle at the Sugarloaf Prospect (granites of the Clarence River Supersuite). Several other occurrences of copper-gold ± molybdenum occur to the southeast of the Nandewar study area.

The Moonbi and Clarence River Supersuites may also be favourable for the recently defined 'intrusion-related gold' style of Thompson et al. 1999 and Lang and Baker 2001 which includes fractionated intrusions of intermediate oxidation state.

#### Porphyry Copper-Gold Tracts (Figure 7-S)

*Tract CuAu A/M/B-C*

This tract consists of I-type, oxidised, variably fractionated intrusions of the Moonbi Supersuite, buffered to five kilometres. The tract covers the Weabonga Gold Field, and many of the occurrences in the Limbri area. The tract also includes areas in the far northeastern parts of the Nandewar study area.

*Tract CuAu B/L-M/B-C*

This tract includes Clarence River Supersuite granites and their equivalents, (including the Nundle Suite, AMIRA International 2003) buffered to five kilometres.

Recent geochemical analyses (AMIRA International 2003) suggest only low or at best low to moderate potential for the Clarence River Supersuite, although some intrusives, particularly in southern portions of the Nandewar study area, do not appear to have been included in this study. The Clarence River Supersuite also exhibits a high degree of chemical variation in the southern part of the study area.

The tract also includes areas in the far north of the Nandewar study area, where granites of the Clarence River Supersuite both outcrop and have been interpreted in the subsurface. The tract also covers most of the Nundle and Niangula Gold Fields.

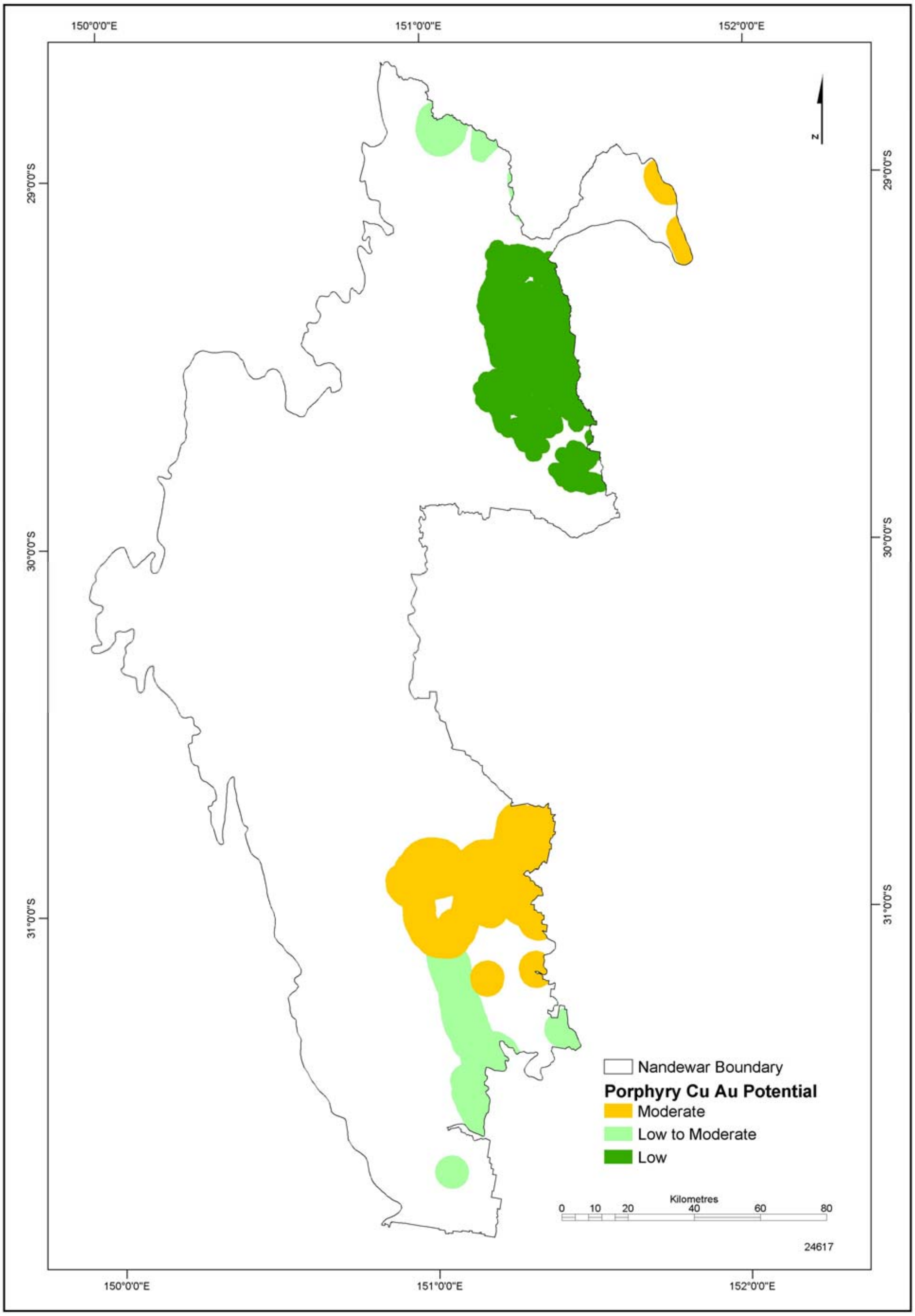



*Figure 7-S. Porphyry copper-gold potential, Nandewar study area*

*Tract CuAu C/L/B*

This tract includes the poorly mapped intrusives within the Emmaville Volcanics in the far north of the Nandewar study area. This area contains a number of sparsely outcropping, unassigned granites and intrusives, buffered to two kilometres.

### 7.4.4 Epithermal Gold-Silver

Epithermal gold-silver deposits are formed during the circulation of heated water (including seawater) and magmatic hydrothermal fluids in the lower parts of volcanoes, or their magmatic equivalents.

The Mount Terrible epithermal deposit was discovered in the early 1990's within the Permian Warrigundi Igneous Complex near Werris Creek. An inferred resource of 132 000 tonnes at 7.8ppm Au has been identified. Although the ore zone crops out, Mount Terrible had no previous mining history.

The Texas area just north of the Nandewar study area in Queensland hosts significant polymetallic and precious metal mineralisation, the origin(s) of which is unclear. The mineralisation is considered by Macmin Silver Ltd (2003) to be epithermal in style, hosted within Early Permian volcanics and surrounding Carboniferous strata. Two mineral associations are known to be present, a silver-lead-zinc-copper-gold association, and a silver-gold association. Interestingly the Texas area, like the Mount Terrible area, had no previous gold mining history.

Another recent discovery in Queensland within Early Permian volcanics occurs at Cracow, with an inferred resource of 1.1 Mt at 11g/t Au, 9g/t Ag (2002). In New South Wales, Bowdens Gift represents a recently discovered Early Permian epithermal system, with a total Indicated and Inferred resource of 18.8 Mt at 99ppm Ag, 0.32%Pb, 0.37% Zn (2002).

Epithermal gold-silver deposits, and their related sub-types (especially distal sub-types), exhibit significant variations in grade and size, especially with regards to surface expressions of mineralisation. The mineralising fluids may be introduced into country rocks, making prediction and size assessments of potential problematic. The potential for this class of deposits within the greater New England region, particularly within the Early Permian, is considered under-recognised.

#### Epithermal Gold-Silver Tracts (Figure 7-T)

*Tract Epi A/M-H/C*

This tract consists of units that satisfy the following criteria:

- subaerial felsic-intermediate volcano-sedimentary units
- have alteration halos mapped or described within them
- host known mineralisation.

In the Nandewar study area, the unit that satisfies these criteria is the Warrigundi Igneous Complex located near Werris Creek.

*Tract Epi B/M/B-C*

This tract includes units of the above tract buffered to two kilometres. It also includes the northern portions of the Emmaville Volcanics, which exhibits strong magnetic contrasts and widespread alteration halos and may host buried epithermal systems.

*Tract Epi C/L-M/B-C*

This tract includes all Emmaville Volcanics not included in the above tract, volcanic units in the northeast and magnetic anomalies in the north of the Nandewar study area. The tract also includes a small recently explored area near Warialda, where altered rocks of the Tamworth Belt outcrop adjacent to a strong buried low magnetic anomaly. Shallow marine volcanic units in the area of the Nundle Gold Field (buffered to two kilometres) are also included.

*Tract Epi D/L/A-B*

This tract consists of the remaining subaerial to partially subaerial volcano-sedimentary sequences with felsic to intermediate volcanics. It consists of the Early to Late Carboniferous overlap assemblage in the western part of the Tamworth Belt.

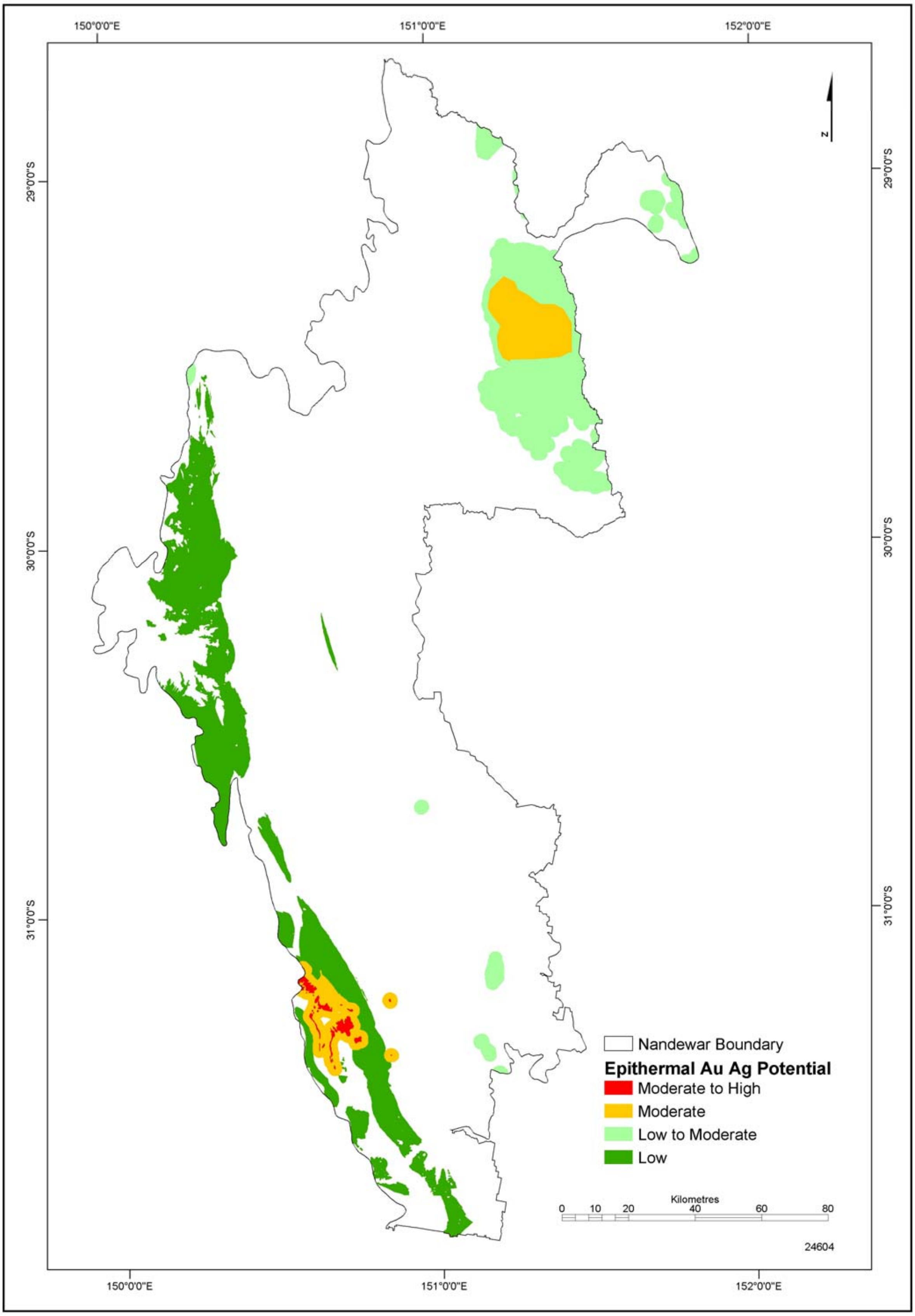



*Figure 7-T. Epithermal gold-silver potential, Nandewar study area*

### 7.4.5 Tin (Greisen and Vein)

Tin deposits are classified as primary (or lode) or alluvial. Primary or lode deposits form in veins, pipes, disseminations and greisens. Alluvial deposits are derived from primary or lode deposits and transported by water to the site of deposition.

The high silica leucogranites in the Nandewar study area have been a major source for alluvial tin. These leucogranites, the Gilgai Granite, Elsmore Granite, Mole Granite, Webbs Consols Granite and Dumboy-Gragin Granite, are associated with Sn, Mo, W, base metals and polymetallic veins, pipes, disseminations and greisens.

The Gilgai Granite has intruded the Tingha Monzogranite and has produced tin, molybdenum and polymetallic mineralisation as disseminations, pipes, veins and joint fills in both granites. Lode tin deposits are usually small scale and pinch out with only minor associated wall rock alteration. Most worked lode deposits only produced several tonnes of ore but there are, in some areas, prolific narrow tin veins not large enough to be separately mined. An exception to this is the Conrad lode (south of Copeton) which produced in excess of 175 000 tonnes of ore (Pb, Cu, Sn, Zn, Ag) (Brown and Stroud 1997).

Greisenisation is pervasive and well developed within the Elsmore Granite, accompanied by Sn ± Mo, W and base metal vein and disseminated mineralisation. The granite has also undergone kaolinisation (see kaolin tract, **Figure 7-P**).

The Dumboy-Gragin Granite hosts mainly small low-grade deposits of tin in quartz-tourmaline veins with accompanying greisenisation. Mining of the deposits has only taken place in the granite to the southwest of Delungra. Granite to the northwest of the town recorded low surface grades of tin (Tenneco Oil and Minerals of Australia Inc & Ridge 1983).

The Mole Granite is the most highly mineralised granite in the New England region, accounting for more than 1200 mineral occurrences (Henley et al. 2001) both within the granite and in the country rocks. The granite is associated with significant greisenisation. Only the northernmost part of the granite outcrops within the Nandewar study area. However there is potential for tin mineralisation extending into the area, with known tin deposits at some distance from the granite contact.

The granites of the Bundarra Supersuite are associated with several small deposits of tin in the southern half of the batholith such as the Giants Den deposit hosted by the Pringles Monzonite. The Watsons Creek alluvial tin deposit is located 2.3 kilometres northeast of the Giants Den deposit and produced 1591 tonnes of tin concentrate between 1886 and 1962 (Brown et al. 1992).

#### Tin (Vein and Greisen) Tracts (Figure 7-U)

*Tract Tin1 A/M-H/C*

This tract includes the leucogranites which are extremely fractionated, high silica (greater than 75% $SiO_2$) granites with minimum melt compositions. Elements such as Sn, Mo, W, Pb act incompatibly in minimum melt granites forming polymetallic mineralisation. Tin dominates mineralisation with ± Mo, W, Pb, Zn, Ag, Au, Cu as disseminations in the leucogranites, greisen or as veins in either the granites or in the country rock.

The leucogranites are buffered to five kilometres to include the potential for mineralised veins hosted by country rock.

### *Tract Tin1 B/L-M/B*

The tract consists of a 5 kilometre buffered zone around the Giants Den deposit and other smaller deposits within the southern part of the Bundarra Supersuite.

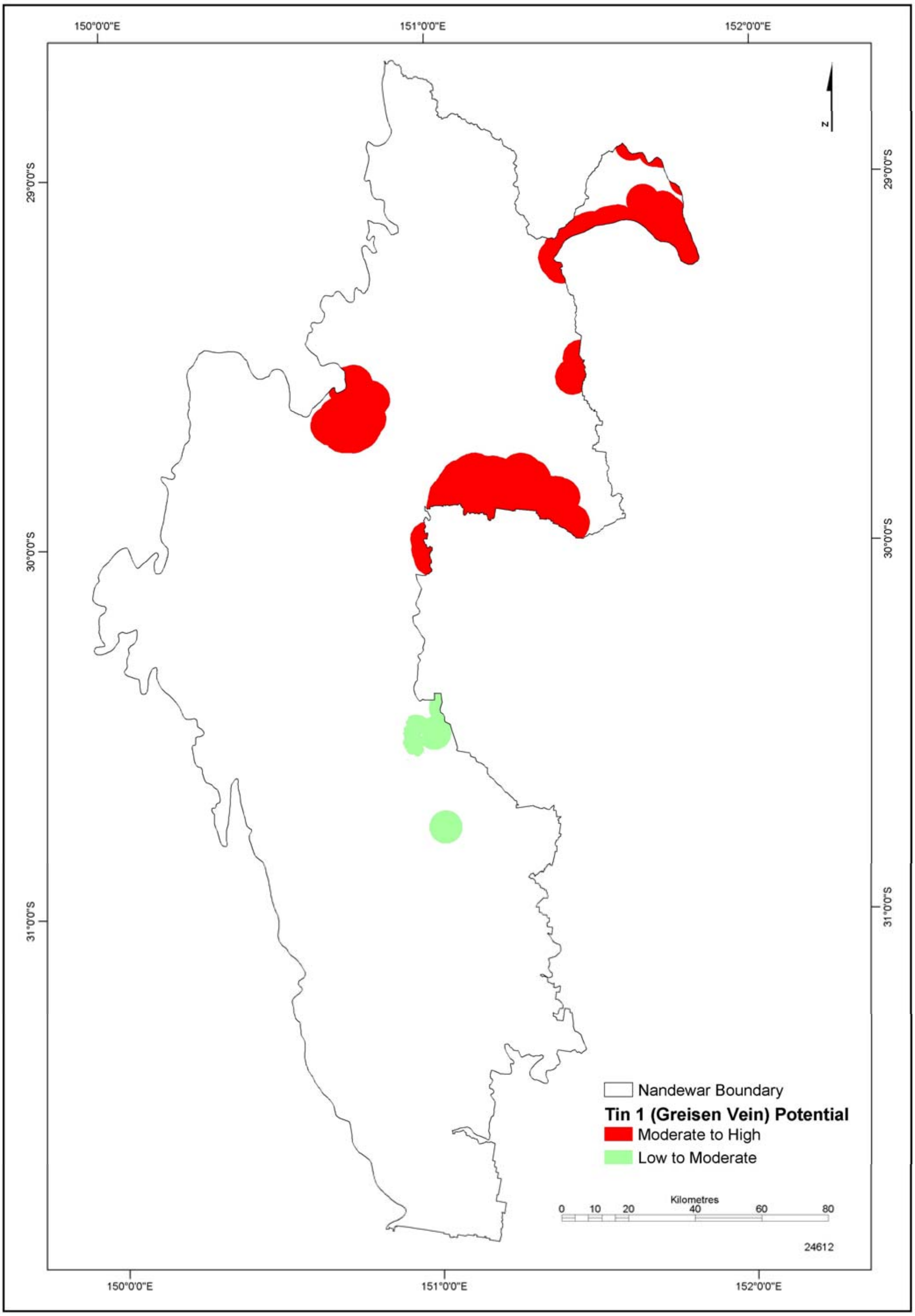



*Figure 7-U. Tin (greisen and vein) potential, Nandewar study area*

### 7.4.6 Tungsten-Molybdenum-Copper-Gold Skarn

Skarn deposits form as replacement deposits of calcareous-bearing rocks resulting from the fluids of an intruding granite forming a reactive halo.

Tungsten-molybdenum skarn occurs immediately adjacent to and surrounds the Inlet Monzonite near Attunga. The skarn is developed both within the country rock and in the monzonite along the contact. The Attunga Mining Corporation Pty Ltd et al. (1970) defined six tungsten prospects, the most prospective of these is the Southern (Scheelite) skarn. In 1969, Geopeko Pty Ltd defined proven reserves of 220 000 to 240 000 tons averaging 0.35% tungsten oxide and 280 000 to 305 000 tons of Inferred and potential resources averaging 0.35% tungsten oxide. Doyle et al. (1981) reassessed Geopeko Pty Ltd data calculating a resource of 260 500 tons at 0.82% tungsten oxide and 0.136% molybdenum when using a 0.25% tungsten cut-off grade.

The western and northern extensions of the Southern skarn have not been defined, but it is possible that the tungsten-molybdenum skarn grades into or overprints the copper-gold skarn 800 metres to the north. Geochemical sampling undertaken by Challenger Resources Pty Ltd (1987-1988) noted the occurrence of copper, gold and silver in the tungsten deposits.

Copper-gold skarn crops out 800 metres north of the Inlet Monzonite and has been mined as part of the Attunga Copper Mine. Doyle et al. (1981) indicated a remaining resource at the Copper Mine of 20 000 tonnes at 4-10% Cu, 0.6-15 g/t Au, 100-200 g/t Ag, 0.1-1.0% Mo and 0.2% Bi. Tungsten and molybdenum mineralisation has also been noted in the copper-gold skarn (Fisher 1943; Snape 1994).

Traditionally the skarn north of the Inlet Monzonite was thought to be polymetallic and it has been proposed that the tungsten-molybdenum skarn and copper-gold skarn are part of the same mineralising event, representing mineralogical zoning (eg Challenger Resources Pty Ltd & Meszaros 1983). It would be expected that copper-gold skarn would be developed distal to both the intrusion and the tungsten-molybdenum mineralisation, which appears to be the case for skarn associated with the Inlet Monzonite. Snape (1994), however, suggested that the copper-gold skarn at the Attunga Copper Mine was geochemically related to a dacitic plug south of the mine and pre-dated the intrusion of the Inlet Monzonite and tungsten-molybdenum skarn mineralisation. This model does not take into account the Mt Paterson and Namoi Gold Mines, less than two kilometres east of the Inlet Monzonite with gold and copper skarn related mineralisation.

Roberts (1982) delineated five metamorphic zones around the Inlet Monzonite and Moonbi Monzogranite (members of the Moonbi Supersuite), defining the contact aureole for these two granites. The skarn-like Kensington Scheelite deposit, two kilometres northwest of the Attunga Creek Monzogranite, may have resulted from the intrusion of this granite (Brown et al. 1992). The Kensington Cu-Au deposit, also assumed to be a skarn, is located three kilometres northwest of the Attunga Creek Granite.

Extensive work has focussed on skarn north of the Inlet Monzonite investigating the tungsten-molybdenum and copper-gold skarns. However, further work is needed to define the extent of the ore body and the correlation, if any, between the two skarn types. Geopeko in the late 1960s delineated skarn to the west and south of the Inlet Monzonite, with limestone noted to outcrop to the south of the granitoid. Little work has been undertaken on these skarns since. It is possible that these skarns host economic mineralisation. Skarn delineated by Roberts (1982) in limestones surrounding the Moonbi Monzogranite also need to be assessed for economic mineralisation.

### Tungsten-Molybdenum-Copper-Gold Skarn Tracts (Figure 7-V)

*Tract WMoCuAuSk A/H/C*

The tract consists of limestone within five kilometres of oxidised, unfractionated to fractionated, intermediate to high silica granitoids. Granites of the southern Moonbi Supersuite are the most prospective, with known occurrences of skarn associated with the Inlet Monzonite and the Moonbi Granite (Roberts 1982, Attunga Mining Corporation Pty Ltd et al. 1970), and W-Mo vein mineralisation associated with the Attunga Creek Granite. Skarn with associated W-Mo and Cu-Au mineralisation has been identified up to 3.5 kilometres north of the Inlet Monzonite (Ray et al. 2003), it is probable that this skarn is associated with the Attunga Creek Granite.

The low silica, oxidised and unfractionated granites of the Clarence River Supersuite at the far northern and southern boundaries of the Nandewar study area have potential for W-Mo-Cu-Au skarn. The granitoids are associated with Cu-Mo and Mo mineralisation to the south of the Nandewar study area. Outside of the Nandewar study area copper-iron skarn is associated with the Clarence River Supersuite at the Queen May and Fine Flower deposits (Downes 1999).

Oxidised lime-rich skarns also have the potential to host economic concentrations of garnet and wollastonite for industrial mineral purposes (Ray 1988; Simandl et al. 1999).

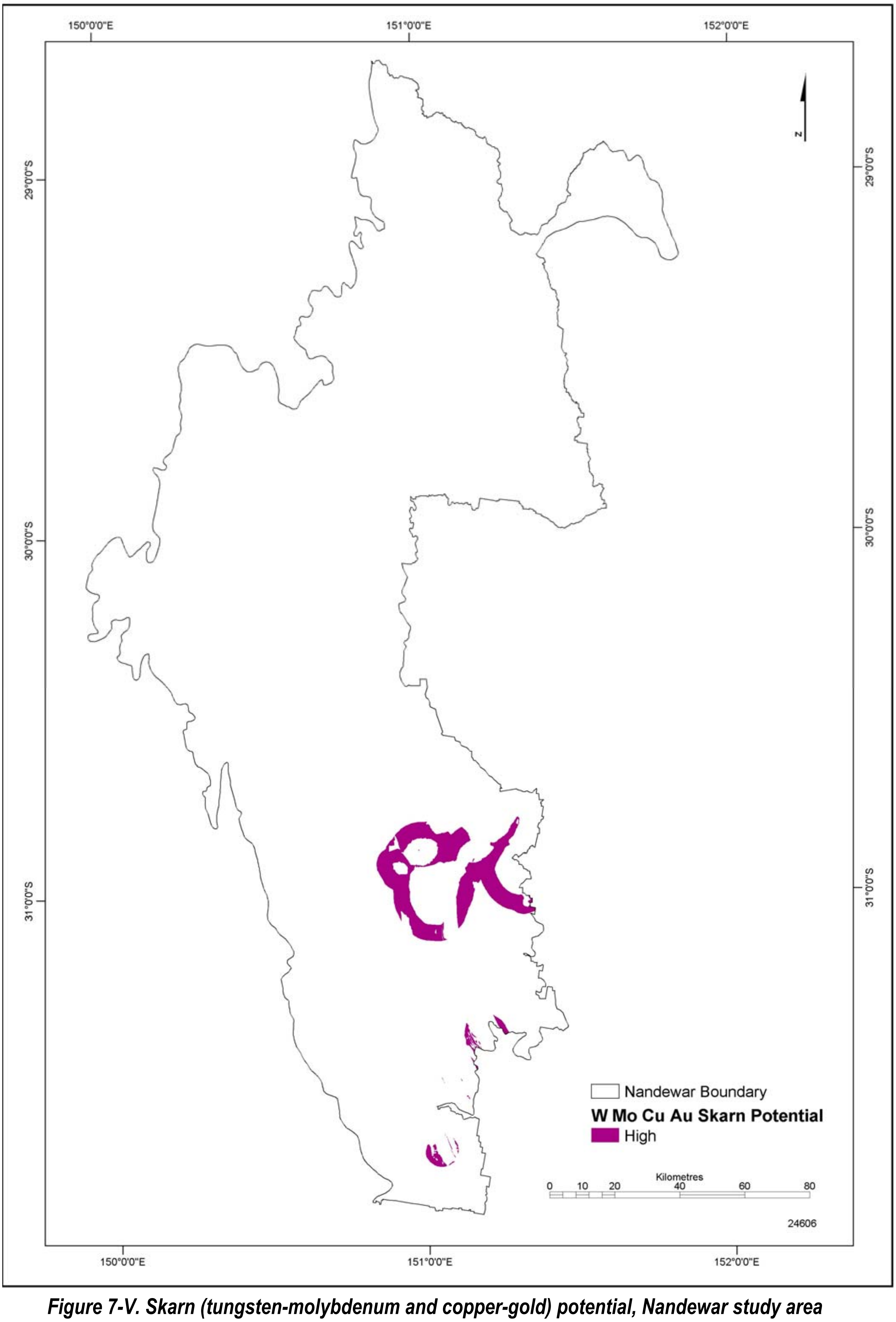



*Figure 7-V. Skarn (tungsten-molybdenum and copper-gold) potential, Nandewar study area*

### 7.4.7 Tungsten-Molybdenum Pipes, Veins and Disseminations

A number of tungsten-molybdenum veins and disseminations occur internally and along the margins of granites of the southern Moonbi Supersuite. The largest identified deposit occurs within the Moonbi Monzogranite where molybdenite mineralisation is accompanied by tungsten and chalcopyrite in quartz veins or disseminated in pegmatite (Brown et al. 1990). Two vein deposits have been worked in the margins of the Attunga Creek Monzogranite comprising molybdenite with subordinate tungsten mineralisation. Total production from both veins has yielded 87kg molybdenite. A quartz vein assayed by Brown et al. (1992) gave 2.0% Mo, 6.6ppm Au, 5.1ppm Ag, 866 ppm W and 0.22% Bi. Veins containing disseminated molybdenite and tungsten within sediments of the Kensington Formation, three kilometres northwest of the Attunga Creek Granite, are thought to be related to that granitoid (Brown et al. 1992). A resource for the Kensington deposit was calculated at 4.2 Mt grading 0.174% $WO_3$ using a 0.1% cutoff (Challenger Resources et al. 1987). Quartz vein deposits have also been reported proximal to the Walcha Road Monzogranite.

Molybdenite mineralisation is also associated with the northern Moonbi Supersuite and includes the 210 Mt Kingsgate deposit (outside the study area) and in various polymetallic vein style deposits associated with I-type highly fractionated leucogranites within the Nandewar study area. Examples have been identified within the Elsmore Granite, Mole Granite and Gilgai Granite. Molybdenite and copper-molybdenite mineralisation has also been identified associated with the Duncans Creek Trondjhemite, included as part of the Clarence River Supersuite, in the southern parts of the Nandewar study area.

Geophysical modelling has also suggested that buried or subcropping intrusions prospective for W-Mo associations could occur within parts of the northern Nandewar study area. The Emmaville Volcanics in particular contains strong aeromagnetic contrasts which have been interpreted to represent both deep and shallow sources. Granite has also been found outcropping within the sequence, which is oxidised (hornblende-bearing) but it is not fractionated and is low in $SiO_2$ (67%).

#### Tungsten-Molybdenum Pipes, Veins and Dissemination Tracts (Figure 7-W)

*Tract W-Mo: A/M/B-C*

The tract comprises unfractionated to fractionated, oxidised intermediate silica granites and the country rocks these granites intrude. The granites are buffered to five kilometres to include the potential for mineralised veins hosted by country rock. The southern Moonbi Supersuite has potential for further occurrences of W-Mo mineralisation as indicated by the numerous known disseminated, pipe and vein deposits and W-Mo skarn. The variation in W/Mo ratio can be related to the oxidation state of the mineralising system. Tungsten will be dominant over molybdenite in more reducing conditions while molybdenite is dominant in oxidised environments (Candela & Bouton 1990).

The tract also includes granites of the Clarence River Supersuite which have limited outcrop and are associated with Cu-Mo and Mo vein mineralisation to the south of the study area. A Clarence River Supersuite granite to the far north of the study area may have potential for W-Mo or Cu-Mo mineralisation.

*Tract W-Mo: B/L/C*

This tract includes molybdenite mineralisation as polymetallic veins, disseminates or pipes within or near the pluton or country rock contact of extremely fractionated high silica leucogranites. The granites are buffered to five kilometres to include the potential for mineralised veins hosted by country rock. Granites identified in this tract include the Dumboy-Gragin Granite, Gilgai Granite, Elsmore Granite, Mole Granite and Webbs Consol Granite.

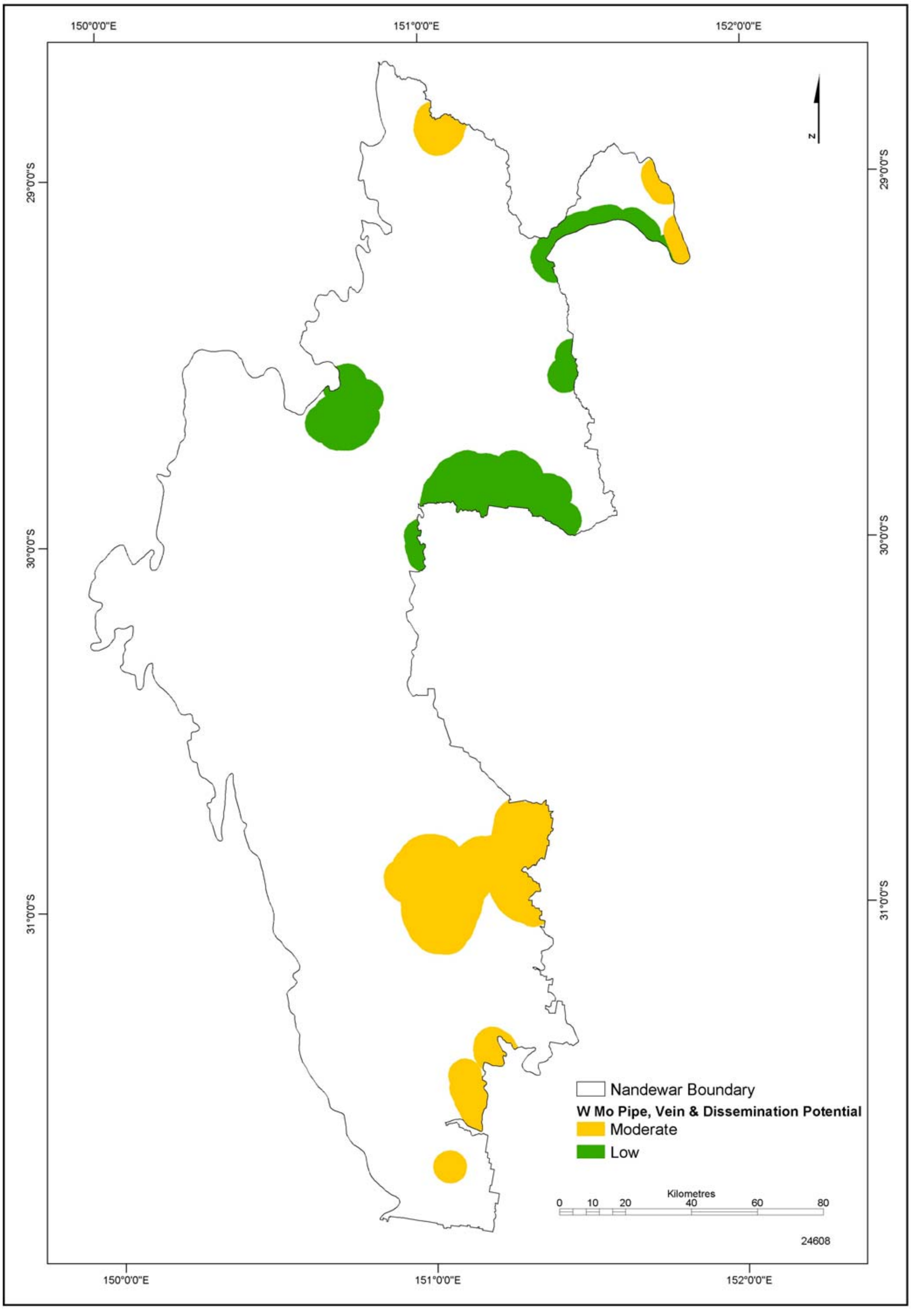



*Figure 7-W. Tungsten-molybdenum pipes, veins and dissemination potential, Nandewar study area*

### 7.4.8 Besshi-Cyprus Volcanic Hosted Massive Sulphide (VHMS)

Besshi-Cyprus volcanic hosted massive sulphide (VHMS) deposits form from the precipitation of high-sulphur concentration fluids in deep marine volcanic terranes, commonly close to the seawater–seafloor interface. The deposits commonly contain sulphides of copper, zinc and silver.

There are a number of Besshi-Cyprus type VHMS occurrences within the Nandewar study area. Deposits and prospects include the Gulf Creek Copper mine, the Dungowan Mine and the Mount Everest Copper Mine. A small resource of about 50 000 tonnes of polymetallic ore has been inferred at the Gulf Creek Mine.

Past production of this deposit type has not been large, and future potential for this style(s) is considered to be limited, largely due to small tonnages and generally low grades associated with these types of deposits.

#### Besshi-Cyprus Volcanic Hosted Massive Sulphide (VHMS) Tracts (Figure 7-X)

*Tract BesCyp A/M-H/D-C*

The tract includes outcropping and subcropping marine, intermediate to mafic volcanic/sedimentary rock packages and hosts all of the occurrences interpreted to be of probable Besshi and/or Cyprus type. It consists of the Woolomin Group, Cambrian to Ordovician age serpentinites and deep marine mafic to intermediate volcanics and cherts of the Woodsreef Melange.

*Tract Bescyp B/M/B-C*

This tract consists of the accretionary complex east of the mapped differentiation with the Woolomin group, which contains undifferentiated units (Texas beds, Sandon beds) prospective for this style of deposit.

*Tract BesCyp C/L-M/B-C*

The tract consists of Early Devonian submarine arc volcanic rocks within the Tamworth Belt which contain significant amounts of mafic to intermediate volcanic rocks extruded in a deep marine setting. The tract also includes the Mostyn Vale Formation (rhyodacitic to basaltic lava extruded in a deep marine setting) that contains a few examples of anomalous base metal prospects.

*Tract BesCyp C/L/B-C*

The tract consists of all remaining outcropping deep marine mafic to intermediate volcanic/sedimentary rock packages of any age in which local deeper marine environments conducive to deposit formation could occur. It includes middle Late Devonian deep marine sequences in the Tamworth Belt.

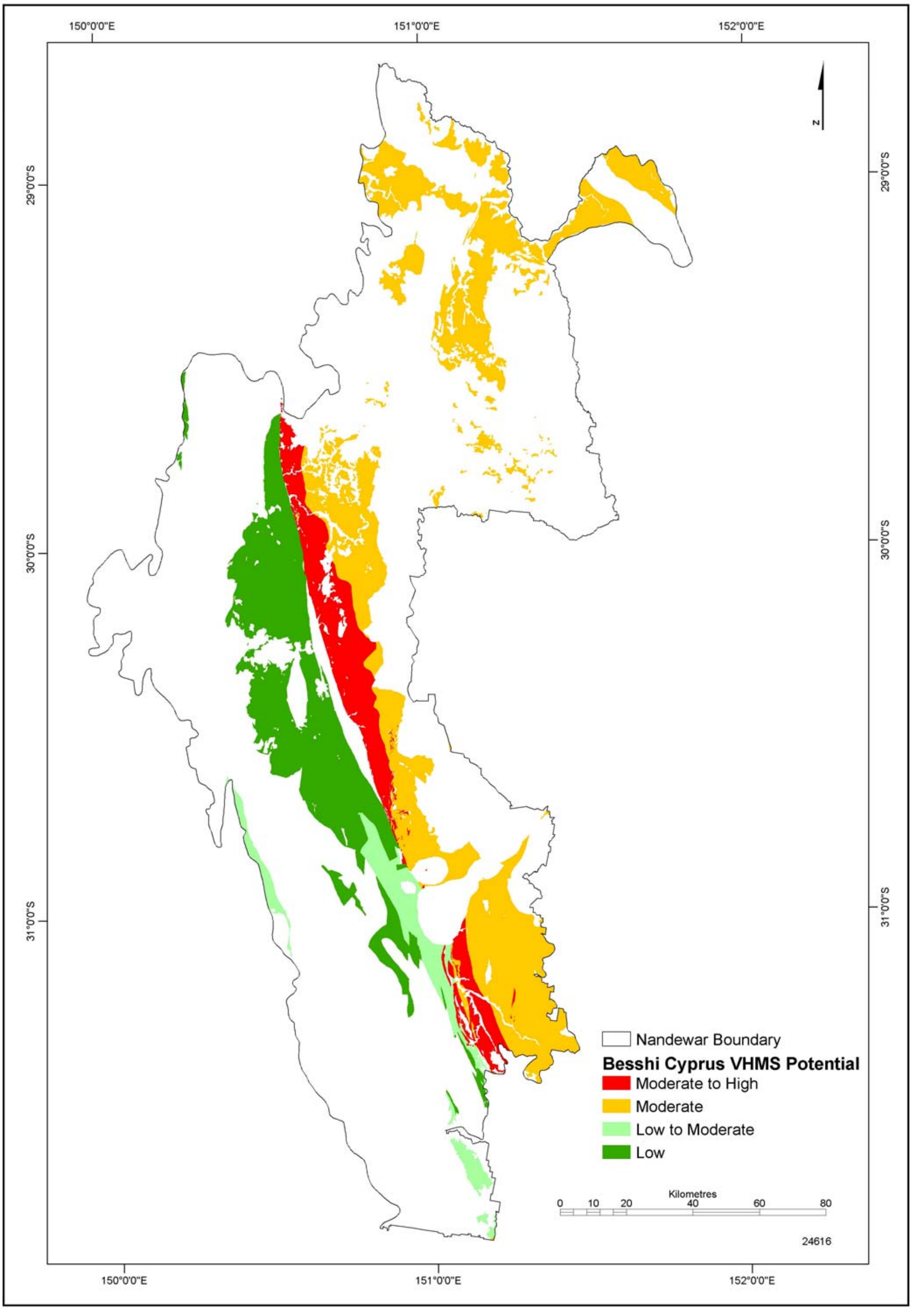



*Figure 7-X. Besshi-Cyprus Volcanic Hosted Massive Sulphide potential (VHMS), Nandewar study area.*

### 7.4.9 Secondary Tin

Secondary tin deposits are derived from the weathering, erosion and deposition of tin from primary sources (veins and greisens). The tin has been deposited in modern and ancient rivers and streams often capped by basalt to form deep leads. In some areas the tin was transported only short distances by gravity (colluvial tin) or not transported at all but left as a residual or *in situ* deposit. Both colluvial and residual tin deposits are included here in the secondary tin tract.

Very significant deposits of tin were mined virtually continuously for over 100 years south of Inverell in the Gilgai, Elsmore and Stannifer area. The area extends south out of the study area to Tingha. The tin was mined from modern alluvials, deep leads and from residual and colluvial deposits.

In the Tingha-Gilgai area deep leads range in depth from several to fifty metres. Most of these deep leads are capped by thick strongly weathered to fresh basalt, shallow to deep basaltic soil, and in many places by surficial concretionary laterite or bauxite (Brown and Stroud 1997). Modern technology may make some of these areas viable in future and allow access to deep lead deposits not previously mined.

Several other areas of alluvial tin are known in the Nandewar study area, including about Warialda and east of Ashford.

Secondary tin potential is largely confined to areas within about ten kilometres downstream of outcrops of favourable granites or known tin occurrences, as the tin minerals (mostly cassiterite) break down rapidly during transport.

#### Secondary Tin Tracts (Figure 7-Y)

*Tract Tin 2 A/M-H/B-C*

This tract includes 100 metre buffers along streams, rivers, Quaternary sediments, Tertiary sediments and Tertiary lavas within ten kilometres of known tin deposits. It also includes extensive areas of deeply weathered residual and colluvial material of possibly Tertiary age covering large parts of the Tinga Monzogranite and Gilgai Granite. Even though most alluvial tin areas have been worked in the past, modern technology may make some of these areas viable in future by allowing access to deep lead deposits not previously mined.

*Tract Tin 2 B/M/B-C*

This tract consists of streams and rivers buffered to 100 metres within 10 kilometres of tin occurrences not in the above tract.

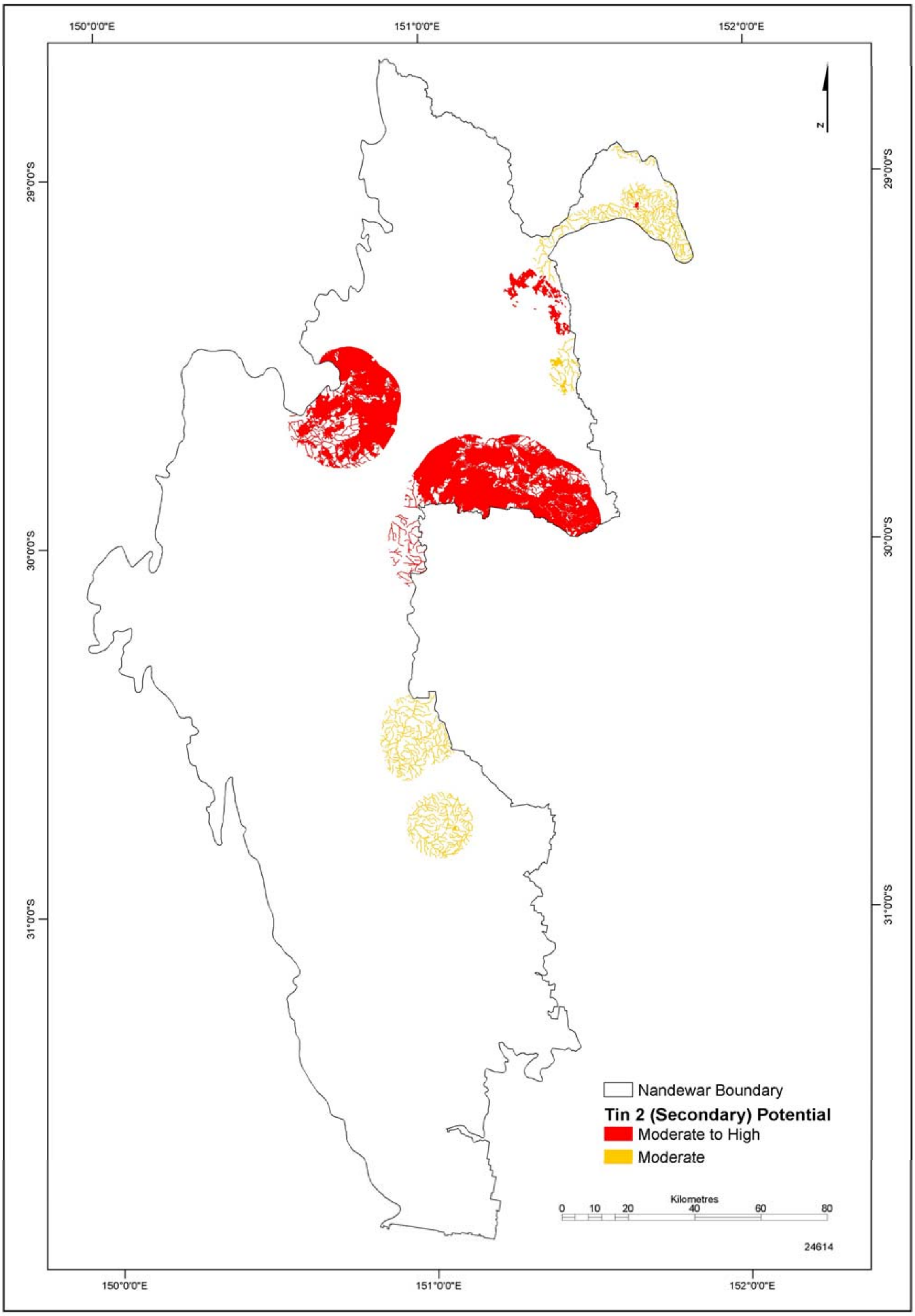



*Figure 7-Y. Secondary tin potential, Nandewar study area*

### 7.4.10 Alluvial Gold

Significant production of alluvial gold has been obtained from the Nandewar study area, in particular from the Nundle, Bingara and Upper Bingara districts during the 19th century. Total alluvial gold production within the study area amounts to well over A$150 million (2003). The potential for modern technology to exploit gold bearing alluvial and/or colluvial deposits, particularly around the major gold fields, has largely not been investigated. Moderate alluvial gold operations in New Zealand in recent years have shown that such extraction can be viable under current socio-economic conditions.

#### Alluvial Gold Tract (Figure 7-Z)

*Tract ALLAU: A/M-H/A-B*

This tract consists of:

- 100 metre buffers along streams and rivers in the vicinity of the Peel Fault Zone
- all Tertiary units in the vicinity of the Peel Fault Zone
- some areas with known unmapped Cainozoic sediments in the Upper Bingara and Peel River areas.

Certainty is reduced by palaeochannels possibly having different orientations to modern channels.

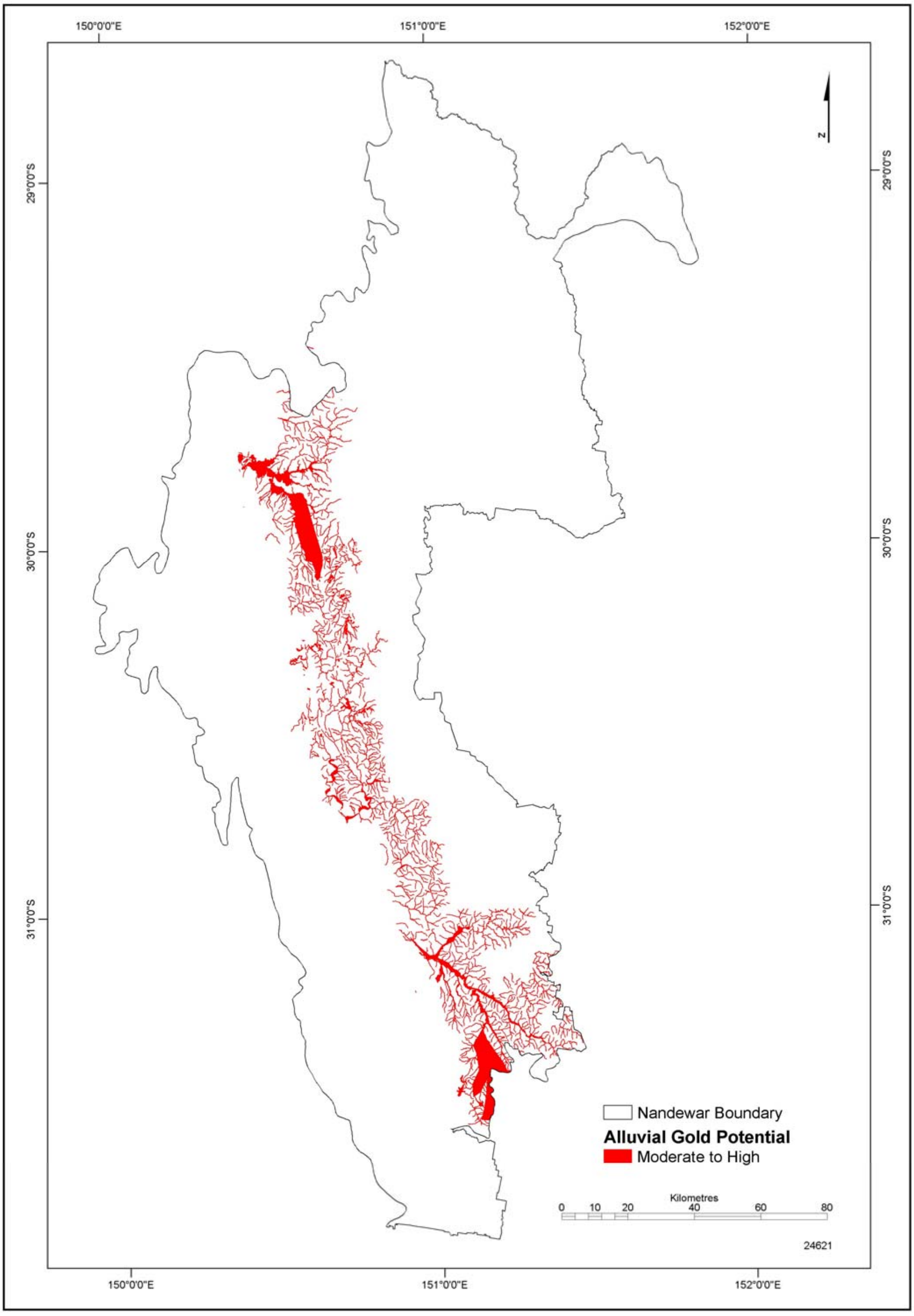



*Figure 7-Z. Alluvial gold potential, Nandewar study area*

### 7.4.11 Silver-Bearing Polymetallic Vein

Silver-bearing polymetallic vein deposits form within and adjacent to favourable intrusions. Deposits in the New England region of this type are spatially and genetically associated with Late Permian to Early Triassic, felsic, I-type, fractionated, and reduced leucogranites, the most important of which are the Mole Granite, Gilgai Granite and Tingha Granite. These leucogranites have recently been assigned to the Uralla Supersuite (AMIRA International 2003). Mineralisation is in the form of silver-rich and base metal bearing veins, pipes and disseminations. Some minor silver-rich vein mineralisation is also apparently associated with the Late Carboniferous-Early Permian S-type fractionated granites such as the Bundarra Plutonic Suite.

The Conrad Silver lodes near Howell are significant polymetallic vein deposits, located just outside the Nandewar study area. The lodes are currently under assessment (2003) by Malachite Resources NL. Another cluster of polymetallic vein deposits occurs in the Clive and Mole River area in the far northeast of the Nandewar study area associated with the Mole Granite, with some small identified resources (Henley & Brown 2000). Some deposits in this area may also represent mineralisation associated with an Early Permian mineralising event.

#### Silver-Bearing Polymetallic Vein Tracts (Figure 7-AA)

*Tract POLY A/M/C*

This tract comprises a five kilometre buffer around gthe leucogranites (Mole Granite, Gilgai Granite, and Dumboy-Gragin Granite). These are felsic, extremely fractionated and reduced granite bodies, although there appears to be some degree of variability in their relative oxidation. A large number of silver-bearing veins are associated with these bodies. The potential for economic-size deposits is only moderate, as most of these deposits are small.

*Tract POLY B/L-M/B-C*

This tract comprises a corridor running from north of the Gilgai Granite to north of the Mole Granite (see above tract) and a two kilometre buffer around unnamed granites within the Emmaville Volcanics. Numerous silver-rich base metal veins occur within this tract hosted by country rocks other than granite. It also includes inferred subsurface granites in the Texas area, and the outcropping Clarence River Supersuite buffered to two kilometres.

*Tract POLY C/L/B*

This tract is defined by the presence of reduced, mildly fractionated granites of the Bundarra Supersuite, and granites of the Moonbi Supersuite. The Bundarra Supersuite contains some silver-bearing base metal occurrences. Granites of the I-type Moonbi Supersuite are characterised as relatively oxidised, but vary in relative oxidation states. Moonbi Supersuite granites are not as fractionated as the leucogranites but contain a few occurrences of silver-bearing base metal veins. Thus the low degree of fractionation as well as relatively oxidised nature of these granites means that the potential of the tract is low.

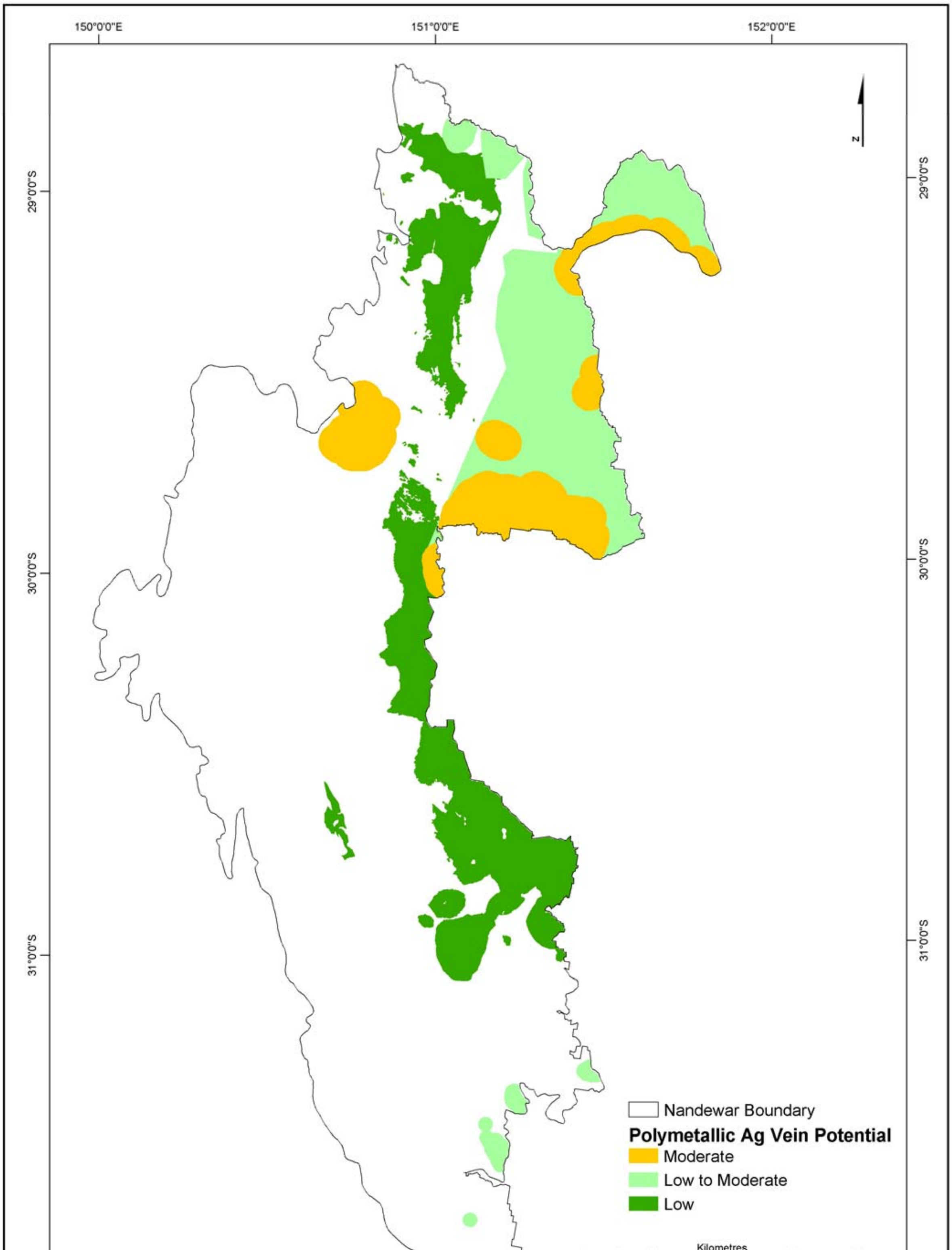



*Figure 7-AA. Silver-bearing polymetallic vein potential, Nandewar study area*

## 7.5 SUMMARY TRACTS OF MINERAL AND PETROLEUM RESOURCE POTENTIAL, NOVEMBER 2003

The following summary maps of mineral and petroleum resource potential for the Nandewar study have been derived by combining (overlaying) the tract maps for all the coal and petroleum tracts, industrial mineral and construction material tracts and metallic mineral tracts. Four types of summary maps have been produced. They are the composite and cumulative potential (**Figures 7-BB, 7-CC**) and the weighted composite and weighted cumulative potential (**Figures 7-DD, 7EE**).

### 7.5.1 Composite and Cumulative Potential

**Figure 7-BB** is a composite of mineral and petroleum potential for the Nandewar study area and shows the highest level of potential assessed for areas in the region. Where tracts for different deposit types overlap, the area is assigned the highest potential level of all the overlapping tracts. In this approach, the tract having the highest potential in any particular area obscures tracts of lower potential. It is important to note that the different types of mineral and petroleum deposits do not have equal socio-economic values.

**Figure 7-CC** shows the cumulative mineral and petroleum potential for the Nandewar study area. In constructing this figure, standard scores were allocated according to a subjective ranking of levels of potential as follows: high potential (18); moderate – high (12); moderate (6); low – moderate (2) and; low (1). In those areas where tracts overlap, the scores are added and this cumulative score is assigned to the overlapping areas. The cumulative mineral and petroleum potential takes account of both the diversity of deposit types that may occur in each area, as well as the level of potential of each of these deposit types.

### 7.5.2 Weighted Composite and Cumulative Potential

**Figure 7-DD** shows the weighted composite mineral and petroleum potential for the region. The weighted composite potential makes some allowance for the relative economic significance between different types of deposits. Deposits have been indexed using the indices listed in **Table 7-G**. The weighted composite score is calculated by multiplying the deposit index by the standard potential score. Where there are overlapping tracts, with different weighted scores, the highest of these scores is assigned to the area of overlap. Tracts with higher weighted potential include coal, petroleum, primary diamond, sapphire and limestone.

**Figure 7-EE** shows the weighted cumulative mineral and petroleum potential for the region. It is similar to the weighted composite mineral and petroleum potential in that the score for each tract is calculated by multiplying the deposit index by the 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. The relative importance of deposit types is taken into account before adding individual potential scores. The weighted cumulative map is similar to the cumulative map but the three zones of elevated scores are enhanced.

Provided the available data and modelling is adequate, the weighted cumulative potential gives a more indicative value of the overall mineral value and potential in any given region. However if the available data is relatively insufficient, or the certainty of the modelling process is low, then the composite potential map tends to be a better guide as to the overall mineral potential. Largely because the available datasets vary between the different deposit types in the Nandewar study area, both types of summary maps have been provided.

The weighted mineral potential data indicates that areas of highest potential are scattered widely in the Nandewar study area. Highest weighted potential areas include the following:

- the Ashford, Werris Creek and Murrurundi areas (coal)
- the Nandewar Range area (petroleum and coal seam methane)
- the Barraba area (diatomite, magnesium and gold)
- the Attunga area (base and precious metals and limestone)
- the Werris Creek area (zeolite, gold and silver)
- the Bingara area (gold and diamond)
- the Inverell area (diamond, tin and sapphire)
- construction materials adjacent to major roads
- gold in a narrow elongated zone through the middle of the Nandewar study area

*Table 7-G. Deposit Index and Weighted Potential Scores, Nandewar study area*

| | | LEVELS OF POTENTIAL & STANDARD POTENTIAL SCORES ) | | | | |
|---|---|---|---|---|---|---|
| | | **High** | **M-H** | **Moderate** | **L-M** | **Low** |
| | | 18 | 12 | 6 | 2 | 1 |
| **DEPOSIT** | **DEPOSIT INDEX** | **WEIGHTED POTENTIAL SCORE (a x b)** | | | | |
| **COAL AND PETROLEUM** | | | | | | |
| Coal | 12 | 216 | 144 | 72 | | 12 |
| Coal Seam Methane (CSM) | 12 | | | 72 | | |
| Petroleum (includes Conventional Gas) | 12 | 216 | | 72 | | 12 |
| **INDUSTRIAL MINERALS AND CONSTRUCTION MATERIALS** | | | | | | |
| Magnesium | 12 | | | 72 | | |
| Primary Diamond | 6 | 108 | 72 | 36 | | 6 |
| Sapphire | 5 | 90 | 60 | 30 | 10 | 5 |
| Limestone | 5 | 90 | 60 | 30 | 10 | 5 |
| Construction Materials | 4 | 72 | | 24 | | 4 |
| Diatomite | 4 | 72 | | 24 | | 4 |
| Alluvial Diamond | 3 | 54 | | | 6 | 3 |
| Serpentinite-Related Deposits | 3 | 54 | | | | |
| Kaolin | 3 | | 36 | 18 | 6 | |
| Zeolite | 2 | 36 | | | | 2 |
| **METALLIC MINERALS** | | | | | | |
| Orogenic Gold | 7 | | 84 | 42 | | 7 |
| Porphyry Copper-Gold | 7 | | | 42 | 14 | 7 |
| Epithermal Gold-Silver | 7 | | 84 | 42 | 14 | 7 |
| Tin (Greisen and Vein) | 5 | | 60 | | 10 | 5 |
| Tungsten-Molybdenum and Copper-Gold Skarn | 4 | 72 | | | | |
| Tungsten-Molybdenum Pipes, Veins and Disseminations | 3 | | | 18 | | 3 |
| Besshi-Cyprus (VHMS) | 3 | | 36 | 18 | 6 | 3 |
| Secondary Tin | 3 | | 36 | 18 | | |
| Alluvial Gold | 3 | | 36 | | | |
| Silver-Bearing Polymetallic Vein | 2 | | | 12 | 4 | 2 |

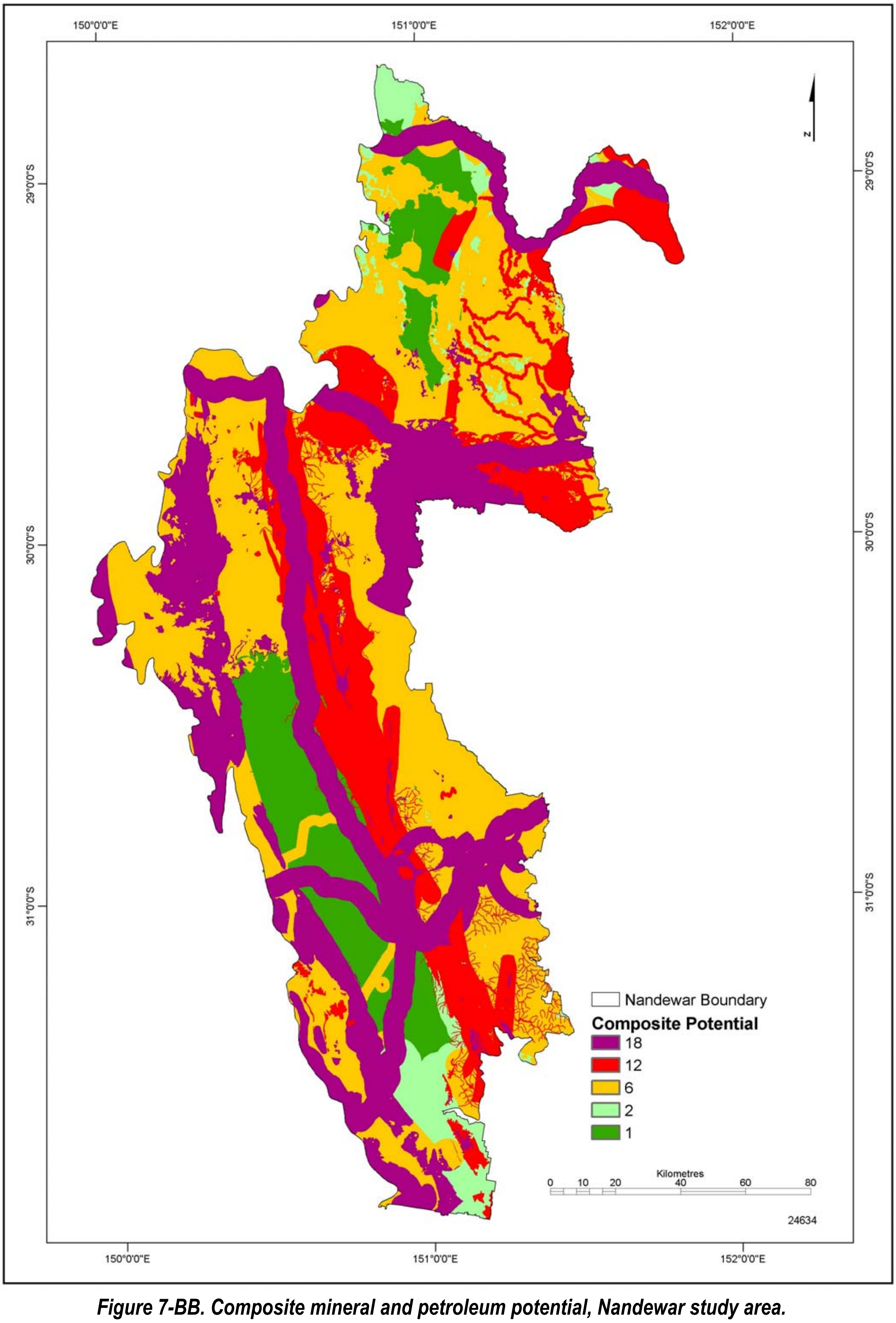



*Figure 7-BB. Composite mineral and petroleum potential, Nandewar study area.*

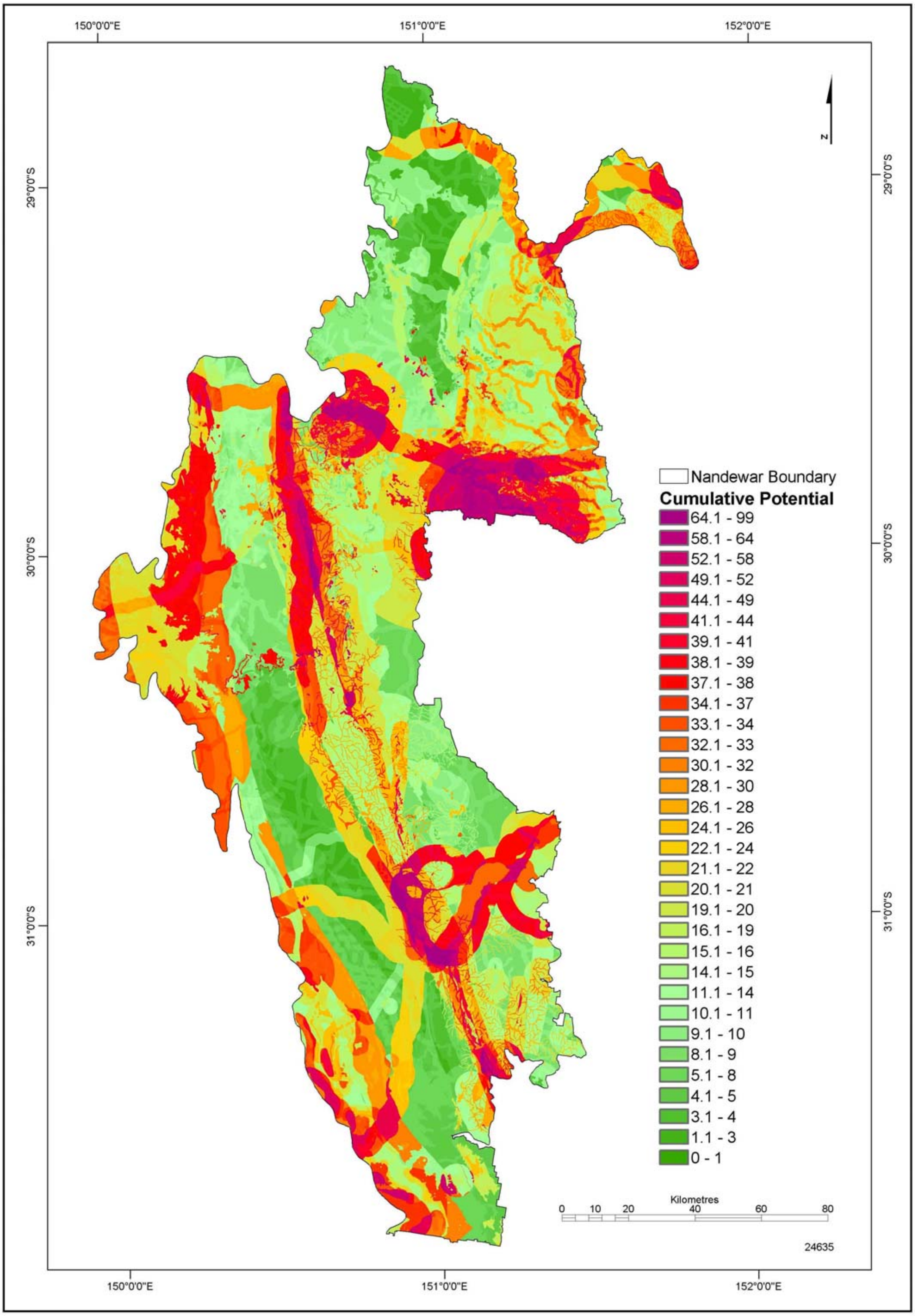



***Figure 7-CC. Cumulative mineral and petroleum potential, Nandewar study area.***

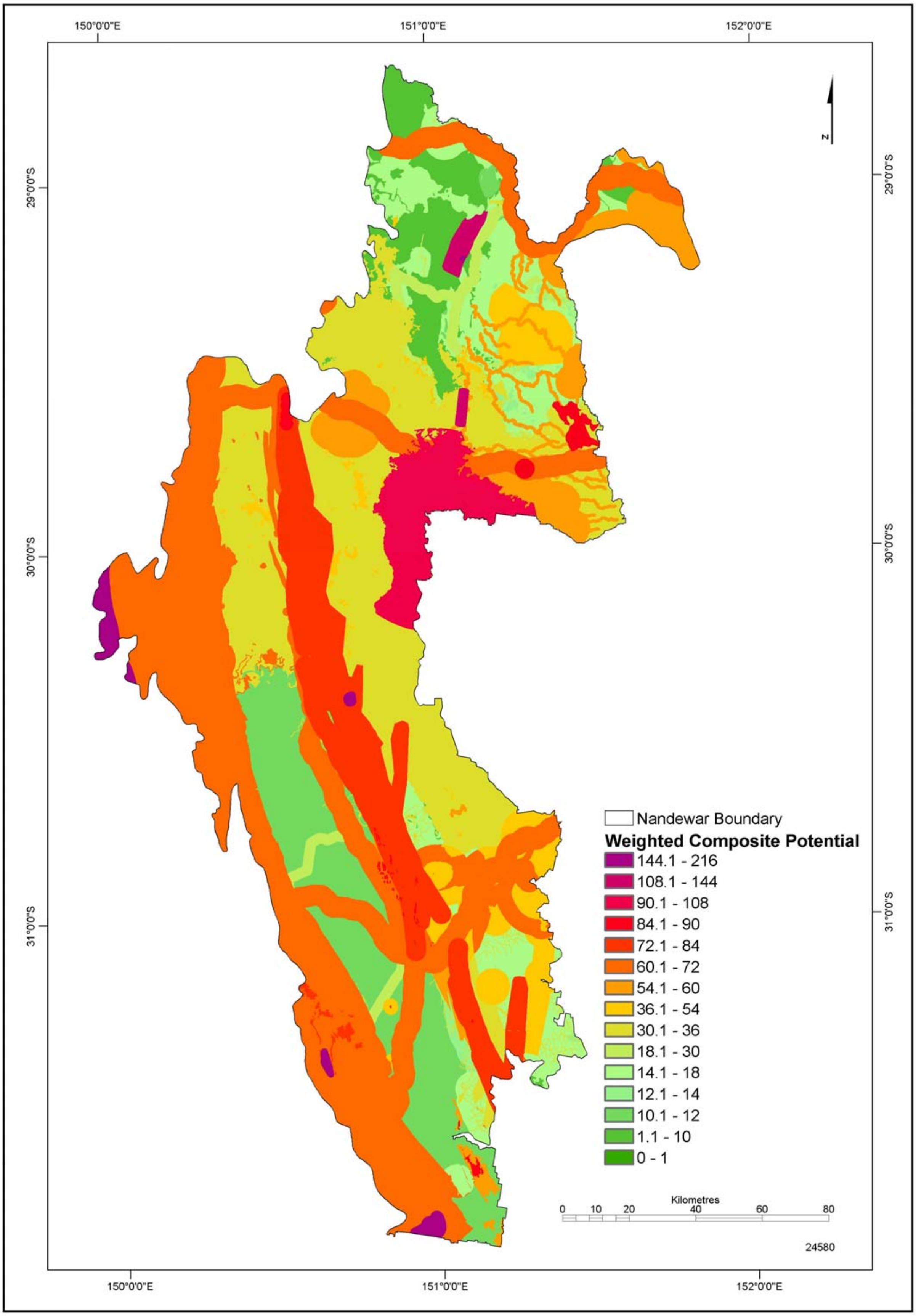



*Figure 7-DD. Weighted composite mineral and petroleum potential, Nandewar study area.*

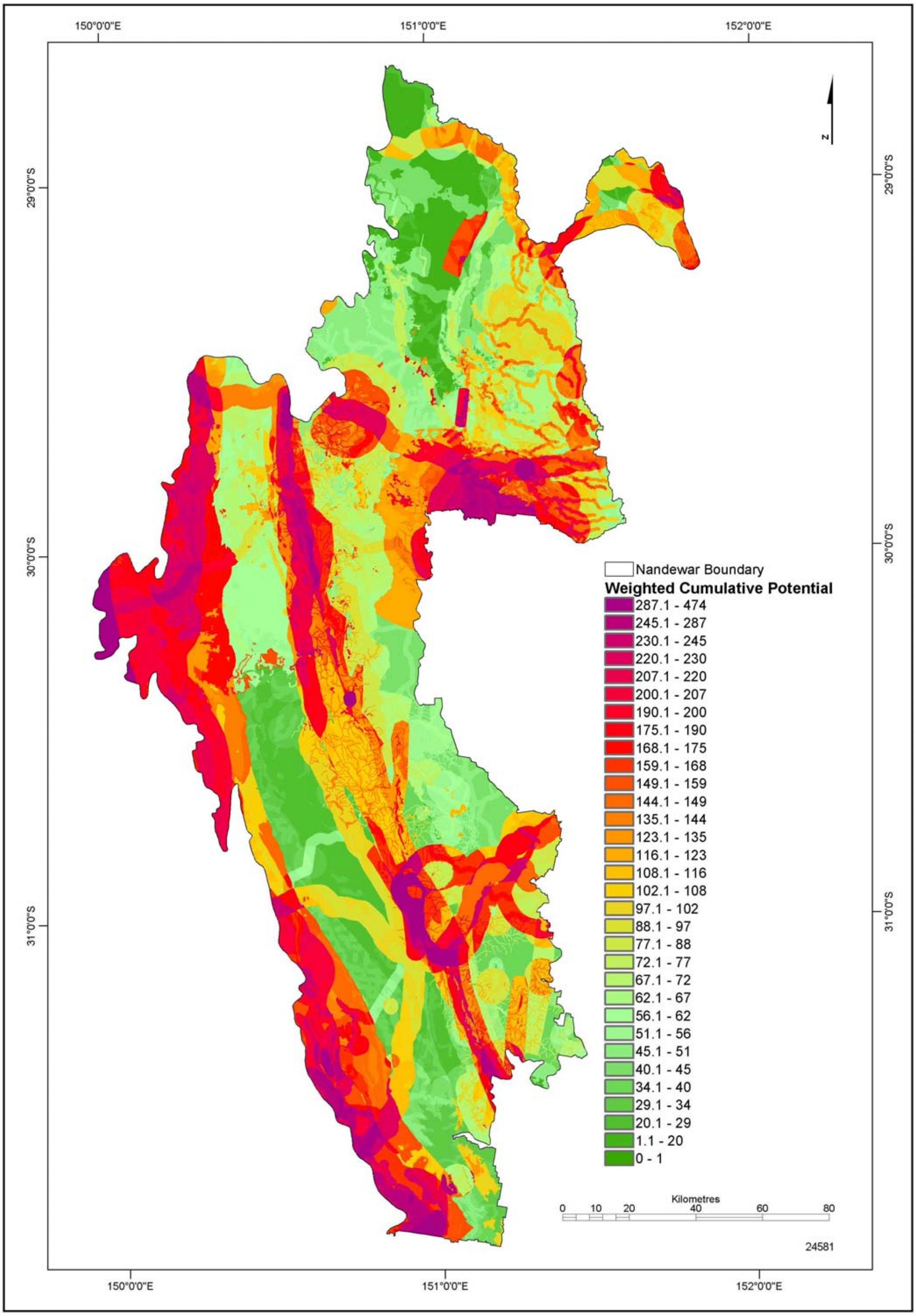



***Figure 7-EE. Weighted cumulative mineral and petroleum potential, Nandewar study area.***

## 7.6 MISCELLANEOUS MINERAL AND PETROLEUM COMMODITIES

A variety of other mineral commodities occur within the Nandwar study area but have not been assessed, either because their occurrence is not considered likely to be economically significant, or because not enough data is currently available to evaluate their potential. Some of these commodities are described below.

### 7.6.1 Petroleum

*Oil Shale*

The Temi oil shale deposit, located in the Murruurundi area, was discovered before 1861. Several prospecting shafts had been sunk in the area by 1865. Very high grades of oil shale were recorded with up to 70% volatile matter in the upper high-grade seam. In 1867 high-grade oil shale was produced but only in limited quantities.

In 1909, the British Oil Australian Oil Company re-opened the mines and built a retorting plant at Murrurundi and a refinery near Newcastle. Between 1909-1911 over 11 800 tonnes were raised, but the mines were again closed in 1913.

There has been little exploration in recent years in the Temi-Murrurundi area and remaining resources are considered to be very limited.

### 7.6.2 Industrial Minerals and Construction Materials

*Semi-Precious Gemstones*

In addition to sapphires and diamonds detailed above, a remarkable variety of semi-precious gemstones are found in the Nandewar study area. High quality quartz crystal, rose quartz, smoky quartz, citrine, aventurine, grass stone, and dark brown to black morion occurs in the Tingha area. Transparent and deep brown cairngorm is found near Bendemeer. Deep green to bluish green nephrite (jade) occurs in several areas adjacent to the Peel Fault, especially near Dungowan near Tamworth. The nephrite forms as lenses associated with talc and serpentinites and has been mined on a small scale. Gem quality garnet has been recovered from ‘Ruby Hill’ (which had been mistaken for ruby) near Upper Bingara. Prehnite occurs in veins in gabbro at Upper Bingara. Prase occurs near Hanging Rock. Volcanic opal has been recovered from volcanic rocks in the Nandewar Volcanic Complex. Quality rhodonite is found in several places, especially about Bingara, Nundle, Bendemeer and Warialda. Zircon is found in numerous places, including Inverell, Bingara and Nundle, and has been mistaken for diamonds at various times.

*Bauxite*

Ferruginous bauxite deposits are widespread in the Central Province near Inverell. The Department of Mines, BHP Pty Ltd and the Australian Aluminium Production Commission prospected these deposits extensively around the time of the Second World War. Some have also been quarried locally as a source for roadbase. The deposits are associated with Tertiary volcanics and attain their highest grades in the oldest units, generally in areas of flat topography.

The average composition of bauxites in the Tingha-Inverell-Warialda area is 39.5% $Al_2O_3$, 30% $Fe_2O_3$, 4.5% $SiO_2$, and 4% $TiO_2$. Resource estimates in the Inverell area are approximately 10.8 Mt (Brown and Stroud 1997). The availability of much larger and higher grade resources at Weipa in North Queensland and elsewhere has greatly reduced the likelihood of large scale development in the Nandewar study area in the foreseeable future. In addition, there are potentially inhibiting social and environmental factors as areas of higher-grade bauxite often coincide with areas of high agricultural productivity.

#### *Bentonite and Fullers Earth*

Bentonite is a type of clay composed largely of smectite group minerals (particularly montmorillonite). It is widely used in a number of industrial applications, the most significant being in iron ore pelletising, as a binding material for foundry moulding sands, and in drilling muds.

Bentonite occurs within the Permian Upper Coal Measures of the Sydney-Gunnedah Basin, and within the Tertiary sequence at Barraba. Fullers earth is known within the Boggabri Volcanics.

Exploration has delineated resources of bentonite in the Quirindi area in recent years and several small operations (just outside the study area) have been opened in recent years. Because of its association within the Upper Coal Measures further exploration, evaluation and development of bentonite resources will be in part carried out in conjunction with ongoing coal exploration and development.

#### *Dimension Stone*

Dimension stone is a natural stone that has been cut or shaped to a specific size for a particular building or decorative application. The term encompasses a large variety of rock types, and is classified by the industry into four broad groups: granite, sandstone, marble, and slate. Dimensions stones have a unique combination of qualities, specifically colour, texture, and durability, that make then attractive in building and interior design applications.

The potential for granite dimension stone has recently been assessed near Bendemeer by Southpac Ltd and Clutha Mines Ltd (1998).

#### *Garnet and Wollastonite*

Garnet and wollastonite have a range of industrial applications and may be recovered in economic concentrations from oxidised lime-rich skarns. (Ray 1988; Simandl et al. 1999).

The Moonbi Supersuite comprises a number of oxidised granites that have high potential as a source of garnet (Meinert 1992). However, skarn associated with the Moonbi Supersuite have not been assessed for its potential for industrial minerals. Roberts (1982) delineated wollastonite and wollastonite-plagioclase zones close to the contact of the Inlet Monzonite and the Moonbi Monzogranite. Various exploration reports on the southern (scheelite) skarn (associated with the Inlet Monzonite) report garnet dominant skarn comprising up to 70% of the rock (Attunga Mining Corporation, 1970).

### *Phosphate*

The Ashford Caves guano deposit comprises between 50 mm and 4.2 metres of cave earth which filled the irregular floor of an extensive limestone cave system. The cave earth, particularly the top 1.5 metres, was impregnated with phosphatic and nitrogenous material derived from bat droppings. Prospecting of the deposits defined possible reserves of 4500 tonnes in the eastern caves and 1500 tonnes in the Bat Cave at an average grade of 8% $P_20_5$. Approximately 1740 tonnes have been mined.

Minor phosphate in the form of guano also occurs on the floor of limestone caves near Moore Creek in the Manilla-Narrabri district. Both areas are environmentally sensitive, resources are small and there is little or no prospect for future development.

### *Magnesite*

Numerous deposits of magnesite occur in or adjacent to the Great Serpentinite Belt developed along the Peel Fault in the central part of the study area. Potential for these deposits is partially covered by the serpentinite-related deposits tract, although undiscovered sediment-hosted deposits could occur in surrounding areas.

Although most deposits appear to be small, little or no systematic exploration has been conducted over the length of the Great Serpentinite Belt and adjacent areas. This is particularly the case for potentially large, sediment-hosted magnesite deposits developed within areas of low relief during the Tertiary, as occurs at the very large sediment-hosted magnesite deposits near Young in southern New South Wales. However, it is considered that the erosional history of areas bordering the Peel Fault Zone makes it relatively unlikely that large-scale sediment-hosted magnesite deposits have developed or been preserved in the subsurface.

Deposits of magnesite within the Nandewar study area were worked between about 1916 and 1960 to provide feedstock for refractories, chemicals and fertiliser. Total recorded production in the Manilla-Narrabri area amounts to some 110 000 tonnes, most of which was obtained from the Attunga magnesite quarry.

Magnesite occurs in three recognised forms in the Nandewar study area:

- as silica carbonate rock, (an alteration product of serpentine);
- as hydrothermal veins; and
- as sediment-hosted concentrations.

Magnesite is marketed in three forms: crude, dead-burned, and caustic-calcined. Crude magnesite is used primarily in the production of dead burned and caustic magnesia, dead burned magnesite is a durable refractory material, and it can be used as a constituent in refractory bricks and other refractory products. Caustic calcined magnesite is used in agricultural, environmental and chemical applications and to make magnesium oxychloride and oxysulphate dements which are resilient, spark proof, and vermin proof. The building industry consumes large amounts of this magnesite for use in flooring, wallboards, and in acoustic tiles.

#### *Mineral Pigment*

Local concentrations of mineral pigment (limonite) occur in the weathered zone developed on mid Tertiary clastic sediments in the Bells Mountain area near Barraba. Mineral pigment has also been recorded at Turrawan close to the boundary of the Nandewar study area in Triassic or Jurassic sediments.

#### *Manganese Silicates*

Manganese silicate deposits (primarily rhodonite) are hosted by chert and jasper sequences within metasediments of the Central Block. Production from the Manilla-Narrabri district up to 1960 amounted to around 180 tonnes of industrial rhodonite and 600-700 tonnes of rhodonite for gemstones. The best quality rhodonite in the district apparently occurs in thermal aureoles around Permian granites. Recent production of rhodonite has occurred near Bendemeer.

Residual manganese deposits within the Nandewar study area were worked until about 1960 as sources of high grade manganese oxides, which were used in making dry cell batteries and steel.

### 7.6.3 Metallic Commodities

#### *Antimony*

Antimony is used mostly as an alloy, and in various industrial applications including the ceramic, glass, paper, paints, plastics, rubber, and textile industries. More than 75% of the world's antimony is used in flame retardants in textiles, plastics and paints.

The New England region is an antimony-rich province, however demand for antimony as a commodity is limited. Antimony has been mined or prospected in several places within the Nandewar study area, notably near Nundle, Bingara and Ashford. Grades up to 65% Sb have been recorded from the Nundle area.

#### *Platinum Group Metals*

Platinum group metals are a group of commodities that have grown steadily in demand during the second half of the 20th century, and this demand is expected to increase. They are used mainly as an autocatalyst in a wide variety of industrial applications, as well as in jewellery, electronics and dental applications.

Anomalous levels of platinum group metals have been reported in stream sediment samples taken from a number of locations in the Upper Bingara area. Limited follow-up investigations of the areas were completed during the 1960's and 1980's.

### *Magnetite*

Magnetite is used in New South Wales as a heavy media in the coal washing process. When finely milled, it remains suspended in water, giving a dense medium suitable for separating impurities from coal.

There are several little-known magnetite occurrences within Tamworth Belt rocks in the Nandewar study area. The Croydon magnetite deposit, located 20 kilometres of Manilla, includes massive coarse grained magnetite with chlorite joint fills, interstitial and vein epidote, and minor white quartz veins. The deposit occurs within the Mostyn Vale Formation.

Magnetite-rich skarn occurs at Ashford in the northern parts of the Nandewar study area, however its potential use in the development of southern Queensland or Ashford coal resources is unclear. The prospect was abandoned during earlier investigations because the magnetite content was less than 30% and the magnetite would have been difficult to beneficiate (Brown & Stroud 1997):

### *Gold Nuggets*

Smalls to large nuggets of unusual crystalline gold have been recovered from the Nundle, Upper Bingara and Bingara Gold Fields. The Nundle Gold Field has produced many rare "beautiful octahedral crystals of gold grouped in dendritic forms" (Wilkinson 1886). These gold specimens appear to have been formed by secondary (weathering) dissolution and precipitation processes, probably in association with extensive calcite alteration within the sequence. Around 400 specimens, including many crystalline examples from the Nundle Gold Field, were displayed in London in the early 1880's. Slabs and nuggets of gold up to 360 ounces in weight have been recorded from the Nundle area (Kermode 1882).