NSW WESTERN REGIONAL ASSESSMENTS

Nandewar

GEOLOGY – INTEGRATION AND UPGRADE

FINAL
April 2004

NAND04

RESOURCE AND CONSERVATION ASSESSMENT COUNCIL

NSW WESTERN REGIONAL ASSESSMENTS

Nandewar

GEOLOGY – INTEGRATION AND UPGRADE

Mark Dawson, Nancy Vickery, Robert Barnes, Victor Tadros, Leslie Wiles

NAND04

RESOURCE AND CONSERVATION ASSESSMENT COUNCIL

INFORMATION

ISBN 1 74029 204 9

This project has been funded and coordinated by the Resource and Conservation Division (RACD) of the NSW Department of Infrastructure, Planning and Natural Resources, for the Resource and Conservation Assessment Council (RACAC)

Preferred way to cite this publication:

Dawson M W, Vickery N M, Barnes R G, Tadros V N and Wiles L A, 2004, Nandewar Geology – Integration and Upgrade, Nandewar Western Regional Assessment. Resource and Conservation Assessment Council, 169pp.

For more information and for information on access to data, contact:

Resource and Conservation Division, Department of Infrastructure, Planning and Natural Resources

P.O. Box 39

SYDNEY NSW 2001

Phone: 02 9228 6586

Fax: 02 9228 6411

Email: info@racd.nsw.gov.au

Key authors: Mark Dawson, Nancy Vickery, Robert Barnes, Victor Tadros, Leslie Wiles

Contents

List of Figures

List of Tables

List of Photographs

List of Plans

Preface and Acknowledgments

This 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, Department of Mineral Resources (DMR).

This project required analysis and integration of a vast amount of both existing and newly acquired data, within a complex and extremely varied geological province. For this reason, many staff members and external consultants 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.

This project was managed through the Strategic Assessments sub-program headed by John Watkins as manager. Rob Barnes was the technical manager. Mark Dawson, Nancy Vickery, and Rob Barnes were responsible for overall compilation and integration of the report and the geological dataset. Leslie Wiles, and Dr Victor Tadros, compiled and provided technical supervision for the Permo-Triassic basins and Ashford Coal Measures sections of this report respectively. Technical supervision, compilation and management of the figures, databases, and GIS analysis of the report was under the direction of Ken McDonald. Ross Spencer, Mark Dawson and Rob Barnes prepared the geophysical datasets. Peter Stonestreet compiled the glossary, list of abbreviations and the list of references. Ken McDonald, Mark Dawson, Nancy Vickery, Llew Cain and, Dr Victor Tadros prepared the figures. Mapping contributions from the Manilla 1:100 000 sheet from Bob Brown and Harvey Henley were also incorporated into this report. Rob Barnes, John Watkins, Ken McDonald and Peter Stonestreet edited the report.

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

- Jeff Brownlow, Kirstine Malloch, Ricki Mantaring, Julie Moloney, Roger McEvilly, Jim Stroud and Bob Brown.

External consultants and professionals who provided valuable technical input were Bill Laing (Laing Exploration Pty Ltd), and Associate Professor Paul Ashley and Dr Warwick Sivell (University of New England).

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.

PROJECT OBJECTIVE(S)

The Geology – Integration and Upgrade project for the Nandewar study, was implemented by the NSW Department of Mineral Resources, Geological Survey of New South Wales branch. The aim was to significantly, and rapidly, improve the existing geological mapping. The objective was to prepare an integrated and upgraded geological dataset for use in scientific and resource assessments and as natural heritage information.

METHODOLOGY

The project was implemented in two phases:

- **Phase One** required the assembly and integration of immediately available digital geoscience mapping data across the study area. This allowed early release of existing information as a composite working dataset. No new data was generated during this phase. Some source data was over thirty years old and quality varied.
- **Phase Two** encompassed the rapid upgrading of geological mapping using the best available remote-sensed and supporting datasets. This phase built on the geological understanding in existing maps supplemented by information derived from newer geological publications, reports and theses. The major advance in geological information derived from the interpretation of remote-sensed data comprising high resolution geophysics (magnetics and radiometrics), Landsat 7 satellite data, and digital terrain data.

Comparison of existing geological information with remote-sensed data allowed on-screen mapping and revision of the geology. Interpretations were validated using existing data (for example maps, drillhole databases, and geoscience observation sites). A small amount of field reconnaissance was undertaken. In addition, the whole rock geochemistry was determined for several samples collected during this project.

KEY RESULTS AND PRODUCTS

The key product is a new, internally consistent interpretation of the surface geology. This interpretation exists as digital spatial data of geological units. Attribute tables in these datasets allow many different types of data inquiry. A report describes the data produced and summarises the geology of the Nandewar study.

The geology mapping upgrade project has resulted in:

- a seamless, internally consistent geological dataset
- a seamless bedrock geology interpretation
- correlation and simplification of names of widespread geological units
- an improved understanding for the development of the Werrie Basin and Ashford Coal Measures
- new insights into the age relations and geochemistry for Tertiary volcanic rocks in the New England area
- recognition of mappable variation (geophysical and lithological) within the Wandsworth Volcanic Group
- significant changes to the extent of accretionary complex units within the Central Block
- identification of previously unrecognised igneous intrusions

The maps and datasets should be useful for many aspects of natural resource assessment and modelling, for improved geological understanding and for mineral potential studies.

Acronyms and abbreviations

DMR: Department of Mineral Resources

K: Potassium

Th: Thorium

U: Uranium

Ss.: Sandstone

Cgl.: Conglomerate

Fmn.: Formation

K-Ar: Potassium – Argon

U-Pb: Uranium – Lead

Rb-Sr: Rubidium – Strontium

SHRIMP: Sensitive High Resolution Ion MicroProbe

Ma: Million years

GIS: Geographic information system

WRA: Western Regional Assessment

RFA: Regional Forestry Agreement

RACAC: Resource and Conservation Assessment Council

GR: Grid reference

GDA94: Geocentric Datum of Australia, 1994

MGA: Map Grid Australia

AGD66: Australian Geodetic Datum, 1966

AMG: Australian Map Grid

Glossary

accretionary wedge: a mass of sediment and oceanic lithosphere that is transferred from a subducting plate to the less dense overriding plate with which it converges.

actinolite: a greenish member of the amphibole group of minerals; a common low-medium grade metamorphic mineral.

alkali(c): said of silicate minerals that contain alkali metals but little calcium; for example the alkali feldspars.

alkaline basalt: a type of basalt, chemically distinct from **tholeiitic basalts** due to their higher component of **alkali** metals.

allochthonous: formed or produced elsewhere than in its present place; of foreign origin, or introduced.

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

alluvium: a general term for clay, silt, sand, gravel, or similar unconsolidated **detrital** material, deposited during comparatively recent geologic time by a stream or other body of running water.

andesite: an extrusive rock of **intermediate** composition.

anticline: a fold, generally convex upward, whose core contains the stratigraphically older rocks. Ant. **syncline**.

arenite: synonym of sandstone.

argillaceous: pertaining to, largely composed of, or containing clay-size particles or clay minerals; said of a sediment (such as marl) or a sedimentary rock (such as shale) containing an appreciable amount of clay.

argillite: A compact rock, derived either from mudstone (claystone or siltstone), or shale, that has undergone a somewhat higher degree of hardening than mudstone or shale but is less clearly laminated and without its fissility, and that lacks the cleavage distinctive of slate.

arkose: A feldspar-rich sandstone that is usually derived from the rapid disintegration of granite or granitic rocks, and often closely resembles granite.

augite: a dark-green to black mineral of the pyroxene group of minerals, common in **mafic** igneous rocks.

autochthonous: formed or produced in the place where now found. Applied to a rock the dominant constituents of which have been formed *in situ*.

back arc: a depression landward of a volcanic arc in a subduction complex, which is lined with trapped sediment from the volcanic arc and the landward plate.

basalt: a general term for dark-coloured **mafic** igneous rocks, commonly extrusive but locally intrusive; the fine-grained equivalent of **gabbro**.

basanite: a feldspathoidal **olivine basalt**.

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.

batholith: a large, generally discordant plutonic mass that has more than 100 square kilometres of surface exposure and no known floor.

blueschist: a bluish schistose metamorphic rock.

breccia: a coarse-grained clastic rock, composed of angular broken rock fragments held together by a mineral cement or in a fine-grained matrix; it differs from conglomerate in that the fragments have sharp edges and unworn corners. Breccia may originate as a result of talus accumulation, explosive **igneous** processes, collapse of rock material, or faulting.

chert: a sedimentary rock of amorphous or extremely fine-grained silica, usually formed from the skeletal remains of marine organisms, found in concretions and beds.

clastic: consisting of fragments of minerals, rocks, or organic structures that have been moved individually from their places of origin.

coal measures: a sequence of rocks containing coal.

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

colluvial: said of any loose, heterogeneous and incoherent mass of soil material and/or rock fragments deposited by rainwash, sheetwash, or downslope creep, usually collecting at the base of gentle slopes or hillsides.

comendite: a sodic **rhyolite** containing **alkalic** amphibole and/or pyroxene.

dacite: a fine-grained **felsic** extrusive rock; according to many, it is the extrusive equivalent of granodiorite.

detrital: synonym of **clastic**.

dip: the angle at which a bed, stratum, or vein is inclined from the horizontal, measured perpendicular to the **strike** and in the vertical plane.

eclogite: a granular metamorphic rock composed essentially of garnet and sodic pyroxene (omphacite), usually indicating high pressures of crystallisation.

en echelon: said of geologic features that are in an overlapping or staggered arrangement, e.g., faults. Each is relatively short, but collectively they form a linear zone, in which the strike of the individual features is oblique to that of the zone as a whole.

epiclastic: said of sedimentary rocks whose fragments are derived from weathering or erosion.

eutaxitic: said of the banded structure of certain extrusive igneous rocks, which results in a streaked or blotched appearance.

facies: a term of wide application, referring to such aspects of rock units as rock type, mode of origin, composition, fossil content, or environment of deposition.

fault: fracture along which there has been movement.

felsic: said of igneous rocks composed chiefly of light-coloured minerals (feldspar and quartz); generally having a silica content of greater than 65%.

ferruginous: pertaining to or containing iron; for example a sandstone that is cemented with iron oxide.

fiamme: (It.) flame; used to describe flame-textured rocks.

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

fold belt: a linear or arcuate region that has been subjected to folding and other deformation.

fore arc basin: a depression in the sea floor located between an accretionary wedge and a volcanic arc in a subduction subduction zone and filled with trapped sediment.

gabbro: a dark-colored, **mafic** intrusive igneous rock; it is the approximate intrusive equivalent of **basalt**.

granite: a medium- to coarse-grained **felsic** igneous intrusive rock.

granulite: a metamorphic rock consisting of even-sized, interlocking mineral grains less than 10% of which have any obvious preferred orientation.

hawaiite: a type of **olivine basalt** in which the plagioclase is less calcic than normal **basalt**.

hypersthene: a dark-coloured mineral of the pyroxene group that is a common rock-forming mineral in **intermediate** to **mafic** igneous rocks.

ignimbrite: the rock formed by the widespread deposition and consolidation of volcanic ash flows.

imbrication: a sedimentary fabric characterised by disc-shaped or elongate fragments dipping in a preferred direction at an angle to the bedding.

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.

intermediate: said of an igneous rock that is transitional between **mafic** and **felsic**; generally having a silica content of 54% to 65%.

I-type: pertaining to granitoids that are derived from the partial melting of an igneous source.

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

kaolinite: the most common of the clay minerals.

lacustrine: produced in a lake.

leuco-: a prefix meaning “light-coloured”; used to designate a rock that is more **felsic** than the specified range, for example leucogranite.

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

lithic: said of a sedimentary rock or a **pyroclastic** deposit containing abundant fragments of previously formed rocks; also said of such fragments.

lithology: The character of a rock described in terms of its structure, colour, mineral composition, grain size, and arrangement of its component parts; all those visible features that in the aggregate impart individuality to the rock.

mafic: said of igneous rocks composed chiefly of dark-coloured minerals (iron and magnesium bearing minerals); generally having a silica content of less than 55%.

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

magnetite: a metallic, black mineral that is strongly magnetic.

matrix: the finer-grained material between the larger particles of a rock .

melange: a body of rock characterised by a lack of internal continuity of contacts or strata and by the inclusion of fragments and blocks of all sizes, both exotic and native.

miarolitic: a term applied to small irregular cavities in igneous rocks, especially granites, into which small crystals of the rock-forming minerals protrude.

mugearite: a type of olivine **basalt** that is potassium feldspar bearing.

mylonitic: showing an intense microbrecciation and shearing which gives the appearance of a flow structure.

nepheline: a mineral that is a common constituent of **alkalic** igneous rocks.

olivine: a greenish magnesium and iron bearing mineral that is common in **mafic** and **ultramafic** rocks.

oolitic: pertaining to a rock or mineral made up of ooliths, small round or ovate accretionary bodies in a sedimentary rock. They are usually formed of calcium carbonate, but may be of dolomite, silica, or other minerals, in successive concentric layers, commonly around a nucleus such as a shell fragment, an algal pellet, or a quartz-sand grain, in shallow, wave-agitated water.

ophiolite: Ocean-floor mafic and ultramafic igneous rocks that form in the early stages of orogenesis and are often subject to later metamorphism, including serpentinisation

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

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. Syn. **orogenesis**.

orthoconglomerate: a conglomerate that has been derived from an igneous rock parent.

paraconglomerate: a conglomerate that has been derived from a sedimentary rock parent.

pelagic: pertaining to a deposit found in deep water far from shore and may be predominantly either organic or inorganic in origin.

petrography: a general term for the science dealing with the description and classification of rocks, based on observations in the field, on hand specimens, and on thin sections.

phonolite: a fine-grained alkaline **felsic-intermediate** extrusive igneous rock.

plagioclase: a series of calcium and sodium feldspars that at high temperatures form a complete series from albite, $NaAlSi_3O_8$, to anorthite, $CaAl_2Si_2O_8$.

polymictic: said of a clastic sedimentary rock composed of many rock types, or a conglomerate with more than one variety of pebble; also, said of the clasts of such a rock.

prehnite: a light green to white mineral that is a characteristic mineral of low temperature, burial metamorphism.

pumpellyite: a greenish mineral that is a characteristic mineral of low temperature burial metamorphism.

pyroclastic: said of rocks formed by the accumulation of fragments of volcanic rock scattered by volcanic explosions.

quartzite: sandstone composed of silica grains so firmly cemented by silica that fracture occurs through the grains rather than around them.

radiolaria: Marine protozoans that possess complex internal siliceous skeletons.

regression: the retreat or contraction of the sea from land areas, and the consequent evidence of such withdrawal (such as enlargement of the area of deltaic deposition). Ant. **transgression**.

rhyolite: a **felsic** extrusive igneous rock; the extrusive equivalent of **granite**.

serpentinite: a rock consisting almost wholly of serpentine-group minerals, derived from the alteration of ferromagnesian silicate minerals, such as olivine and pyroxene. Accessory chlorite, talc, and magnetite may be present.

smectite: any clay mineral with swelling properties and high cation-exchange capacities; an expansive clay.

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

strike: the course or bearing of the outcrop of an inclined bed, vein, or fault plane on a level surface; being the direction of a horizontal line perpendicular to the direction of the **dip**.

S-type: pertaining to granitoids that are derived from the partial melting of a sedimentary source.

subduction: the process of one lithospheric plate descending beneath another.

syncline: a fold, generally concave upward, whose core contains the stratigraphically younger rocks. Ant. **anticline**.

tectonic: structural or deformational.

terrane: a fault-bounded body of rock of regional extent, characterised by a geologic history different from that of contiguous terranes; generally considered to be a discrete **allochthonous** fragment of oceanic or continental material added to a craton at an active margin by accretion.

terrigenous: derived from the land or continent.

tholeiitic basalt (tholeiite): a type of basalt, chemically distinct from **alkaline basalts** due to their lower component of **alkali** metals.

tor: a high, isolated crag, pinnacle, or rocky peak; or a pile of rocks, much jointed and usually granitic, exposed to intense weathering, and often assuming peculiar or fantastic shapes.

trachyte: a fine-grained **felsic-intermediate** extrusive igneous rock.

transgression: the spread or extension of the sea over land areas, and the consequent evidence of such advance (such as strata deposited unconformably on older rocks). Ant. **regression**.

tuff: a general term for all consolidated **pyroclastic** rocks. Adj. **tuffaceous**.

turbidite: a sediment or rock deposited from, or inferred to have been deposited from, a turbidity current (a bottom-flowing current laden with suspended sediment, moving swiftly down a subaqueous slope and spreading horizontally on the floor of the body of water).

ultramafic: said of an igneous rock composed solely of dark-coloured minerals, for example monomineralic rocks composed of **hypersthene**, **augite**, or **olivine**.

unconformity: The structural relationship between rock strata in contact, characterised by a lack of continuity in deposition, and corresponding to a period of non-deposition, weathering, or especially erosion prior to the deposition of the younger beds, and often marked by absence of parallelism between the strata.

volcaniclastic: pertaining to a **clastic** rock containing volcanic material in whatever proportion, and without regard to its origin or environment.

1 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 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 completed for the east coast Regional Forestry Agreement (RFA) process.

In January 2003, the Department of Mineral Resources (DMR) commenced the regional assessment of the Nandewar study area. The DMR 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 primary objective of the “Geology – integration and upgrade” project was to provide a series of geoscientific datasets on the geology to be used in subsequent scientific assessments, including, soil, flora, fauna and mineral assessment modelling.

The Western Regional Assessments in western NSW 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 knowledge of the geological settings in an area is built into geological datasets and can be then directly applied to mineral and petroleum exploration.

Geological maps represent one of the most fundamental datasets that can be used for natural and economic resource studies in any area. Rocks form in a wide variety of environments and in the Nandewar study area rock-forming environments have included:

- Lakes and rivers

- Shallow oceans and seas
- Deep oceans
- Volcanoes and volcanic arcs (including explosive and more passive events)
- Plutonic and deep crustal settings, and
- Mantle (sub crustal) settings

Rock types vary both chemically and physically. Variations play a primary role in determining soils. Types of rocks present and their geological history are major factors in determining topography. These in turn lead to variations in soils and soil fertility and other factors, which play a role in flora variations which themselves affect fauna. The geological history of an area can be complex and the present landscape is the product of this history that can be traced back hundreds if not thousands of millions of years.

The geology of the Nandewar WRA area had been mapped by the Geological Survey of New South Wales at 1:250 000 scale, for the most part during the 1970s at a rapid reconnaissance standard. In some areas a subsequent series of metallogenic maps upgraded some of this mapping but in other areas these maps were more geologically generalised than earlier maps. In addition, limited areas were covered by more detailed mapping, generally at 1:100 000 scale, some of which was compiled from field work at 1:25 000 scale.

These data exist as hardcopy maps and digital geological coverage of individual 1:250 000 sheet areas of the most recently published maps. The digital datasets contain various levels of detail and vary in age and quality. The detail of geology available for any particular area has been a function of the availability of technical resources and priorities established over more than 125 years of geological mapping in New South Wales.

Western Regional Assessments (WRAs) have required the re-evaluation of the existing datasets. Limitations of the existing data have been recognised along with the appreciation that many of the users of geological maps are requiring more information on the near surface units. Many dated geological maps paid scant attention to the surficial units. In addition, other scientific studies, such as mineral potential assessments, require interpretations of interesting geological units even where they are covered by surficial materials (for example units extending under river channels).

As a result, the geological mapping integration and upgrade project was developed to synthesise existing data and improve the mapping of surface units and interpretation of bedrock covered by surficial units.

Far more detailed interpretation of the surficial geology has been possible because of:

- an increasing awareness of, and a descriptive framework for, surficial units be they weathered rock, soil or transported but unconsolidated material,
- the availability of new datasets such as satellite imagery (Landsat 7), radiometrics (measuring variations in the small amounts of natural radioactivity occurring in all rocks),

magnetics (measuring small distortions in the Earth's magnetic field caused by magnetic minerals in rocks) and digital terrain models (computer generated three dimensional views of the Earth's surface),

- access to computer and geographic information system and image processing technology that allows rapid interpretation of geological units over large areas.

Some of this work blurs the boundary with geomorphology, soils mapping and what is now termed *regolith mapping*. This project recognises that much of the Australian landscape represents the product of extensive weathering and transport of surficial material.

Improved interpretation of covered bedrock has been possible because of improved datasets (especially aeromagnetics) and because the nature of the geology of the study area allows for regional interpretations to be made with confidence.

The result has been a new, integrated and internally consistent geological interpretation and recompilation of the geology of the Nandewar WRA study area.

The project reported here describes the geological integration and upgrade project. In the first instance, available and existing information was integrated into a single useable dataset. It also describes in summary form the geology of the study area.

GEOLOGY IS A FUNDAMENTAL DATASET

Geology is the science that deals with the earth, the rocks of which it is composed, and the changes which it has undergone or is undergoing (Macquarie Concise Dictionary).

A geology map is a simplified representation of the geological units occurring in an area. Mapped geological units can comprise one or several types of rock, but they are generally grouped when they have a similar age and formed in similar ways.

Geology maps underpin many natural resource studies. The rocks weather to soils, and the chemistry and hardness of rocks, and the geological history of the area along with the effects of climate, have together resulted in the landscape we now see. Flora and fauna strongly correlate with geology and hence soils and the landscape. Mineral deposits form in specific types of geological settings and by understanding the geology we can predict where mineral and petroleum deposits might be found.

2 Methodology

2.1 INTRODUCTION

Geological maps are a representation of the distribution of packages of rocks across a given area. Typically maps are constructed by grouping rocks with similar ages, lithologies (rock types) or those formed in similar geological settings.

Maps are prepared by making a limited number of point observations in the field. When broad mappable rock units have been identified, boundaries between mappable units are recorded. In detailed maps, important boundaries can be traced in the field and recorded onto base information such as aerial photographs or topographic maps. In other areas, boundaries can be interpreted between observation points by inference or interpolation. For example, if two different rock units were observed a kilometre apart but the contact between these units could not be seen, a boundary can be inferred.

As technology has progressed, it has been possible to use additional support information to help determine where geological unit boundaries should be mapped. In addition, it is not necessary to repeat good field observations where they have been well recorded and located.

This project has made much use of newly available technology and data including:

- new datasets such as airborne geophysics;
- geographic information system (GIS) and image processing software for viewing and interpreting information;
- computer systems which allow availability and sharing of a large range of existing datasets; and
- a project environment which allowed for direct recording of interpreted boundaries from the supporting datasets.

The methodology used for this project has been modified substantially from standard regional mapping practice. Nevertheless, this project has generated information which can be linked to existing DMR data systems (such as COGENT) and can be integrated with other natural resource datasets.

The focus has been on obtaining the maximum benefit from new information and processes to improve existing maps within the constraints of available time and resources. As a result, many of the improvements to mapping have derived from improving the spatial accuracy between units already known to exist. In addition, geophysical datasets allow the recognition of groups of units with similar characteristics over large areas. In the past some of these associations had not been recognised. Only a very small amount of field validation has been possible during this project.

2.2 PHASE ONE – INTEGRATING EXISTING DATA

2.2.1 Geological mapping and data available at the start of this project

Maps of the geology of the State of New South Wales exist in many forms and scales. The most simplified maps cover the whole state on a single small sheet and by necessity are very generalised. Large areas are grouped together by similarities of lithology (rock type), age, or the geological setting in which the rocks were formed or can now been found (for example sedimentary basins). The maps are very useful for making syntheses over large areas.

The most commonly available geology maps have been published at scales of 1:250 000 or 1:100 000. At these scales it is possible to graphically represent units as small as about 250 metres to 100 metres across. Typically, however, units on these maps are from hundreds of metres to kilometres across. Most maps can be described as lithostratigraphic maps. Lithostratigraphic maps use a combination of rock types as well as stratigraphic position (or order of formation) to represent units. For example, a sequence made up of beds of sandstone and shale might be mapped as a formation comprising sandstone and shale as it would be impossible to effectively map the individual lithologies (i.e. rock types such as sandstone and shale) at the scale of the map. In many areas it is impossible to effectively map rock types in detail because of the lack of outcrop and because many rock units consists of many interbedded types of rocks.

In some areas, geological mapping has been undertaken at scales of 1:10 000 scale or larger. Mineral exploration companies have typically done this type of mapping over small areas during mineral exploration. Geological researchers and geology students commonly investigate a particular geological feature in a relatively small area. This type of mapping tends to focus on the distribution of particular types of rocks and can sometimes include mapping that separates outcrops from soil-covered areas.

The source data used at the start of this project is derived from geological maps at 1:250 000 and 1:100 000 scale maps published by the Department of Mineral Resources and its predecessors. Many of these had been digitised from hardcopy. The data comprised a series of datasets each covering the area of the source map. In effect, the data represented information of the age of the source maps. The oldest maps where published in 1969 and the most recent was published in 2001. An index to the 1:100 000 and 1:250 000 map sheets that intersect the Nandewar study area can be observed in Figure 2-A and Table 2-A.

To effectively use these datasets, each had to be standardised and then joined. A continuous topologically structured geological coverage was created in Arc/Info for Phase One and comprised parts of the sheets shown below.

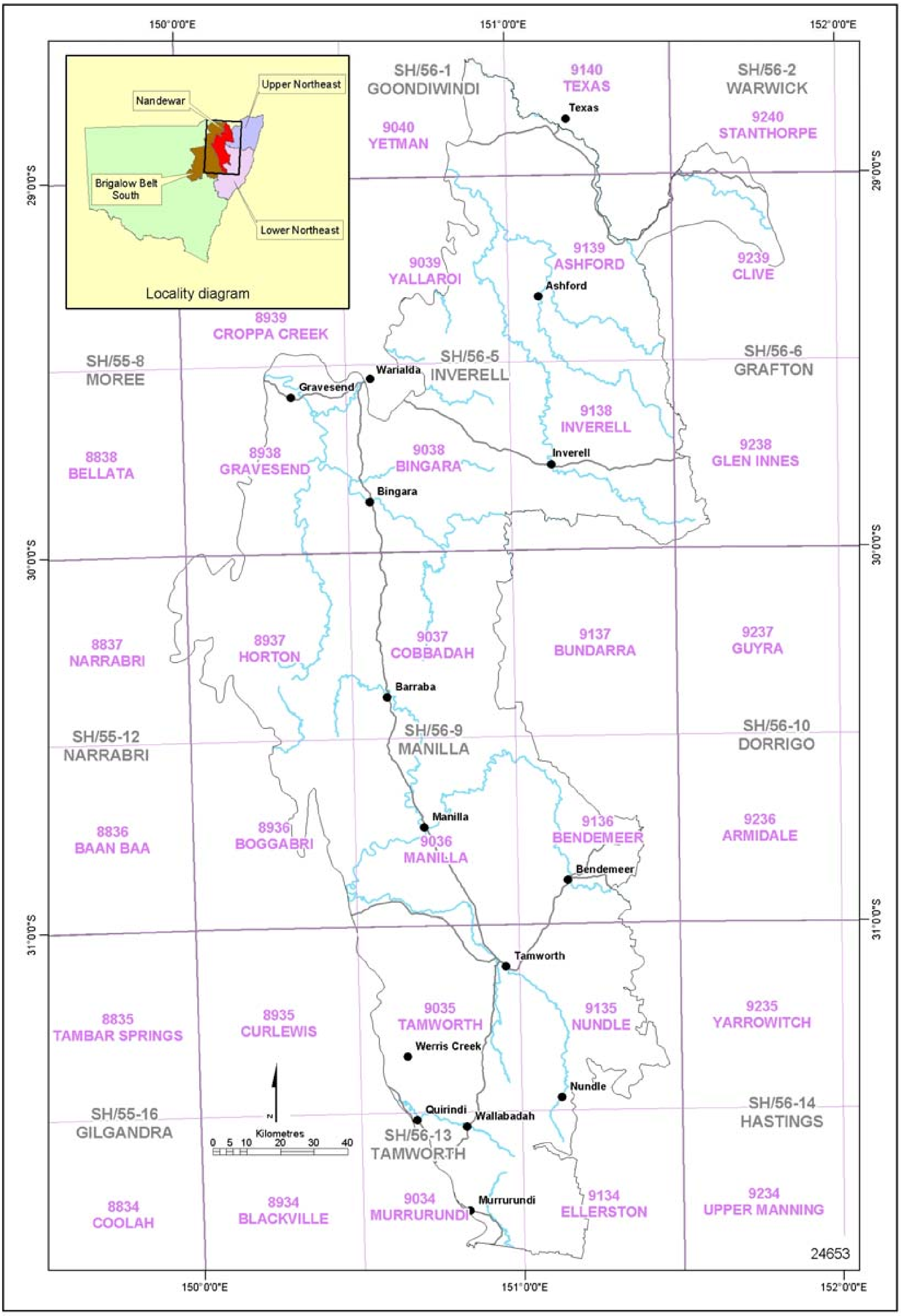


Figure 2-A. Index to 1:100 000 and 1:250 000 map sheets in the Nandewar study area.

Table 2-A. Index to 1:250 000 map sheet names in the Nandewar study area.

Sheet number	Map sheet name	Australian Map Grid Zone
SH/56-2	WARWICK	AMG56
SH/56-1	GOONDIWINDI	AMG56
SH/56-6	GRAFTON	AMG56
SH/56-5	INVERELL	AMG56
SH/56-9	MANILLA	AMG56
SH/55-12	NARRABRI	AMG55
SH/56-13	TAMWORTH	AMG56

2.2.2 Phase One - data preparation

The geology for Phase One was compiled from:

- Published 1:250 000 scale geological maps of the Goondiwindi and part of the western Tamworth (1971) geology sheets.
- Geological information on Department of Mineral Resources published 1:250 000 metallogenic maps for the Inverell (1997), Manilla-Narrabri (1992), Tamworth- Hastings (1987) and Grafton-Maclean (2001) map sheets.
- Geological data compiled in digital form for the Brigalow Belt South Bioregion Geology Integration and Upgrade project (to the west) and the Upper and Lower North East Comprehensive Regional Assessment (CRA) areas (to the east). These datasets were held in the Department of Mineral Resources.

2.2.3 Phase One - digitising and data processing

BRIGALOW BELT SOUTH: Data from the DMR Geology Integration and Upgrade project Barnes et al (2002) abuts the Nandewar study area to the west and included a fifteen kilometre buffer overlapping the Nandewar study area. This information provided a starting point for further development of the digital geology of the Nandewar.

UPPER NORTH WEST: The dataset UNRW5GE was created for previous regional studies and includes parts of the Goondiwindi, Inverell, and Manilla 1:250 000 sheets. These data were derived from geological base maps used for metallogenic mapping. Attributes were assigned on a sheet-by-sheet basis and boundary errors had not been corrected.

LOWER NORTH EAST: The datasets created for previous Comprehensive Regional Assessment studies were the UNER5GE covering northeastern NSW and the LNEN5GE (Lower Northeast North), LNES5GE (Lower Northeast South), TAMW4GE (Tamworth West), MURR4GE (Murrurundi) and GUTA5GE (Gunnedah–Tamworth) data. These were combined and attributes assigned on a sheet by sheet basis. This is essentially data prepared for the Lower North East CRA in the Tamworth and Singleton sheets combined with some additional data in the western Tamworth sheet area. Additional data from Winston Pratt (geologist, Singleton office) was incorporated to update an area across the GUTA5GE – TAMW4GE map edge at Caroona. Part of this dataset had been used in the eastern parts of the Brigalow Belt South digital geology dataset.

A compilation by Emeritus Professor John Roberts (University of New South Wales) of specific rock units in the west of the study area had been digitised by Ken McDonald using Autocad and was included in the Brigalow overlap data.

2.2.4 Phase One – Attribution of mapped geological units

In order to make a geological dataset useful, descriptions of the geological units must be prepared. This information has traditionally been carried as a geological legend on the face of the geological map. With the advent of GIS, it has been possible to add a substantial amount of additional information, which can help to categorise the mapped units.

For Phase One, information on geological units was assembled from the map legends and added to a single table. A large amount of the information which exists on a map face contains implicit information, and for database purposes it is necessary to make this information explicit.

The Phase One geology coverage was released for distribution to stakeholders as "Nand5ge_amg56 - Interim geological coverage of the Nandewar Western Regional Assessment area in NSW at 1:250,000 scale equivalent comprising the area covered by parts of the Narrabri SH/55-12, Goondiwindi SH/56-1, Inverell SH/56-5, Manilla SH/56-9, Tamworth SH/56-13 and Grafton SH/56-6 sheet areas" in April 2003. The coverage of the geology was released as polygons (nand5geology_poly), and as separate arc coverage (nand5geology _line) of geological boundaries and faults at 1:250 000 scale equivalent. The coverage portrays mapped geological units and is attributed with lithological and stratigraphic descriptions.

2.2.5 Limitations of existing data in Phase One

A number of inadequacies and inconsistencies existed in the Phase One data. These were:

- the range in ages of the source datasets and hence state of geological knowledge portrayed,
- the varying styles of portrayal of geological units;
- variations in the original purpose of the maps available (for example data included standard geological maps, maps prepared as bases for metallogenic maps and maps prepared to portray coalfields information);
- differing scales of source datasets; and most importantly
- that all the maps had been prepared before the availability of detailed regional airborne geophysical data.

These factors meant that the Phase One geological coverage could not be used effectively for region-wide modelling or portrayal of units. As a consequence, it was considered necessary to upgrade these datasets using rapid interpretation techniques using newly available airborne geophysical data (radiometrics and magnetics) and satellite imagery (Landsat 7) in conjunction with a range of other available datasets.

2.3 PHASE TWO – UPGRADING GEOLOGY

2.3.1 Data available to assist in data upgrading

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 data.

Data used in this process can be classed as follows:

- Existing geological mapping, interpretations and datasets
- Various versions of geological maps
- Geological theses and maps
- Mineral exploration company reports
- Departmental mapping
- Field observations
- Mineral deposit databases (which commonly include geological observations);
- Drill hole databases
- Geochronology (absolute and relative)
- Geochemistry
- Petrology
- Geomorphological mapping
- Geological reports, publication and diagrams
- Aerial photographs (possibly marked up with previous or new geological interpretations)

Remote-sensed data which can assist geological interpretation:

- Radiometric data (see Figure 2-C)
- Magnetic data (see Figure 2-D)
- Satellite images
- Digital terrain models
- Gravimetric (gravity) data (see Figure 2-E)

Supporting datasets which can assist in geological interpretations include:

- Stream datasets
- Topographic and cadastral maps and datasets
- Property maps

2.3.2 Data preprocessing

In order to make these datasets useful and available it was necessary to:

- systematically georegister all of the information onto a common geodetic datum;
- store the data in a systematic data directory on a computer server accessible by all of the geologists and geophysicists in the project; and

- maintain an index of the data and new interpretations as they were generated.

This process involved some difficulties as the DMR has adopted the National standard GDA94 datum while the Nandewar Western Regional Assessment was to be completed on the old AGD66 datum. It was decided that using the new GDA 94 datum provided for the best use of available data and will allow all of the datasets generated by the DMR to be used long into the future. As a result, all DMR project work has been completed internally on the GDA94 datum but copies for release have been projected to the old AGD66 datum in AMG Zone 56 coordinates for the assessment.

2.3.3 Geophysical data

Introduction

The entire extent of the Nandewar study area is covered by geophysical data of varying detail and quality. Airborne magnetic and radiometric data and ground acquired gravity data were utilised in the Nandewar study. Figure 2-B shows the airborne geophysical coverage over the area. The ground gravity data are taken from the Australian National Gravity Database 2003 (Wynne et. al 2003) and have been reprocessed by the NSW Department of Mineral Resources.

From the airborne survey data, magnetic field data and radio-element data were used. A brief overview of the geophysical data is given here. More specific relationships between the geophysical response and the geology are given throughout the text.

Magnetic data

The airborne magnetic data for the Nandewar study area are shown in Figure 2-D. Although the image is continuous, it is made up from 13 different surveys that have been merged into a single seamless coverage. The detail and quality of the different surveys is highly variable. Reasons for this variability include the time taken to acquire the data, (the oldest data acquired in 1980, the most recent in 2002), the distance between the flight lines (the most significant factor influencing data quality) and the survey altitude. Flight line separation is 200 metres for the most detailed data but is as large as 1500 metres for the oldest survey data.

Approximately two thirds of the Nandewar study area is covered by the more 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.

Radiometric data

Approximately one third of the Nandewar study area is not covered by high-resolution airborne radiometric data. The areas without high-resolution coverage were only flown at 1500 metres line spacing in regional surveys. The radiometric acquisition system was not calibrated to enable modern processing of the data. Figure 2-C shows an image of the available high resolution radiometric data that, like the magnetic data, is a seamless merge of a number of different surveys that had different acquisition parameters (see Figure 2-B for details).

A ternary radiometric image has been created by applying a colour to each of the potassium (red), thorium (green) and uranium (blue) radioelement channels. For example, if potassium were shown on its own it would appear as shades of red to black, with black representing the lowest values and bright red for the highest values. The colour, hue and brightness of different areas within the image relate to the amount of potassium (K), uranium (U) and thorium (Th) in the ground.

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.

Gravity data

The Bouguer gravity data for the Nandewar study area are shown in Figure 2-E. 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 (according to current theory, very significantly thicker under areas of raised topography). These thicker areas of crust can have a significant influence on the gravity data, particularly in areas with varying topography.

Nominally, the area is covered by a grid of readings every 11 kilometres, although a small part of the area has a greater density of readings. Since the data over the area are widely spaced the information contained in the gravity data indicate large scale structure and therefore, are more applicable to the interpretation of the regional structure of the area.

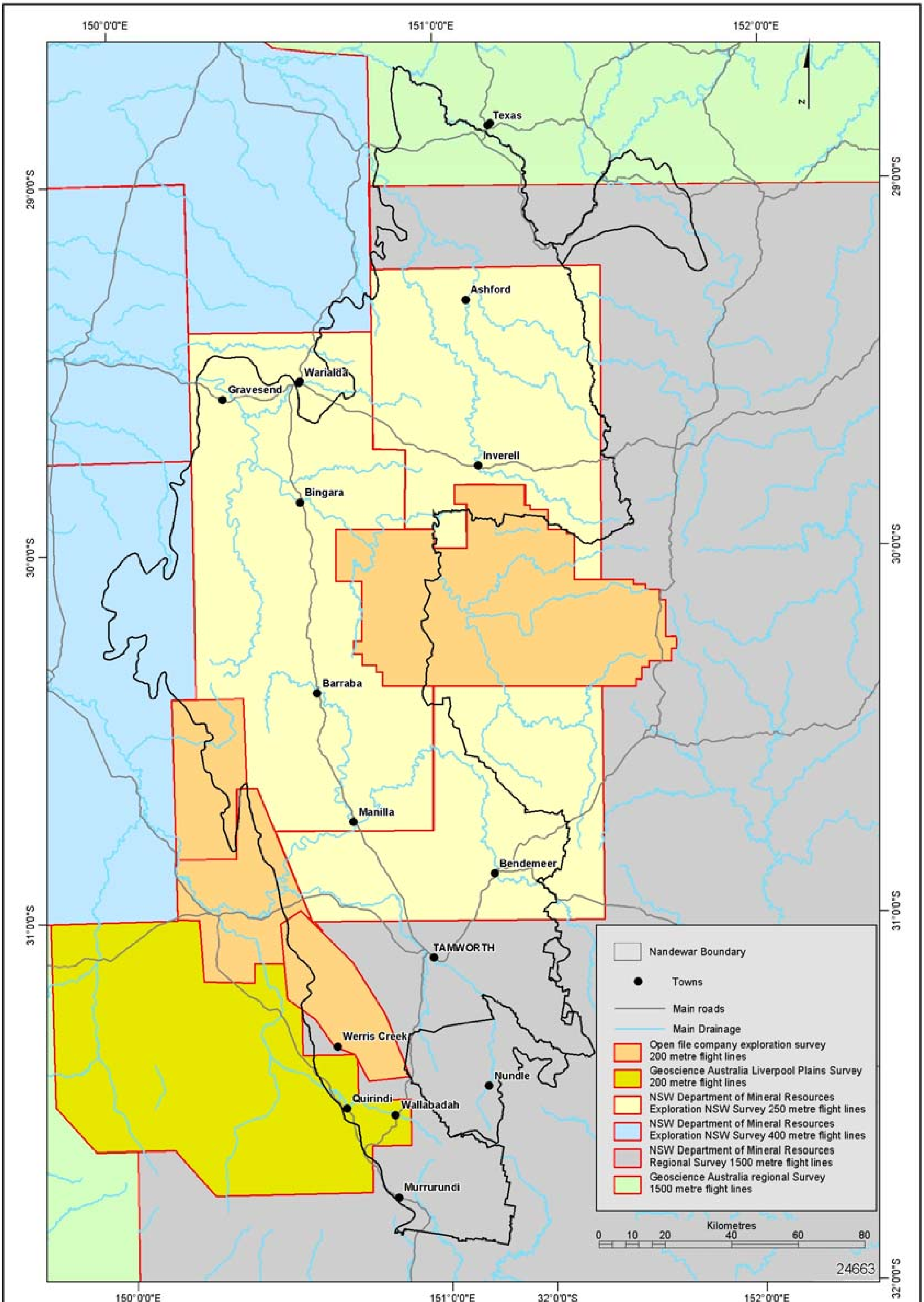


Figure 2-B. Airborne geophysical survey coverage of the Nandewar study area.

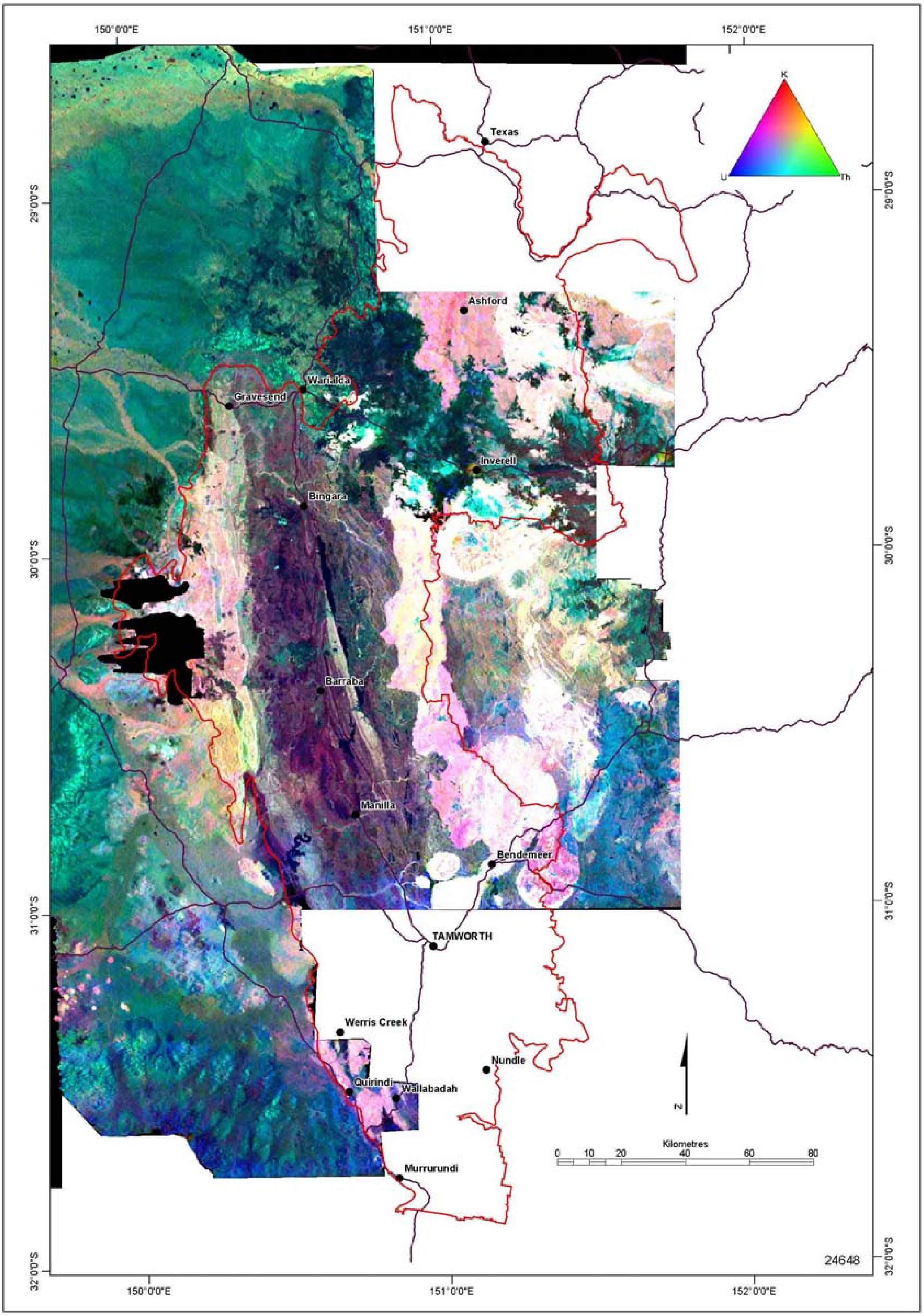


Figure 2-C. Composite ternary radiometric image of the Nandewar study area.

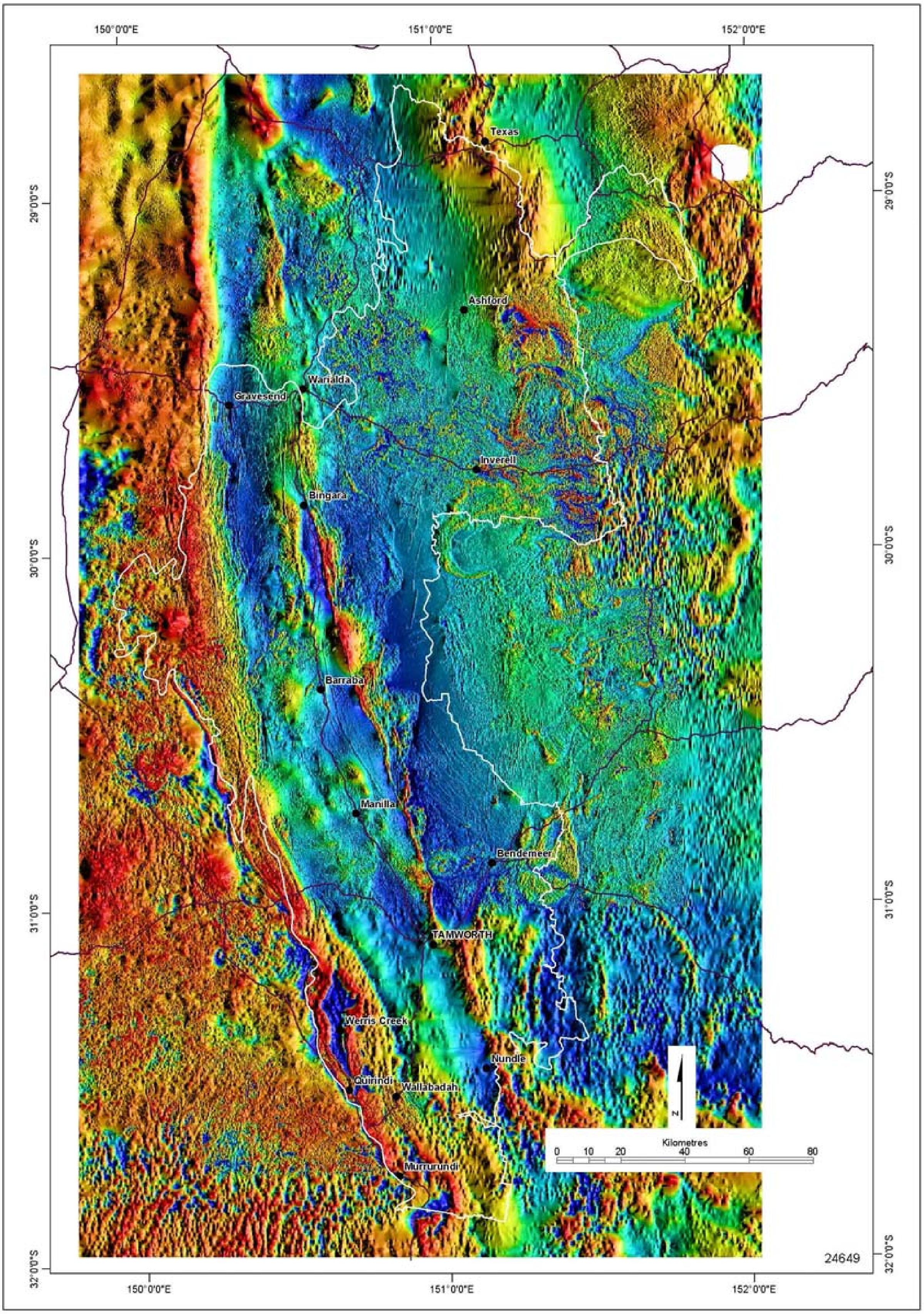


Figure 2-D. Total magnetic intensity pseudocolour image of the Nandewar study area.

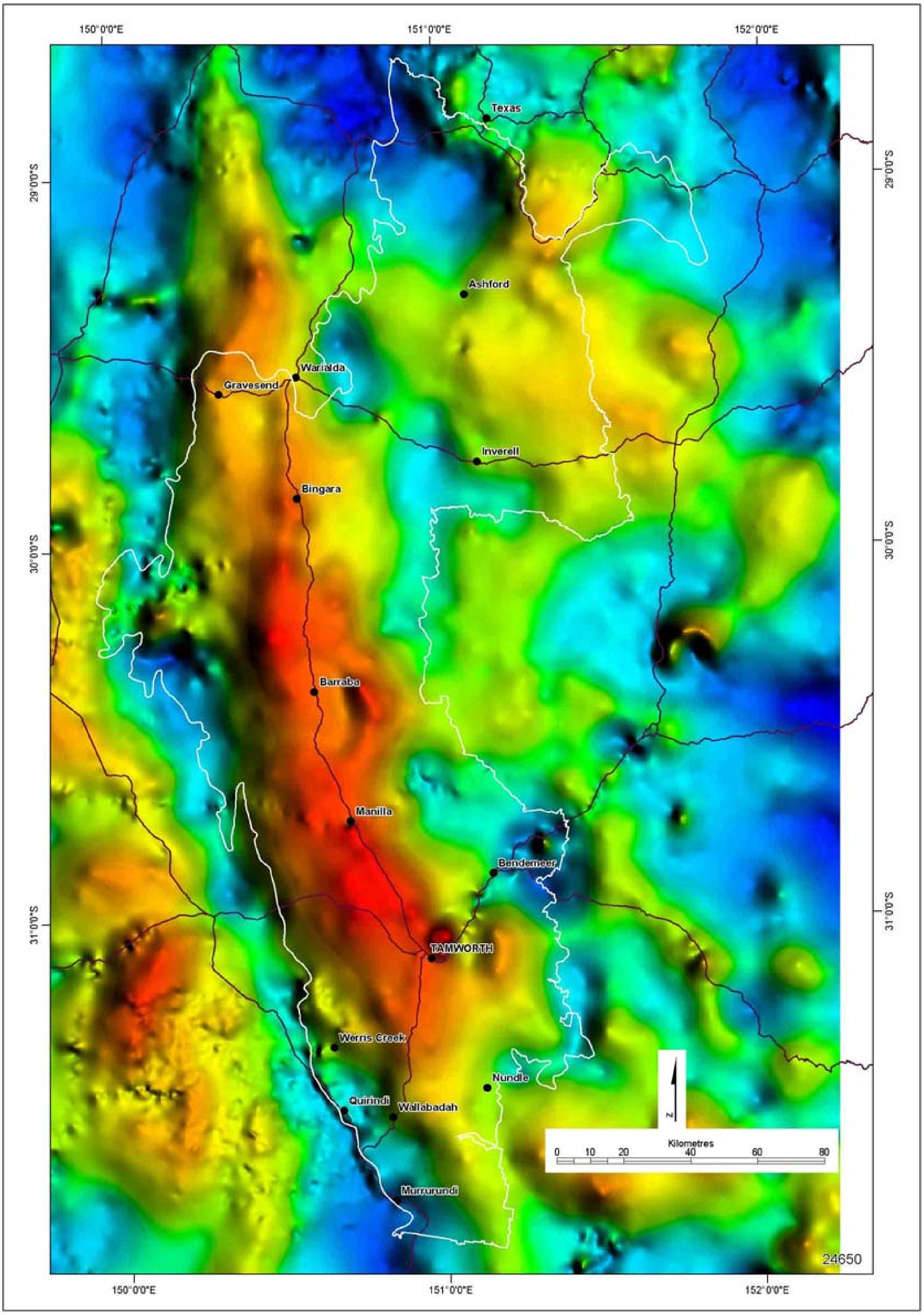


Figure 2-E. Isostatically corrected pseudocolour Bouguer gravity image of the Nandewar study area.

2.3.4 The rapid interpretation of geology and subsequent conversion to spatial geoscience information (the Brigalow method)

For the Nandewar WRA, the methods developed for the Brigalow Belt South Bioregion regional assessment were adopted and improved. The upgrading of the geology for the Brigalow Belt South Bioregion regional assessment required the interpretation of information on a scale and with a rapidity which had not previously been attempted within the Geological Survey of New South Wales. An input of many person years would be typical for many of the maps produced as standard products by the Geological Survey of New South Wales. By comparison, approximately one tenth of the typical time was applied to each map sheet area for this project. The key to the rapid upgrading of mapping is to:

- use existing observations combined with continuous geophysical and remotely sensed data to effectively extrapolate knowledge into areas where direct observations are limited;
- standardise interpretations across large areas; and
- identify areas where existing observations do not appear to explain the remotely sensed data.

The availability of a huge collection of data available in digital form through structured directory trees from a centralised computer server system allowed geologists to undertake desk-based on-screen reinterpretation of the geology. Existing geological interpretations can be compared with geophysical imagery and other supporting datasets and revisions made or anomalies identified.

3 Geology

3.1 GEOLOGICAL SUMMARY

The geology of the Nandewar study area is dominated by:

- The New England Fold Belt; comprising thick sequences of Silurian to Carboniferous mostly deep marine sediments (arc-forearc succession and subduction complex), Late Carboniferous-Triassic granitoids and associated felsic volcanics, Permian marine to terrestrial basin sediments and structurally emplaced Cambrian ophiolite sequences;
- Portions of Permo-Triassic basin sediments that include the Sydney-Bowen Basin, the Werrie Basin, and the Warialda Trough;
- Surat Basin sediments that comprise a sequence of Jurassic to Early Cretaceous sedimentary and volcanic rocks;
- Tertiary volcanic successions that have intruded and overlie the New England Fold Belt basement and basin sediments; and
- Quaternary sediments that predominantly form as transported valley fill material in current drainage systems and as adjacent terraces.

The Nandewar study area encompasses a diverse and geologically complex region that includes the New England Fold Belt, overlying Permo-Triassic sedimentary basins and extensive Tertiary volcanic cover. Terms for geological ages can be seen in Figure 3-A.

The New England Fold Belt (also known as the New England Orogen) 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. The New England Fold Belt is dissected by the Peel Fault, separating gently folded and coherent packages of deep marine sediments of the 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 were deposited in a deep marine environment and represent, in part, a subduction zone complex. These sediments sparse microfossils that indicates sedimentation from the Silurian to Carboniferous periods. 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.

The Peel Fault contains a series of serpentinite lenses along its length that represent highly deformed, dismembered portions of Cambrian aged 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 New England Fold Belt.

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).

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.

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 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.

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; quoted in 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 study area.

Era	Period	Epoch	Youngest Age Millions of years	Oldest Age Millions of years	
PHANEROZOIC			0	545	
CAINOZOIC			0	65	
	QUATERNARY		0	1.8	
"Age of mammals"		HOLOCENE	0	0.01	
		PLEISTOCENE	0.01	1.8	Human beings, Australia occupied - 40,000 years, peak of last ice age 20,000 years
	TERTIARY		1.8	65	
		TERTIARY-NEOGENE	1.8	23.8	
		PLIOCENE	1.8	5.3	Appearance of man
		MIOCENE	5.3	23.8	
		TERTIARY-PALEOGENE	23.8	65	
		OLIGOCENE	23.8	33.7	
		EOCENE	33.7	54.8	
		PALEOCENE	54.8	65	
MESOZOIC			65	251	
	CRETACEOUS		65	141	
"Age of Dinosaurs"		LATE CRETACEOUS	65	97.5	Last dinosaurs
		EARLY CRETACEOUS	97.5	141	
	JURASSIC		141	205	
		LATE JURASSIC	141	159	
		MIDDLE JURASSIC	159	184	Oldest birds
		EARLY JURASSIC	184	205	
	TRIASSIC		205	251	
		LATE TRIASSIC	205	230	
		MIDDLE TRIASSIC	230	241	Oldest dinosaurs and mammals
		EARLY TRIASSIC	241	251	
PALAEOZOIC			251	545	
	PERMIAN		251	298	Mammal-like reptiles, last trilobites and graptolites
"Age of Fishes"		LATE PERMIAN	251	270	
		EARLY PERMIAN	270	298	
	CARBONIFEROUS		298	354	
		CARBONIFEROUS-SILESIAN	298	325	First mammal like reptiles
		LATE CARBONIFEROUS	298	325	
		CARBONIFEROUS-DINANTIAN	325	354	Reptiles, fern forests
		EARLY CARBONIFEROUS	325	354	
	DEVONIAN		354	418	
		LATE DEVONIAN	354	369.5	First amphibians, insects
		MIDDLE DEVONIAN	369.5	384	
		EARLY DEVONIAN	384	418	
	SILURIAN		418	441	Jawed fishes
		LATE SILURIAN	418	421	Vascular land plants
		EARLY SILURIAN	421	441	
	ORDOVICIAN		441	490	
		LATE ORDOVICIAN	441	459	
		MIDDLE ORDOVICIAN	459	477	
		EARLY ORDOVICIAN	477	490	Vertebrates, jawless fishes
	CAMBRIAN		490	545	
		LATE CAMBRIAN	490	497	
		MIDDLE CAMBRIAN	497	508	Shell fish, trilobites
		EARLY CAMBRIAN	508	545	
PROTEROZOIC			545	2500	First many-celled creatures
NEOPROTEROZOIC			545	1000	
	NEOPROTEROZOIC		545	650	
	CRYOGENIAN		650	850	
	TONIAN		850	1000	
MESOPROTEROZOIC			1000	1600	
	STENIAN		1000	1200	
	ECTASIAN		1200	1400	
	CALYMMIAN		1400	1600	
PALEOPROTEROZOIC			1600	2500	
	STATHERIAN		1600	1800	
	OROSIRIAN		1800	2050	
	RHYACIAN		2050	2300	
	SIDERIAN		2300	2500	
ARCHAEAN			2500		Oldest life on Earth - 3.5 billion years
					Age of the Earth 4.5 billion years

Figure 3-A. Geological time-scale reference for age terms used in this report.

The Tamworth Belt comprises faulted and gently folded, mildly metamorphosed Middle Cambrian to Early Permian sedimentary and volcanic rocks. Flood and Aitchison (1988) redefined the Tamworth Belt as the Gamilaroi terrane and interpreted the assemblages therein to represent an 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 an approximately 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 and Sydney-Bowen Basins to the north and west. The Tamworth Belt is subdivided into five groups according to age, composition and distribution. These groups are:

- Middle Cambrian to Ordovician "unnamed early Palaeozoic succession";
- Early to Middle Devonian Tamworth Group;
- Late Devonian to Early Carboniferous Parry Group;
- late Early to Late Carboniferous "Carboniferous overlap assemblage";
- Permian sequence near Peel Fault.

The Tamworth Belt dominates the western half of the study area from Croppa Creek in the north to south of Murrurundi.

The New England Batholith covers an area of approximately 16 000 square kilometres, incorporating all the granitoids 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 granitoids 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-Early Permian S-type (Bundarra and Hillgrove) and three Late Permian-Early Triassic I-type supersuites (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.

Periods of extension and compression between the Early Permian and Middle Triassic 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 Permo-Triassic basins occur within the study area, the Sydney-Bowen Basin, Werrie Basin, and the Warialda Trough.

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–Early Cretaceous continental basin and contain early fluvial sediments and terrestrial volcanics 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 study area, members of the Surat Basin outcrop in a thin (less than ten kilometres) strip from the Nandewar Ranges to west of Texas.

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.

3.2 CENTRAL BLOCK

CENTRAL BLOCK

The Central Block is a fault bounded structural block comprising a series of terranes. Terranes are remnants of rock sequences, which have formed at different times and/or geological environments but are now juxtaposed. For these notes, the Central Block is taken to include the following terranes and rock packages:

- Weraerai terrane, comprising highly dismembered ophiolitic sequences (Woodsreef Melange) with overlying volcaniclastic sediments (Dinoga Formation);
- Djungati terrane, comprising deep marine sediments of the Woolomin Group and Wisemans Arm Formation;
- Anaiwan terrane; a thick, locally highly deformed succession of deep to shallow marine sediments that include the Cara and Whitlow Formations to the south and west and the Texas and Sandon beds to the north and east that together define the subduction complex sediments;
- Early Permian marine sediments of the Manning Group, Bondonga beds, and undifferentiated successions in the northeast of the study area;
- Early Permian terrestrial sequences of the Ashford Coal Measures and Glenmore Formation; and
- Late Permian felsic volcanics of the Wandsworth Volcanic Group.

Is unconformably overlain in the Nandewar study area by:

- Permian sediments and volcanics of the Werrie Basin;
- Triassic sediments of the Warialda Trough;
- Jurassic sediments of the Surat Basin; and
- Tertiary sediments and volcanic rocks.

Is intruded by Permo-Triassic members of the New England Batholith

3.2.1 Introduction

The Central Block is a structural block and comprises a series of terranes defined by Flood and Aitchison (1988). For the perposes of the notes, sequences which overlie the terrane as separate basins or as volcanic piles are included under this heading. These terranes amalgamated and accreted to form a significant portion of the southern New England Fold Belt during the late Palaeozoic-early Mesozoic. The terranes represent disrupted ophiolite sequences (ocean floor mafic and ultramafic rocks that form in the early stages of orogenesis-Weraerai terrane) and subduction complex sequences deposited in deep marine settings (Djungati and Anaiwan terranes). Aitchison *et al*. (1992) have used radiolarian fossils to date the siliceous subduction zone sediments as Middle Silurian to Late Devonian (Djungati) and Late Devonian to Early Carboniferous (Anaiwan), establishing temporal differences to the nearby Gamilaroi terrane (part of Tamworth Belt). The extent of the Central Block in the Nandewar study area can be observed in Figure 3-B.

The Weraerai terrane is represented by a narrow, discontinuous package of highly dismembered ophiolitic and overlying volcaniclastic rocks. This terrane is sandwiched between arc and arc-basin (forearc) rocks of the Gamilaroi terrane to the west, and a subduction related succession of deep marine sediments to the east (Djungati and Anaiwan terranes). The Weraerai terrane

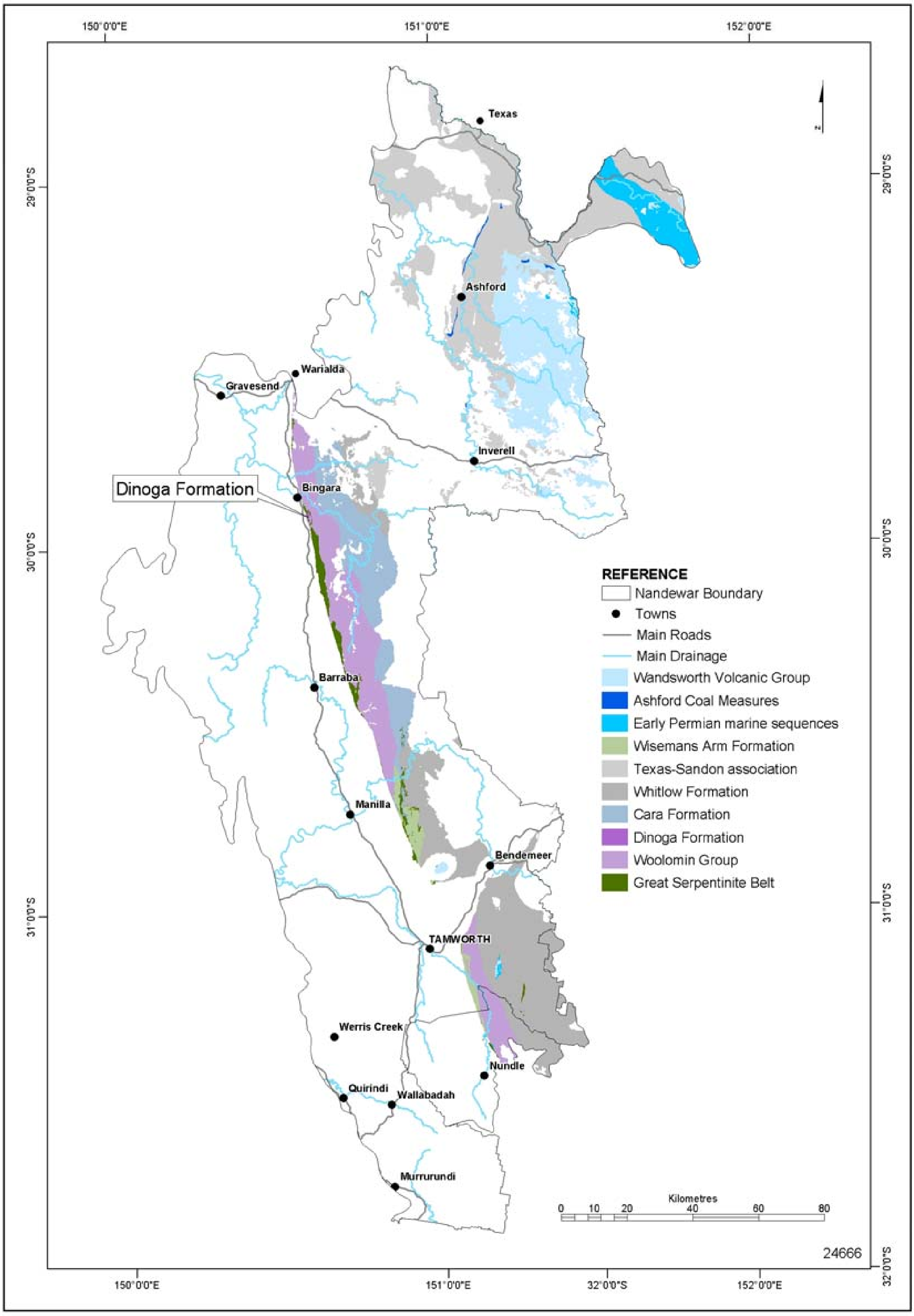


Figure 3-B. Surface distribution of the Central Block in the Nandewar study area.

comprises the ophiolitic Woodsreef Melange (Great Serpentinite Belt) and the overlying volcaniclastic sediments of the Dinoga Formation, as defined by Flood and Aitchison (1988).

The Djungati terrane comprises the Woolomin and Wisemans Arm Formations that are variably fossiliferous, deep marine sediments. Radiolarian data indicate that Middle Silurian to Late Devonian age sedimentation took place in an environment influenced by volcanic island arc activity with little terrigenous input (Aitchison *et al.,* 1992). Further to this, Aitchison *et al.* (1992) postulated that significant differences between the Djungati Terrane sedimentation and 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 this terrane occurred during the latest Devonian to Early Carboniferous and coincided with arc volcanism and related tectonic activity (Aitchison *et al*., 1992).

The Anaiwan terrane, a disrupted terrane, includes the Cara and Whitlow Formations and the Texas and Sandon beds. It contains thrust-repeated slices of basalt, chert, tuffaceous siltstones, sandstones and minor conglomerates (Flood and Aitchison, 1988). Radiolarian microfossils reveal a Late Devonian to Early Carboniferous age of deposition. The Anaiwan terrane is interpreted as a subduction complex (Aitchison *et al*., 1992), with a lithostratigraphic succession that comprises basal basalts overlain by ribbon bedded chert and volcaniclastic sediments. 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. They also contend that the oceanic crust is not significantly older than autochthonous rocks (that is ones that are at the site of their formation) within the Anaiwan terrane.

3.2.2 Woodsreef Melange

The Woodsreef Melange was formally defined by Aitchison *et al*. (1988) to supersede the Great Serpentinite Belt terminology of Benson (1913). The Woodsreef Melange represents a dismembered ophiolite assemblage that is now dominated by serpentinised ultramafic rocks, predominantly harzburgite, with minor subordinate variably metamorphosed igneous intrusive rocks (Brown *et al.,* 1992). The ophiolite assemblage includes blocks of gabbro, dolerite, plagiogranite, basalt and minor sedimentary rocks (Flood and Aitchison 1988). The assemblage is variably metamorphosed, from essentially pristine to blueschist/eclogite facies, typical of high-pressure subduction-related regimes.

The Woodsreef Melange outcrops as a series of attenuated, discontinuous bodies outcropping proximal to, and to the east of, the Peel Fault along a strike length of over 300 kilometres, from Warialda in the north to Taree to the southeast (Photograph 3-A) (Aitchison and Ireland, 1995). Contact relationships are structurally controlled with all serpentinite margins being fault surfaces. The western margin is the Peel Fault and the eastern margin is controlled by north-northeast oriented structures. The Woodsreef Melange structurally overlies the Woolomin Group to the east and is overlain by the Dinoga Formation.

The age of the Woodsreef Melange is poorly constrained, however zircon U-Pb dating of plagiogranites by Aitchison and Ireland (1995), despite a complicated history of inheritance and disruption, reveal an age of approximately 530 Ma (Middle Cambrian). This is in agreement with biostratigraphic ages determined by Compston *et al*. (1992; quoted in Aitchison and Ireland, 1995) of 520-530 Ma. Timing of emplacement of the Weraerai terrane into its current (structural) location has proven difficult to quantify. Aitchison and Ireland (1995) indicate that some rocks of the Weraerai terrane have been affected thermally by the intrusion of the Bundarra Supersuite, dated as Early Permian (279-286 Ma) by Shaw and Flood, (1981, 1982).

Photograph 3-A. Woodsreef Melange with Tertiary gravels lying unconformably above, near Woodsreef mine. GR 282700 6635120.

The radiometric and magnetic signatures of the Woodsreef Melange are easily recognisable. Low counts for K, Th and U produce a very dark, uniform response, contrasting with that of most surrounding rocks, although metabasalts and chert commonly produce a similar radiometric response. The now altered and metamorphosed ophiolite has distinctive high magnetic values. Magnetite is a by-product of serpentinisation (hydration) of ultramafic rocks and its abundance in the altered ophiolite is significantly increased during this process. In contrast to this, ophiolitic rocks that have not been altered produce a much more subdued response, leading to an overall high, though heterogeneous response from the Woodsreef Melange (Figure 3-C). Many altered gabbros have very low magnetic response and don't contrast with surrounding rocks. Recent geophysical surveys over the Peel Fault clearly delineate the extent of the Woodsreef Melange and indicate depth extent to these attenuated bodies proximal and distal to recognisable outcrop (Brown, 2001).

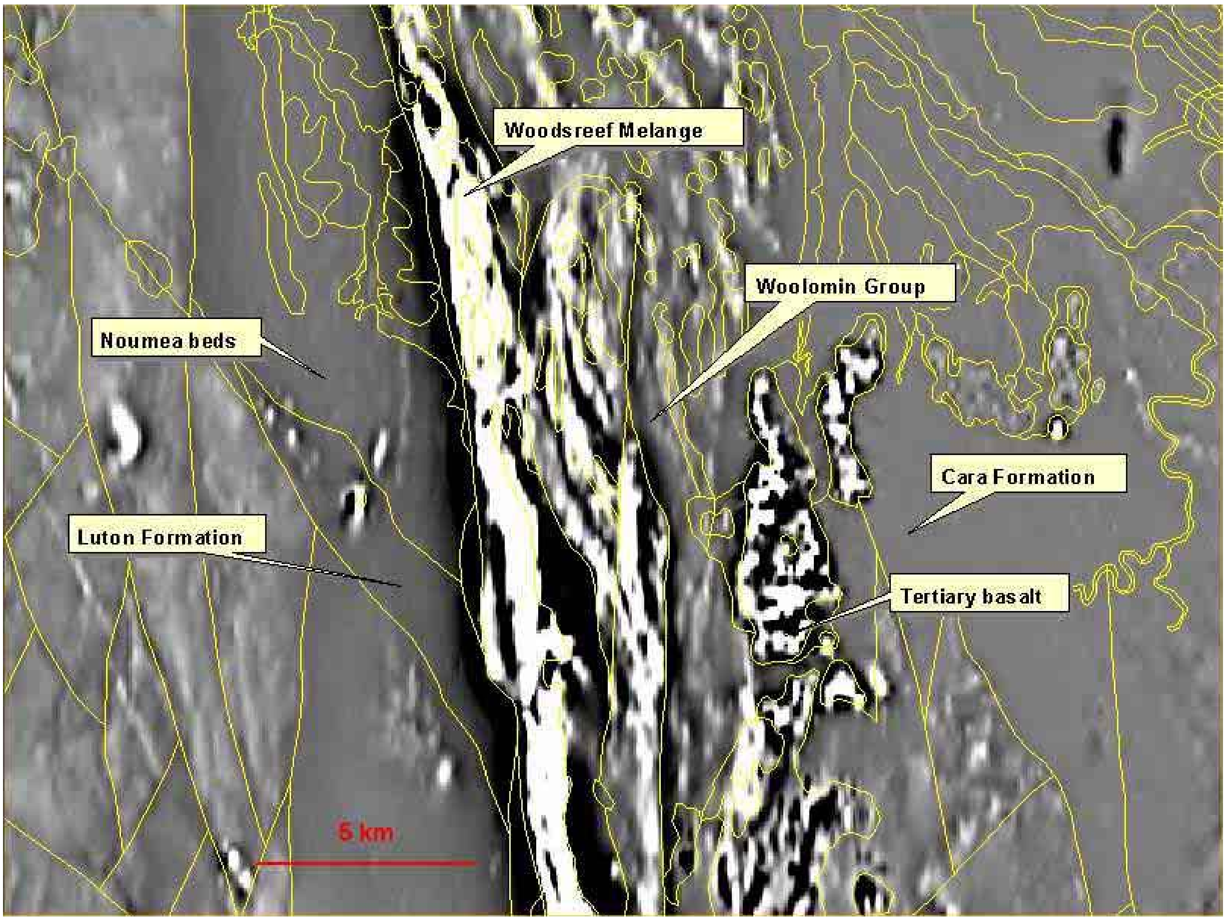


Figure 3-C. First vertical derivative of the reduced to the pole magnetic image highlighting contrasts between different geological units. Note extremely high magnetic response due to the Woodsreef Melange.

3.2.3 Woolomin Group

Introduction

The Woolomin Group was formally defined by Aitchison *et al.* (1988) and includes the Bobs Creek and Nangahrah Formations where recognised, but is commonly mapped as an undifferentiated sequence of deep marine sediments. The Woolomin Group forms part of the Djungati terrane with the Wisemans Arm Formation, as defined by Flood and Aitchison (1988). Aitchison *et al.* (1992) have constrained the age of sedimentation in the Djungati terrane using radiolarian chert from the Woolomin Group between Middle Silurian and Late Devonian. They postulated that the Djungati terrane formed part of an oceanic basin that was removed from terrigenous influence. Volcanic island arc activity subsequently influenced sedimentation, which was tectonically disrupted by the latest Devonian to Early Carboniferous.

Aitchison *et al.* (1992) postulated that sedimentation typical of the Woolomin Group represents that of a deep marine setting rather than that of subduction complexes. Within the Nandewar study area, the Woolomin Group outcrops immediately east of the Peel Fault and Weraerai terrane, from just south of Warialda to Nundle. The Bobs Creek and Nangahrah Formations are recognised for most of the extent of the Woolomin Group in the Nandewar study area except the southerly portion from east of Tamworth to Nundle where it is undifferentiated.

Nangahrah Formation

The Nangahrah Formation is situated between the Woodsreef Melange and Bobs Creek Formation where it forms a narrow, elongated belt of sediments approximately parallel to the Peel Fault. Stroud (1990) reported that in the southernmost portion of the Inverell 1:250 000 map sheet the Nangahrah Formation is situated between the Peel Fault and the Woodsreef Melange. The Nangahrah Formation is a highly deformed package, metamorphosed to pumpellyite-actinolite facies, that includes basal metabasalt overlain by red banded chert (Photograph 3-B) and argillite that may locally contain olistostromes (chaotic blocks of heterogeneous material incorporated into the sedimentary pile during possible deep marine slumping). In general, contact with the Bobs Creek Formation is thrusted, although Stroud (1990) noted that in some areas the contact may be gradational. Radiolarian biostratigraphy reveals an age of formation from Middle Devonian to Early Carboniferous, though preservation of radiolaria is, at best, sporadic.

Photograph 3-B. Red ribbon banded cherts of the Woolomin Group, near Bingara. GR 266040 6697110.

The Nangahrah and Bobs Creek Formations are difficult to distinguish by radiometric imagery, both producing a low response in the K, Th and U channels, although the K channel is slightly higher than Th & U, reflecting the similar provenance of these sediments. Increased proportions of metabasalt within the Nangahrah Formation however, are manifest as a higher, but heterogeneous magnetic response that clearly distinguishes the Nangahrah from the Bobs Creek Formation (Figure 3-D).

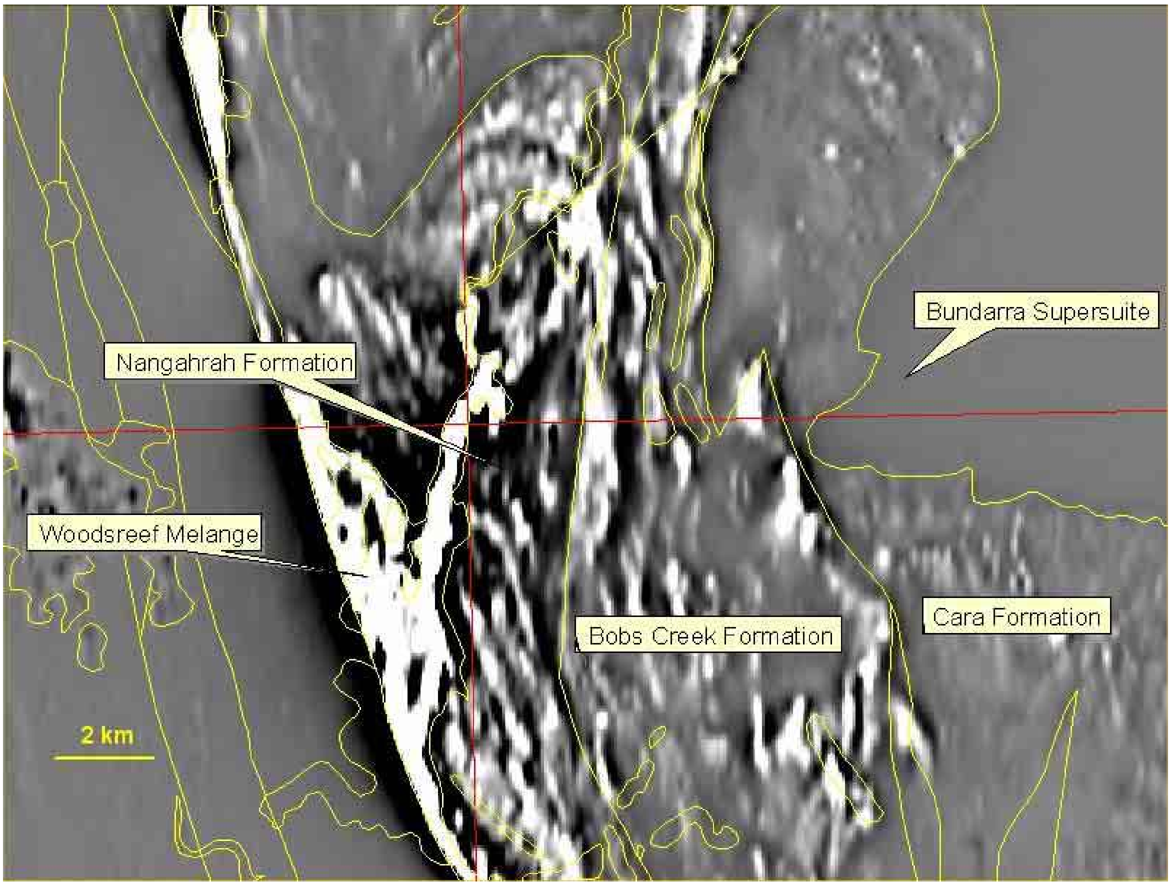


Figure 3-D. Contrasting magnetic properties of the Nangahrah and Bobs Creek Formations.

Bobs Creek Formation

The Bobs Creek Formation outcrops as a thin package of rocks of similar affinity to the Nangahrah Formation, between that unit and the Cara Formation to the east. The Bobs Creek Formation contains less basalt than the Nangahrah Formation in the type area (Stroud 1990), but this is not the case globally. The Bobs Creek Formation is less deformed than the Nangahrah Formation and is metamorphosed to only prehnite-pumpellyite facies (Aitchison *et al.,* 1992). The sequence is similar to the Nangahrah Formation and metabasalts, where present, are overlain by ribbon bedded and radiolarian chert, which in turn are overlain by a distinctive sequence of argillites and cherts (Photograph 3-C). Radiolarian data indicate a possible age range from Middle Devonian to Early Carboniferous (Blake and Murchey 1988a; quoted in Stroud 1990).

3.2.4 Dinoga Formation

The Dinoga Formation was formally defined by Aitchison *et al.* (1988) and is included in the Weraerai terrane. It comprises fault-bounded, discontinuous lenses of volcaniclastic sandstones, argillites and conglomerates. Blocks of coralline limestone with uncertain affinity are biostratigraphically dated as Early Devonian (Pickett, 1986a, b; quoted in Aitchison and Flood, 1988). The Dinoga Formation outcrops in a restricted area from Bingara to east of Barraba (Stroud, 1990). Radiometric and magnetic responses do not clearly discriminate the Dinoga Formation from nearby Woolomin Group sediments.

Photograph 3-C. Fine-grained argillites within the Bobs Creek Formation. GR 263180 6724930.

3.2.5 Wisemans Arm Formation

The Wisemans Arm Formation outcrops on the Manilla and Nundle 1:100 000 map sheets as a disrupted siltstone-dominated deep marine assemblage that locally comprises chert-dominated sequences. The Wisemans Arm Formation is thrust against the Nangahrah Formation as repeated slices and against the Cara Formation to the east. Leitch and Cawood (1980) recognised the Wisemans Arm Formation as a fault-bounded strip of previously undescribed siltstone, tuff, sandstone and conglomerate that contain olistoliths of bedded chert, between the Woolomin Group and the Peel Fault. All of the rocks of the Wisemans Arm Formation are metamorphosed to prehnite-pumpellyite facies and generally dip steeply to the west. East of the Moss Vale Fault, radiolarian age data constrain the age of the Wisemans Arm Formation between latest Devonian to Early Carboniferous (Aitchison *et al.,* 1992), though radiolaria are poorly preserved in these sediments.

Siltstone beds dominate the stratigraphy within the Wisemans Arm Formation, as either finely laminated horizons or massive beds up to several metres in thickness. Subordinate sandstone beds range in thickness between ten millimetres to over three metres, the thicker of these commonly pebbly. Granule to boulder conglomerates are poorly sorted and contain both rounded and angular fragments set in a silty sandstone matrix. Most of the conglomerates are clast-supported (Leitch and Cawood, 1980) and clasts are dominated by compositionally diverse volcanic-derived material, including basaltic, andesitic fragments with plagioclase grains, embayed volcanic quartz and detrital clinopyroxene. Other clasts include chert and intraformational, angular and typically squashed (partially lithified) siltstone.

Olistoliths are exotic blocks of rock that have been transported by submarine slumping. In the Wisemans Arm Formation they comprise chert and subaerial intermediate volcanic blocks up to tens of metres in diameter. Conglomeratic material is also common and contains clasts up to 1.5 metres in diameter dominated by chert with subordinate boulders of limestone, siltstone and volcanic rock that are embedded in cobble conglomerate to siltstone (Leitch and Cawood, 1980). The matrix is detrital with approximately equal proportions of mineral and lithic (rock) grains set in a groundmass of partly primary and secondary origin, the result of breakdown of unstable grains during incipient metamorphism. Leitch and Cawood (1980) interpret the chaotic nature of these rocks as being the result of debris flow rather than of tectonism, as evidenced by the lack of shearing of the matrix rocks. Olistoliths are derived from both the Tamworth Belt (magmatic arc-forearc) and Central Block (deformed oceanic crust) at the start of, or during, subduction (Leitch and Cawood, 1980).

Only the northern extent of Wisemans Arm Formation on the Manilla 1:100 000 map sheet is covered by geophysical imagery. The radiometric response indicates a low total count with K greater than Th and U, though localised Th-richer areas occur, possibly due to regolith/weathering effects. The distinction between Wisemans Arm Formation and adjacent Woolomin Group and Cara Formation is not easily recognised using radiometric imagery due to lack of contrast. Localised lenses of Woodsreef Melange however, are easily recognised due to its very low total count response.

The magnetic signature of the Wisemans Arm Formation is dominated by strong magnetic overprinting by serpentinites and it is therefore difficult to determine boundary changes with certainty (Brown, 2003).

3.2.6 Cara Formation

The Cara Formation is the basal formation of the Anaiwan terrane of Flood and Aitchison (1988) and was formally defined by Aitchison *et al*. (1988), forming part of the subduction complex. The Cara Formation occurs immediately to the east of, and is in fault contact with, the Woolomin Group and Wisemans Arm Formation. An unconformable relationship with the overlying Whitlow Formation to the east is interpreted by Aitchison *et al*. (1988). The Cara Formation is dominated by fine-grained, siliceous, commonly tuffaceous argillites with subordinate metabasalt, chert, volcaniclastic sandstone and pebble conglomerate. Argillites are thinly bedded to massive and locally represent mass flow deposits (R. Brown, DMR Armidale, *pers. comm*.). Argillites commonly contain radiolaria, which constrain the age of the Cara Formation to Late Devonian-Early Carboniferous (Blake and Murchey, 1988a, 1988b; quoted in Stroud, 1990). Cara Formation sediments are locally intensely faulted and Aitchison (1988; quoted in Stroud, 1990), notes that an axial plane cleavage is well developed and is indicative of mesoscopic folding in some areas (Photograph 3-D). The interpreted depositional environment is a deep marine setting with mainly pelagic and hemipelagic sediments accumulating on a basaltic basement. Occasional input of terrigenous material is inferred from the presence of wacke and conglomerate turbidite beds (Stroud, 1990).

Photograph 3-D. Mesoscopic folding of fine-grained argillaceous sediments within the Cara Formation. GR 275740 6708020.

The Cara Formation is easily distinguishable from surrounding rock packages using radiometric imagery (Figure 3-E). A heterogenous, low to moderate radiometric response is produced by the Cara Formation. Heterogeneities reflect contrasting lithological compositions of individual units, ranging from low K greater than Th and U (metabasalt) to moderate K, U and Th values (felsic tuffaceous material). Radiometric imagery therefore enables significant lithological variation within the Cara Formation to be easily mapped for the first time. The magnetic response generated by the Cara Formation is significantly more subdued than the nearby Woolomin Group, enabling clear distinction between these formations. A distinct magnetic halo produced by the intrusion of the Bundarra Supersuite into the Cara Formation has extended for up to four kilometres into the Cara Formation (Brown, 2001).

3.2.7 Whitlow Formation

The Whitlow Formation was formally defined by Aitchison *et al*. (1988) and unconformably overlies the Cara Formation to the east. The formation comprises low grade, regionally metamorphosed, multiply deformed, thickly bedded, coarse-grained and minor fine-grained felspathic volcaniclastic arenites and wackes with subordinate siltstone and conglomerate (Brown *et al.,* 1992). Rare olistostromal beds are also recognised, as is oolitic detritus within volcaniclastic arenites. Contact metamorphism of the Whitlow Formation has occurred proximal to the Dumboy-Gragin Granite and the Bundarra Supersuite. Poor exposure and thrust repetition has prevented the determination of unit thickness of the formation.

Stroud (1990) interpreted its depositional environment as deep marine grading to shelf environment. There is a mixture of terrigenous sediments, together with mainly pelagic and hemipelagic sediments and a significant terrigenous input is interpreted from the extensive development of arenite grading into wacke (turbidites) (Stroud, 1990). Radiolarian data provide an age of Early Carboniferous for the Whitlow Formation (Aitchison *et al.,* 1992).

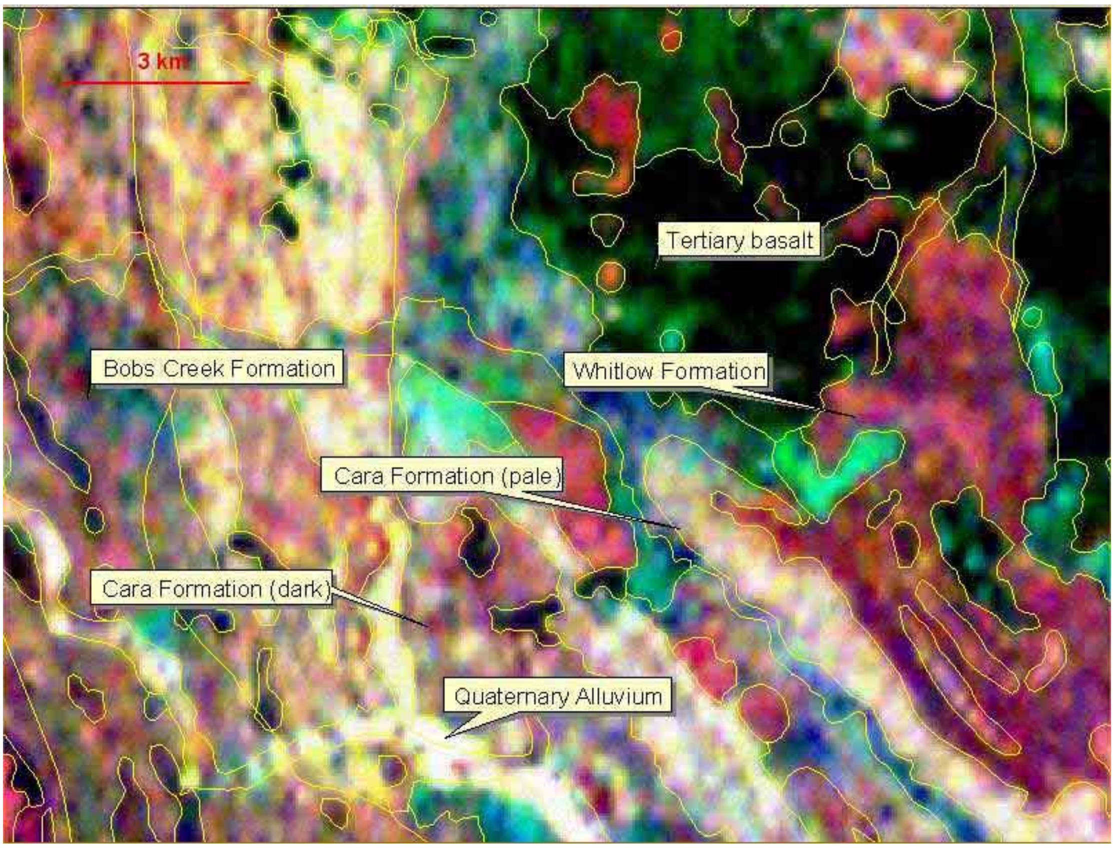


Figure 3-E. Contrasting radiometric signatures of the Bobs Creek, Cara and Whitlow Formations. Note the very high radiometric response of the Quaternary alluvium indicating granitic provenance.

The radiometric signature of the Whitlow Formation is distinctive in its northerly extent on the Bingara 1:100 000 map sheet, producing a low response, with K greater than Th and U. Tertiary basalt cover producing a low response and a response due to Th-rich regolith/Quaternary material obscures the Whitlow Formation partially in this area (Figure 3-E). The Whitlow Formation in its southerly extent, where it is in contact with Bundarra and Moonbi Supersuite granitoids, produces a higher response in all of the radiometric channels with higher Th and lesser K and U. The magnetic response is predominantly low, except in areas proximal to the Bundarra Supersuite where thermal alteration has occurred. This effect is obscured in areas proximal to the Moonbi Supersuite granitoids.

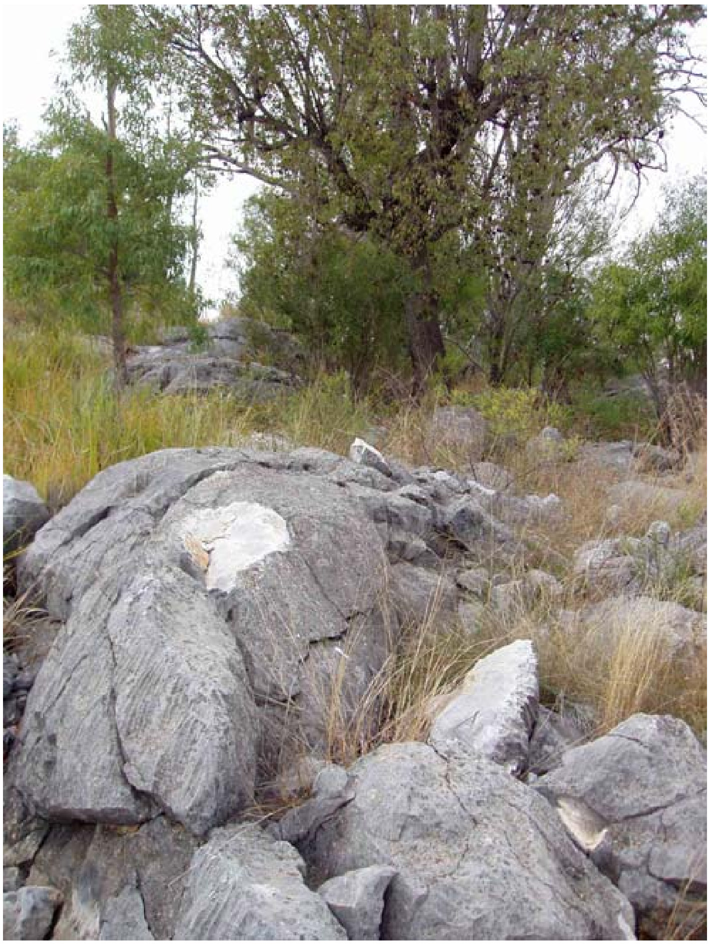
3.2.8 Texas beds and Sandon beds

The Sandon beds outcrop as a series of small inliers on the Inverell and Bingara 1:100 000 map sheets and in a small area on the edge of the study area on the Bendemeer 1:100 000 map sheet. The Texas beds outcrop over large areas of the northern portion of the Nandewar study area, particularly on the Ashford, Yallaroi and Inverell 1:100 000 map sheets. For the purposes of this report, the Texas and Sandon beds will be treated together due to their age and lithological similarities. Stroud (1989) concluded that a gradual facies change marks the boundary between these units. Turbidites dominate the Texas beds but are only locally abundant within the Sandon beds, particularly on the Manilla 1:100 000 map sheet (R. Brown, DMR Armidale, *pers. comm*.). The Texas and Sandon beds form the uppermost portions of the subduction complex and are the highest stratigraphic units of the Anaiwan terrane (Stroud, 1989). The lithological package comprises lithic wacke, conglomerate, siltstone, mudstone with subordinate chert, jasper and spillite (sea floor altered basalt).

The Texas and Sandon beds are thick sequences (up to several kilometres) of deep marine sediments metamorphosed to prehnite-pumpellyite facies and variably deformed with intensity increasing from the southwest to northeast (Stroud, 1989). The units are typically thinly bedded, with layers ranging from ten to 100 centimetres in the Texas Beds (Photograph 3-E). The thickest layers are generally coarse wacke or conglomerate horizons (Stroud, 1989). Portions of the Texas and Sandon beds have been contact metamorphosed by intruding granitoids of the New England Batholith. In the northernmost portions of the Nandewar study area thermal alteration associated with emplacement of the Mole Granite has affected the Texas beds for up to two kilometres around the intrusion.

Photograph 3-E. Folded interbeds of mudstone and chert within the Texas beds. GR 322110 6733330.

A narrow, north-south striking limestone unit, the Ashford Limestone, is recognised within the Texas beds approximately 15 kilometres northwest of Ashford. This unit is continuous along its strike length for approximately 13 kilometres with a prominent inflection mid-way along its length. The Ashford Limestone (Photograph 3-F) has been contact metamorphosed by intrusion of the Bundarra Supersuite, producing a skarn assemblage that includes magnetite, garnet, epidote, wollastonite and diopside.



Photograph 3-F. Outcrop of the Ashford Limestone. GR 304610 6764660.

The Texas and Sandon beds produce very similar magnetic and radiometric responses and are easily recognisable, contrasting significantly with nearby granitoids and volcanics (Figure 3-F). The radiometric response is predominantly uniform, highlighting only rarely the bedding within these units. The moderate total count response of the Texas and Sandon beds contrast with the much higher response of the granitoids and felsic volcanics and the much lower Tertiary volcanic response. Brown (in press) noted that significant improvements to mapping can be made using radiometrics, particularly with respect to the Sandon beds. Magnetic imagery has identified magnetite-bearing horizons within the Texas beds that suggest broad scale folding in the Inverell 1:100 000 map sheet area. The magnetic response of the Texas and Sandon beds is significantly different to the more potassic Bundarra Supersuite granitoids and the highly magnetic, heterogeneous Emmaville Volcanics and Tertiary volcanics. Brown (in press) concluded that internal subdivision within the Texas beds is not appropriate, confirmed by geophysical imagery.

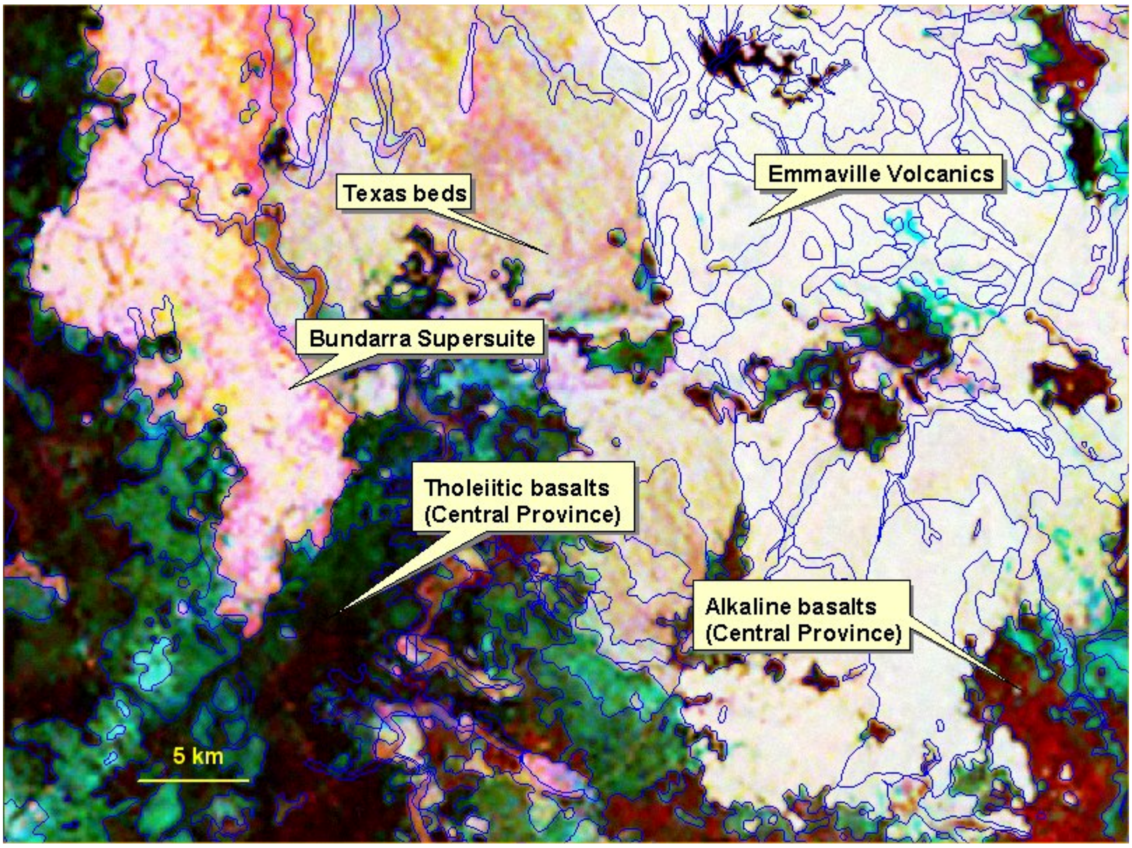


Figure 3-F. Radiometric image highlighting the contrast in response of the Texas beds to nearby volcanics and granitoids.

3.2.9 Early Permian marine sequence

Manning Group

The Manning Group is a deformed Early Permian extensional marine sedimentary basin sequence outcropping in the southern New England Fold Belt (Jenkins and Offler, 1996). A small fault bounded portion of the Manning Group crops out in the south east of the Nandewar study area and is represented by the Echo Hills Formation, which comprises coarse conglomerates and interbedded shales. The age of the Manning Group is constrained by fossil evidence (Jenkins and Offler, 1996). In the Nandewar study area only regional magnetic geophysical imagery exists over the Manning Group.

Bondonga beds

The Bondonga beds are Early Permian marine sediments comprising massive orthoconglomerate, paraconglomerate, lithic sandstone and minor siltstone (Henley *et al.,* 2001). Bedding is poorly developed and suggests, where present, that probable folding and local overturning of the sequence is apparent. Elongate lenses of conglomerate, sandstone and siltstone indicate regional folding and imbrication (Barnes and Willis 1989). Contact relationships are poorly preserved and the Bondonga beds are interpreted to be in fault contact with or to overlie the Texas beds unconformably. An Early Permian age is assigned to the

Bondonga beds on the basis of lithology (conglomerates and felsic volcanic rocks) and fossil data (Barnes and Willis 1989).

In the Nandewar study area the Bondonga beds outcrop in the extreme northeast, forming a northwest oriented belt of sediments possibly in-folded into the Carboniferous Texas beds (Barnes and Willis 1989). This portion of the study area is not covered by recent geophysical imagery.

Undifferentiated Early Permian marine sediments

Laterally restricted occurrences of Early Permian marine sediments outcrop in the northern portion of the Nandewar study area along the eastern boundary. These sediments are unnamed and comprise a mixed lithology that includes para- and orthoconglomerates and lithic sandstone (Brown and Stroud, 1997). The sequence is possibly up to 700 metres thick, including 200 metres of conglomeratic sediments. The depositional environment is tentatively interpreted as an oceanic embayment (Brown and Stroud, 1997).

The unnamed Early Permian sediments produce a moderately high radiometric response with K greater than Th and U, contrasting with the higher Emmaville Volcanics, Mole Granite and the much lower Tertiary volcanics. The magnetic signature is generally low but variable, contrasting with the Mole Granite and Tertiary volcanics, though some similarities with the Emmaville Volcanics exist (Brown, in press). Geophysical data indicates relative accuracy of previous geological mapping.

3.2.10 Early Permian terrestrial sequence

Ashford Coal Measures

Introduction

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 (Figure 3-G). 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, and in places do, persist under a cover of soil and alluvium in the north to the Queensland border towards Texas, and under alluvium and basalt in the south to Arrawatta, some 16 kilometres north of Inverell (Figure. 3-G).

The distribution of the measures along this strip suggests that the present 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).

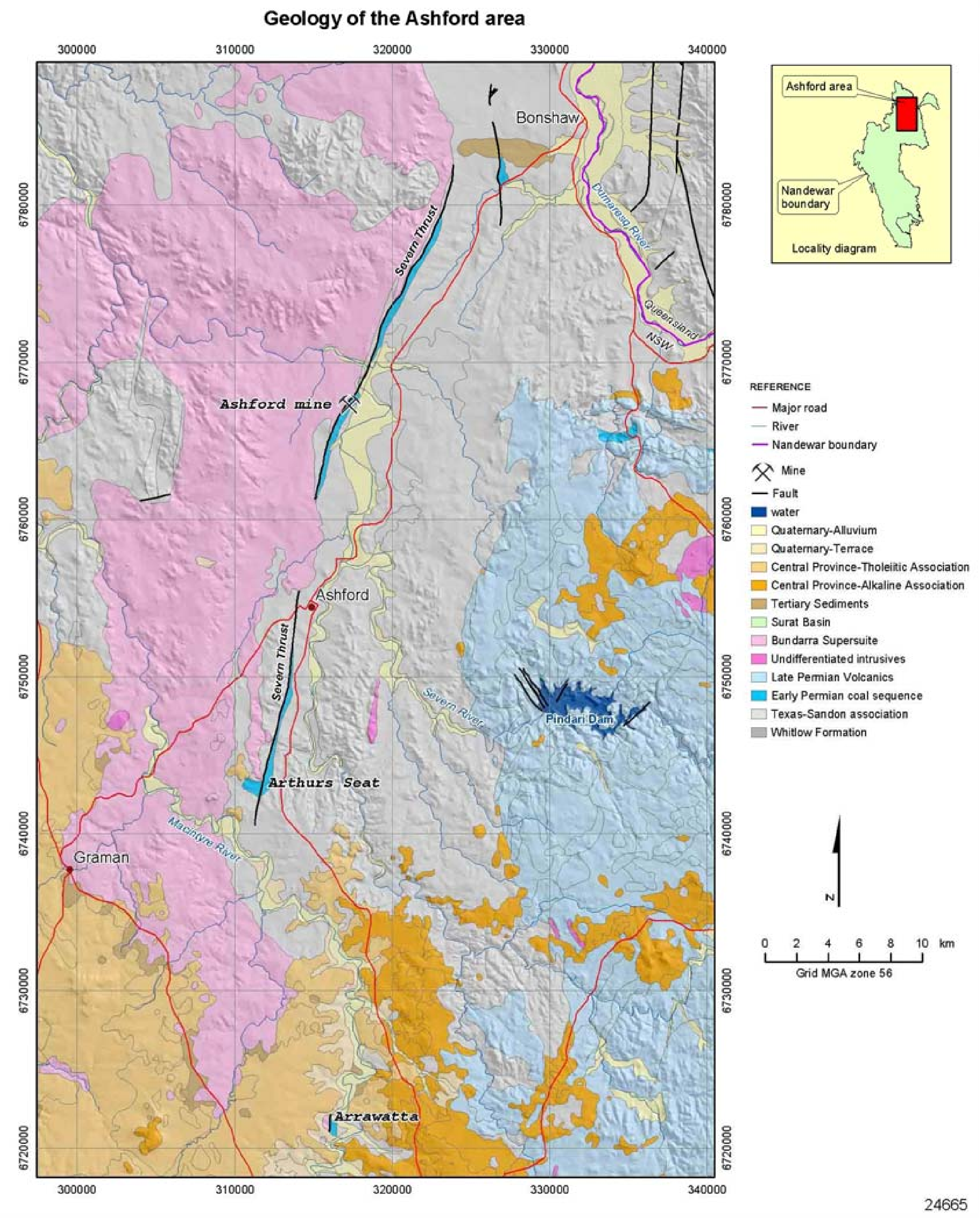


Figure 3-G. Geological map showing the location of the Ashford Coal Measures.

Stratigraphy

The Ashford Coal Measures are subdivided into three members. In ascending order, these are the Ashford Member (containing the Ashford seam), the Bonshaw Member (containing the Bonshaw seam and its splits) and the Bukkulla Member (Figure 3-H).

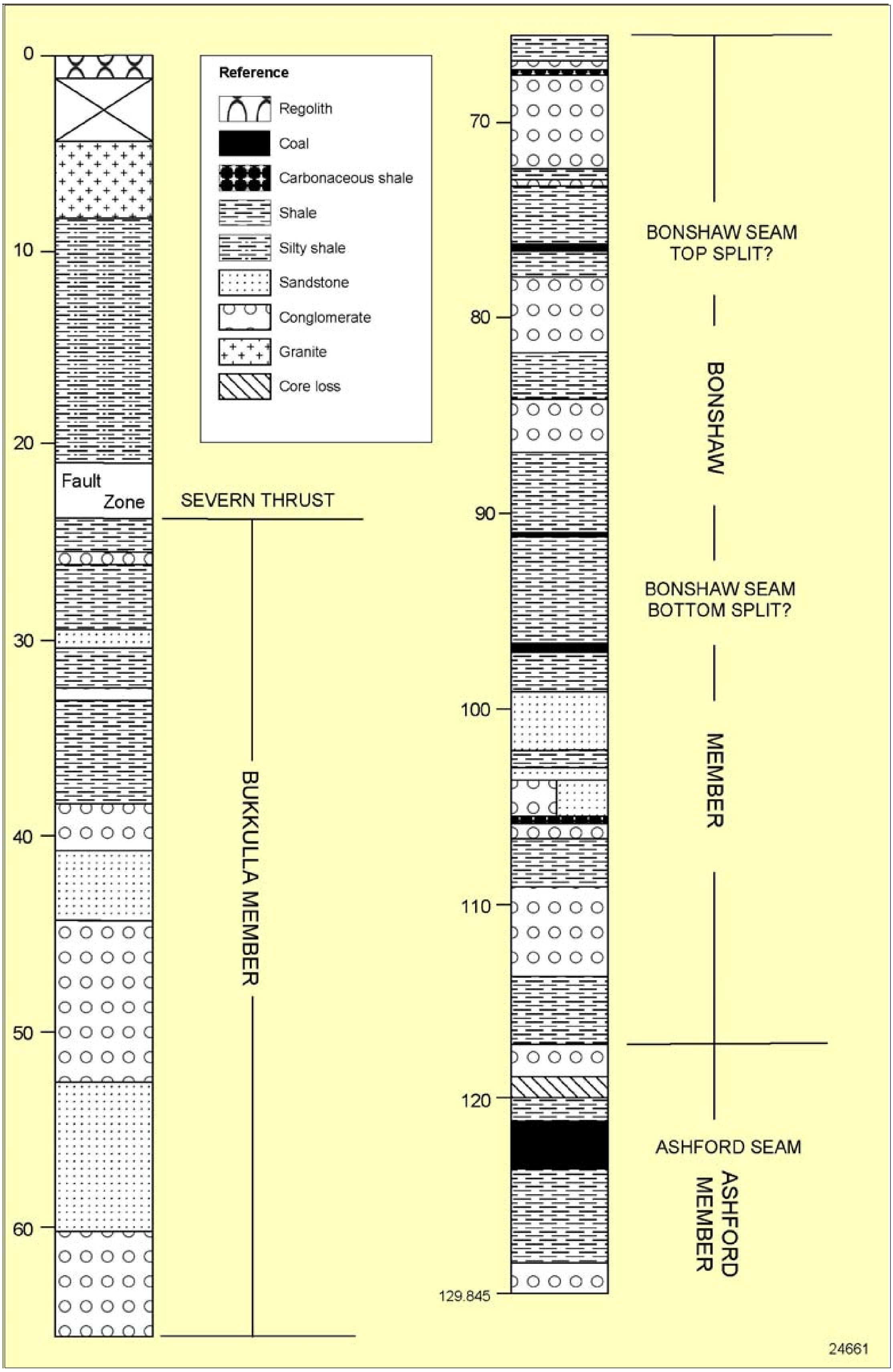


Figure 3-H. Stratigraphy of the Ashford Coal Measures, from drill hole BMR DDH 6.

The Ashford Coal Measures have an unconformable eastern (and basal) contact to the underlying Carboniferous Texas beds. The Severn Thrust marks the upper (and western) contact separating the coal measures from the Texas beds or the Permian Bundarra Supersuite in some areas. Erosional contacts are reported to exist between the Ashford Member and the overlying Bonshaw Member and at the base of the Bukkulla Member (Kimber, 1977). The coal measures have been correlated with the Early Permian Greta Coal Measures of the Sydney Basin on the basis of the presence of *Glossopteris-Gangamopteris* flora and the close similarities in lithological sequence and thickness.

The coal measures within the old colliery lease are up to 170 metres thick and dip to the west at 20 to 35 degrees. These contain two seams: the Bonshaw seam and the Ashford seam. The Bonshaw Member is a 50 metres thick sequence dominated by coarse-sandstone, conglomerate and interbedded layers of fine sediments, including carbonaceous shale with rare, thin coal plies, the most prominent of which is the Bonshaw seam. This seam ranges from 0.15 metres to 1.2 metres in thickness and has no economic potential where drilled. The Bonshaw seam consists of carbonaceous claystone and thin coal layers and therefore has little or no economic significance.

The Bonshaw Member is underlain by the Ashford Member, which contains the economically important Ashford seam, which lies from five to 76 metres above the Carboniferous basement. This seam consists of bituminous, medium volatile, high rank coking coal and ranges in thickness from 2.5 metres to approximately 17 metres, with extreme local variability. This is largely due to small-scale step faulting in sympathy with the Severn Thrust. Depositional and structural controls have contributed to the great variation in seam thickness. Conglomerates derived from Early Carboniferous basement rocks are irregularly present throughout the coal measure sequence and occasionally erosively above the Ashford seam. Numerous minor normal and reverse cross faults have also contributed to anomalous thicknesses. The seam thins to the south of the colliery but is shallowly underlain by a lower seam, or bottom split, 1.19 metres to 1.37 metres thick.

Structure

The Ashford Coal Measures have dips ranging from 20 to 40 degrees in a northwest direction (300 degrees) in the area of the old Ashford mine. To the south, near Arthurs Seat, dip is approximately 75 degrees.

Intense multiphase structural deformation in the form of folding and faulting is apparent in the open cuts at Ashford Mine (Photograph 3-G). The structural features reflect the resultant stresses imposed upon the Ashford deposit during syn-depositional and post-depositional phases. These features suggest that the coal has responded during periods of maximum stress by behaving in a fluid-like manner (Kimber, 1977; Brown and James, 1987). This is evident in the almost “mylonitic” texture of the coal as observed in numerous locations at the No.10 cut. The intensity of the structural deformation has reduced the fabric of the coal deposit to a highly friable, non-cohesive material that has a greatly increased fines content (Brown and James, 1987).

Photograph 3-G. Thrust fault at the Ashford Colliery.

Tectonics

The rocks of the Ashford area have been subjected to two major tectonic events. The first was the Kanimblan Orogeny which resulted in folding of the Lower Carboniferous sediments, probably soon after deposition. The granites were probably intruded during the closing stages of this orogeny (Browne, 1949). The second was the Hunter-Bowen Orogeny of Late Permian time, resulting in folding of the Early Permian sediments and the development of the Severn Thrust and its subsidiary faults.

The Severn Thrust is a major structural feature, some 32 kilometres long. The dip of the fault can be seen in Cut No. 9 of the old colliery area, where the granite is overthrusting the coal measures. Mapping by White Industries Limited (1979) has confirmed that the fault is a system of *en echelon* faults with downward stepping to the east. Early models suggested dips of 45 to 60 degrees or 70 degrees for the fault. This interpretation severely limited the resources of the Ashford Coal Measures as a steeply dipping fault would have cut off the shallow dipping coal seam around 100 metres below the surface [Figure 3-I (A)]. 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.

Bekker (1977) concluded that because it is a thrust, the Severn Thrust is likely to have a moderately low angle dip. During the 1987 drilling program (White Industries Limited, 1987), several boreholes went through overthrusting rocks into the coal measures. DDH6, drilled near the western boundary of the mining lease, provided evidence that the Severn Thrust is a reverse fault dipping to the west, where the granite and intruded Carboniferous sediments have been thrust to the east, at low angle, over-riding the coal measures and sub-parallel to the roof of the Ashford seam. The drilling also proved that the Ashford seam extends down dip to the west beyond the open cut highwall boundary underneath the granite for at least 1.5 kilometres and along strike for almost two kilometres [Figure 3-I (B)].

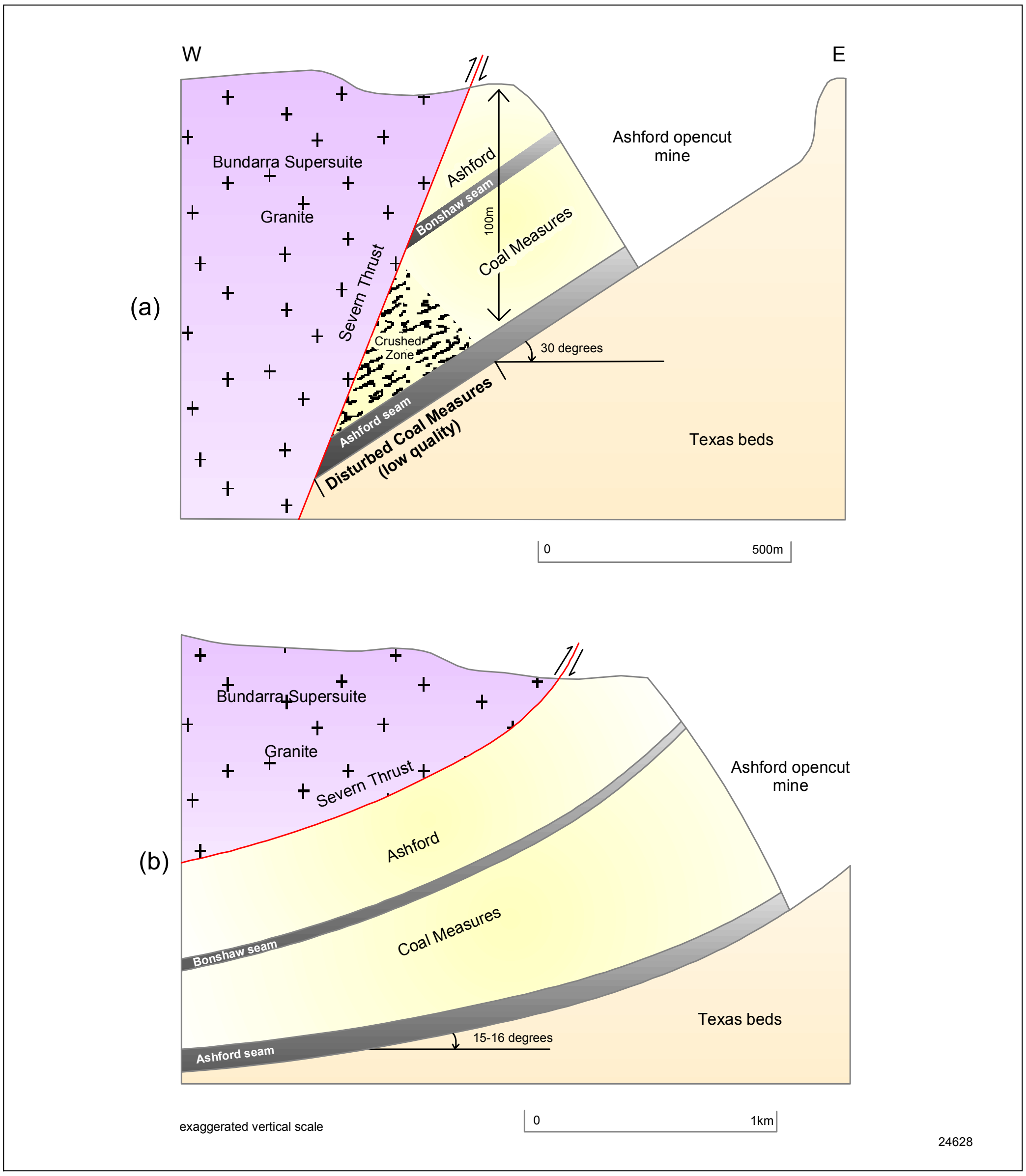


Figure 3-I. (a). An early model showing a steeply dipping Severn Thrust limiting the subsurface extent of the Ashford seam (after White Industries, 1979). (b). A current model showing a shallow dipping Severn Thrust sub-parallel to the underlying Ashford seam (after White Industries, 1987).

The regional strike of the coal measures is about ten degrees further to the east than the actual bedding strike. Extensive offsetting through cross-faulting has been indicated, both by outcrop pattern and by drilling. This is not so evident in the Arthurs Seat area where the fault can be traced for a total of about five kilometres without significant offsetting, until it is folded to form a syncline, plunging to the north-northwest.

It is possible that the main reason the coal measures are in the form of discontinuous bodies along strike is that the areas in between formed topographic highs during the time of coal measure deposition. Although this may be the case in some instances, drilling by White Industries Limited (1979) has shown that the coal measures have been faulted out in some places.

Two major thrusts are present in the Spring Gully area, where two outcrops of coal measures lying east-west of one another are separated by an outcrop of Lower Carboniferous sediments. Faulting also occurs within the coal measures and can be observed in all areas where substantial outcrop is present (Bekker, 1977). The extent of such faulting can be seen in the highwall of one open pit, the No. 7 old colliery area, where numerous relatively minor normal and reverse faults are present, accounting for some of the rapid and substantial changes in coal seam thickness noted from drilling in the colliery area.

Glenmore Formation

The Glenmore Formation was formally defined by Stroud (1992) and is an Early to early Late Permian shallow marine sequence confined to the Ashford 1:100 000 map sheet in the northern Nandewar study area. The Glenmore Formation unconformably overlies the Texas beds and is unconformably succeeded by the Emmaville Volcanics (Photograph 3-H) (Stroud, 1989). Lithologies include boulder conglomerate, coarse arenite and minor fossil-bearing calcareous horizons, claystone and coal. The Glenmore Formation comprises texturally and mineralogically immature clastic sediments interbedded rarely with limestone and epiclastic sediments (Moore, 1982; quoted in Stroud, 1992). Clasts within the coarse conglomerates range in size from three to 30 centimetres and comprise chert, lithic wacke and rare fine-grained conglomerate and medium-grained igneous rock (Stroud, 1992). The thickness of the Glenmore Formation averages 30 metres and does not exceed 100 metres. Recent geophysical imagery does not extend north to cover the Glenmore Formation.

3.2.11 Late Permian Volcanics

Wandsworth Volcanic Group

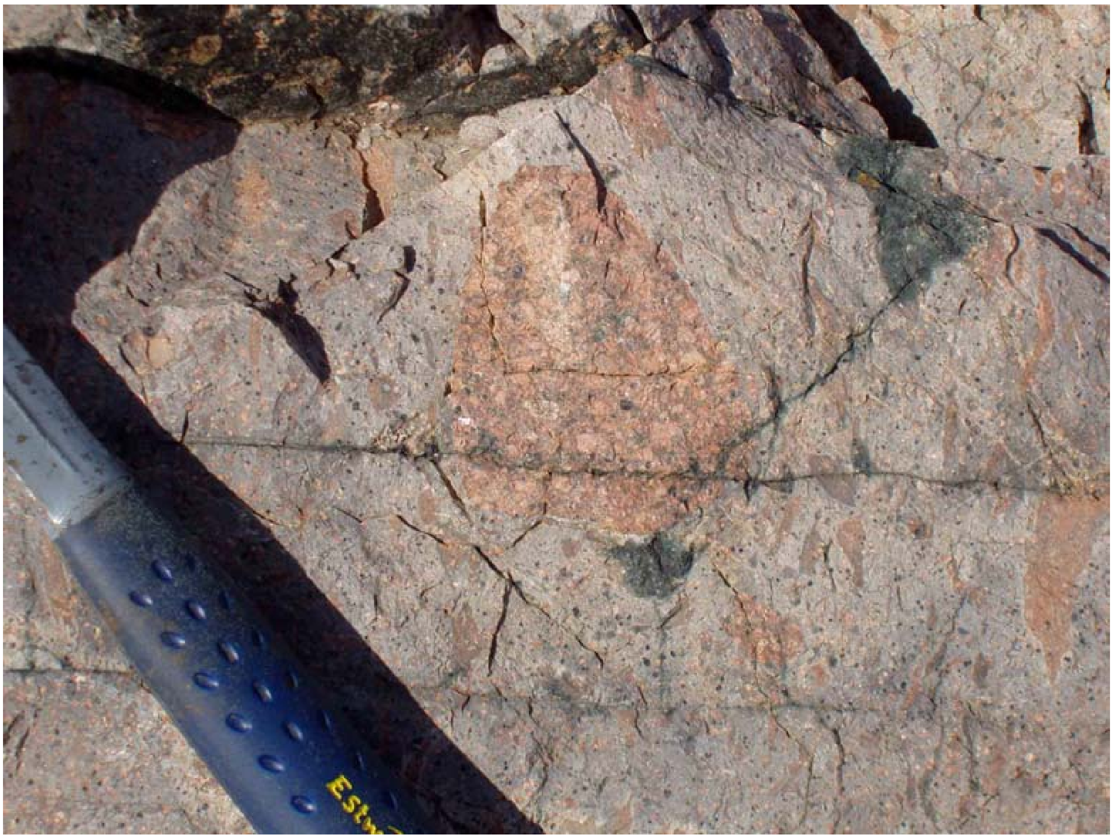
The Wandsworth Volcanic Group was defined by Barnes *et al*. (1991) to encompass a coherent group of terrestrial and shallow marine volcanics in the Central Block of the New England Fold Belt. Volcanism took place in the Late Permian in response to a major period of plutonism and produced thick sequences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

Photograph 3-H. Contact between the Glenmore Formation (most of photo) with overlying Emmaville volcanics (top right hand corner). GR 335260 6764960.

Emmaville Volcanics

The Emmaville Volcanics are the dominant unit of the Wandsworth Volcanic Group in the Nandewar study area, predominantly on the Inverell and Ashford 1:100 000 map sheets. Flat lying rhyolitic, rhyodacitic and rare andesitic ignimbritic flows and minor lavas and epiclastic rocks comprise the Emmaville Volcanics. In the Pindari Dam area rhyolitic to andesitic volcanics are recognised with minor epiclastic sediments; variants include ignimbrites (welded tuffs), lava flows, airfall tuffs and flow banded rhyolite (Photograph 3-I). Detailed mapping and distribution of these units has not been undertaken to date in this area where outcrop is extensive. Minor outcrops of granitoids of limited lateral extent have also been recognised within the Emmaville Volcanics but are generally poorly delineated.

New magnetic and radiometric data over the Emmaville Volcanics has revealed many complexities within this unit in the Nandewar study area. Brown (in press) gave a comprehensive description of the geophysical characteristics of the Emmaville Volcanics. The Emmaville Volcanics produce a high radiometric signature that clearly distinguishes these rocks from the nearby Texas beds, Tertiary volcanics and northern Bundarra Supersuite. Variations within the radiometric and magnetic responses reflect discrete flows, epiclastic beds and possibly previously unmapped granitoids within the Emmaville Volcanics (Figures 3-J and 3-K). Figure 3-J is a "felsic stretch" that is designed to gain the most information about the felsic rocks (that is, the New England Batholith and associated rocks) from a radiometric image. Since these felsic rocks are typically much higher in natural radioactive elements than the other rocks in the Nandewar study area, the colours applied to the radiometric data need to be customised to enhance these rocks alone. This is because with most image display techniques it is not possible to show the large variation within single rock types while also showing the vastly different radiometric properties of different rock types. The resulting images display a lot of colour in the felsic rocks but most of the other areas in the images appear dark and featureless. Geophysical imagery suggests that laterally persistent lithological associations within the Emmaville Volcanics may be mappable, hence subdivision of this unit may be possible.



Photograph 3-I. Ignimbrite from the Pindari Dam area showing fiamme and felsic igneous fragments with later crosscutting chlorite-rich vein sets. GR 329150 6747800.

Together with radiometric imagery, magnetics indicate the presence of at least three large, approximately hemispherical, zoned bodies in the Pindari Dam area, which are interpreted as caldera structures (Brown, in press). The bodies increase in size to the south, are shallow and are exposed at the surface. Magnetic imagery also indicates continuation of these structures beneath the Texas beds to the west (Brown, in press). R Spencer (2003, DMR Sydney, *pers. comm.*) suggested that modelling indicated that a deeper magnetic body may also be present beneath the Emmaville Volcanics. Using geometry and size relationships, Brown (in press) interprets an evolutionary series from the oldest caldera in the north to the youngest in the south.

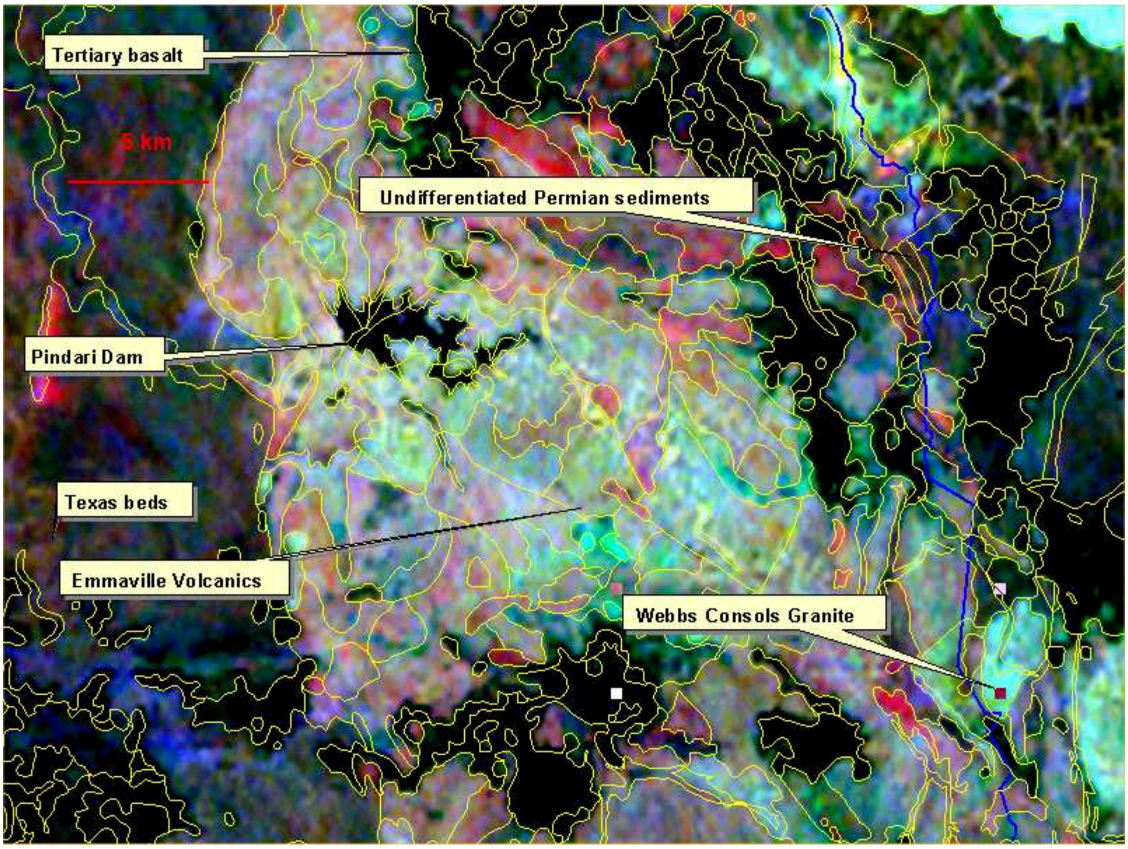


Figure 3-J. Radiometric image of Emmaville volcanics and surrounding lithologies. Note contrast within the volcanics.

Although direct age dating of the Emmaville Volcanics has not been undertaken, age is constrained by lithological relationships. The Emmaville Volcanics overlie Carboniferous metasediments and Early Permian conglomeratic marine units, and are intruded by Permo-Triassic granitoids including the Mole Granite, indicating a Late Permian age (Barnes *et al.,* 1991).

Undifferentiated Late Permian Volcanics

Undifferentiated members of the Wandsworth Volcanic Group include rhyolitic, rhyodacitic and dacitic ashflow tuffs and minor lavas (Brown *et al.,* 1992). They unconformably overlie Carboniferous to Early Permian sediments and are locally intruded and thermally altered by Late Permian granitoids. Crystal-rich, quartz-feldspar ignimbrites dominate, though some units containing minor lithic clasts. Despite minor local deformation, eutaxitic textures are commonly well preserved. Geophysical responses are essentially identical to the Emmaville Volcanics.

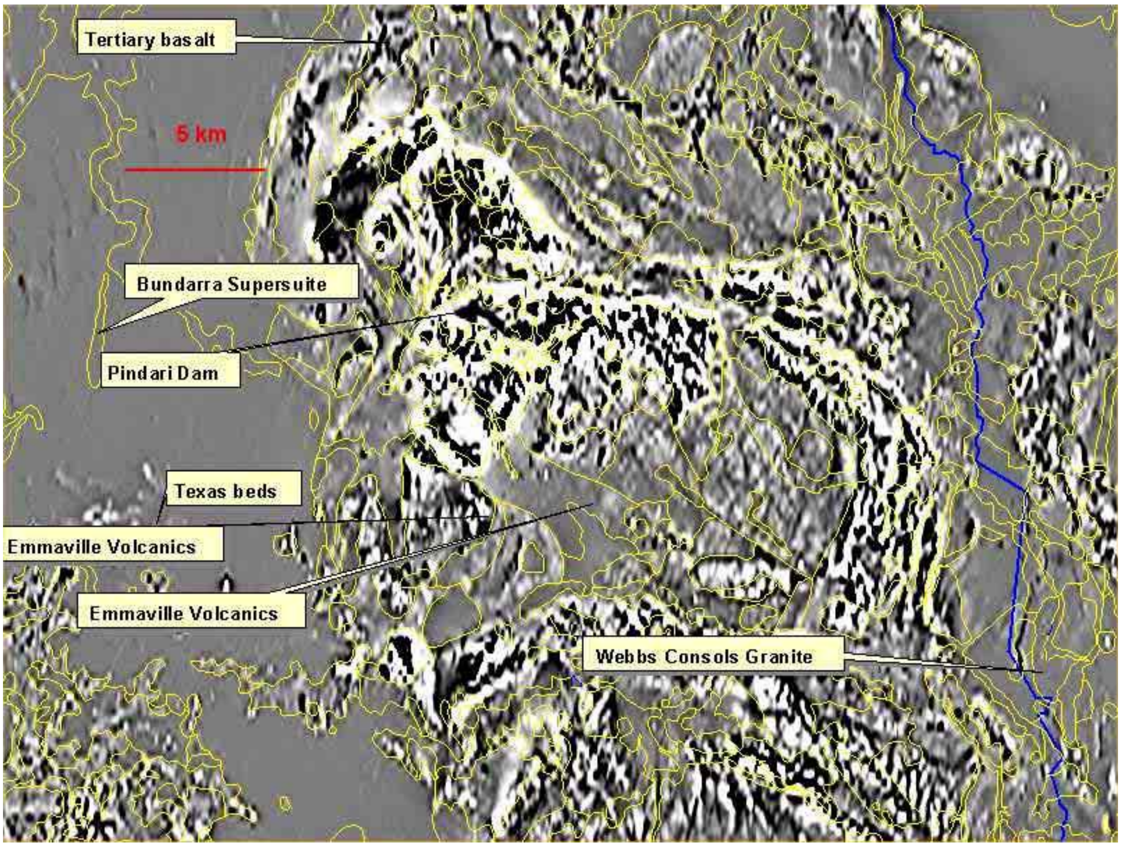


Figure 3-K. First vertical derivative of total magnetic intensity image of Emmaville Volcanics shows the three caldera-type structures and the extreme magnetic complexity over this unit.

3.3 TAMWORTH BELT

TAMWORTH BELT

Comprises faulted and gently folded sediments and volcanics that were deposited in an arc-forearc environment;

Ranges in age from Middle Cambrian to Early Permian;

Is separated from the Central Block to the east by the Peel Fault;

Disconformably overlies and is thrust over rocks of the Surat and Sydney-Bowen basins;

Is separated within the Nandewar study area into five groups:

- Middle Cambrian to Ordovician “unnamed early Palaeozoic succession”;
- Early to Middle Devonian Tamworth Group;
- Late Devonian to Early Carboniferous Parry Group;
- late Early to Late Carboniferous “Carboniferous overlap assemblage”; and
- Early Permian strata adjacent to the Peel Fault.

3.3.1 Introduction

The Tamworth Belt comprises faulted and gently folded, mildly metamorphosed Middle Cambrian to Early Permian sedimentary and volcanic rocks. Geographically, the Tamworth Belt extends in a north-northwest direction from Port Macquarie to Warialda as a 40 to 100 kilometre wide belt. 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.

In the Nandewar study area, the Tamworth Belt can be 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) Early Permian strata next to Peel Fault. The distribution of these groups in the Nandewar study area can be observed in Figure 3-L. A detailed stratigraphy of the Tamworth Belt can be observed in Figure 3-M.

The Tamworth Belt rocks have been mildly deformed, producing a series of north trending and variably plunging folds. The major expression of the folding is the Rocky Creek Syncline. Regional scale faults and thrusts that resulted in post folding dislocation are a feature of the Tamworth Belt. Low-grade regional metamorphism has affected most of the rocks of the Tamworth Belt.

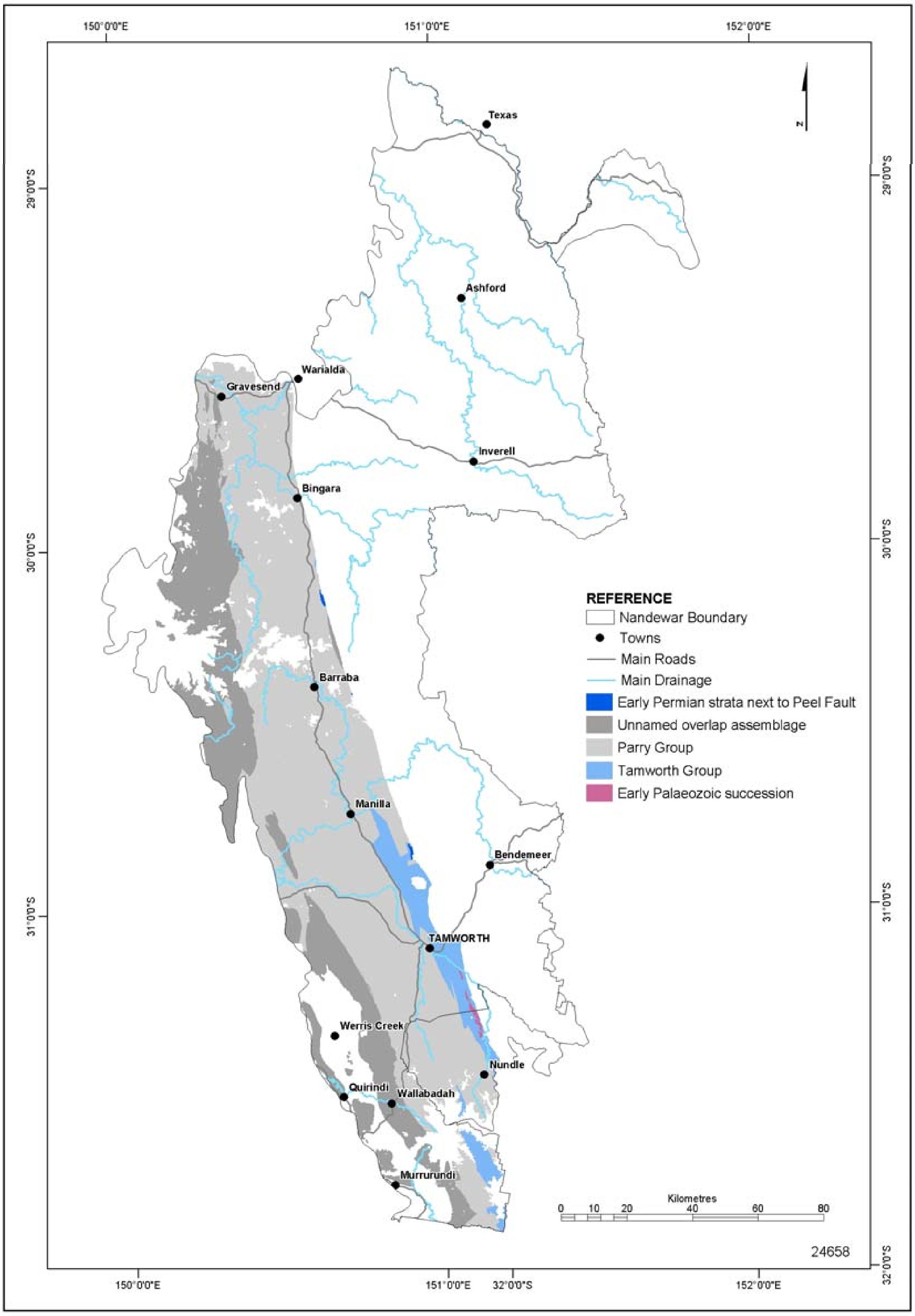


Figure 3-L. Surface distribution of the Tamworth Belt in the Nandewar study area.

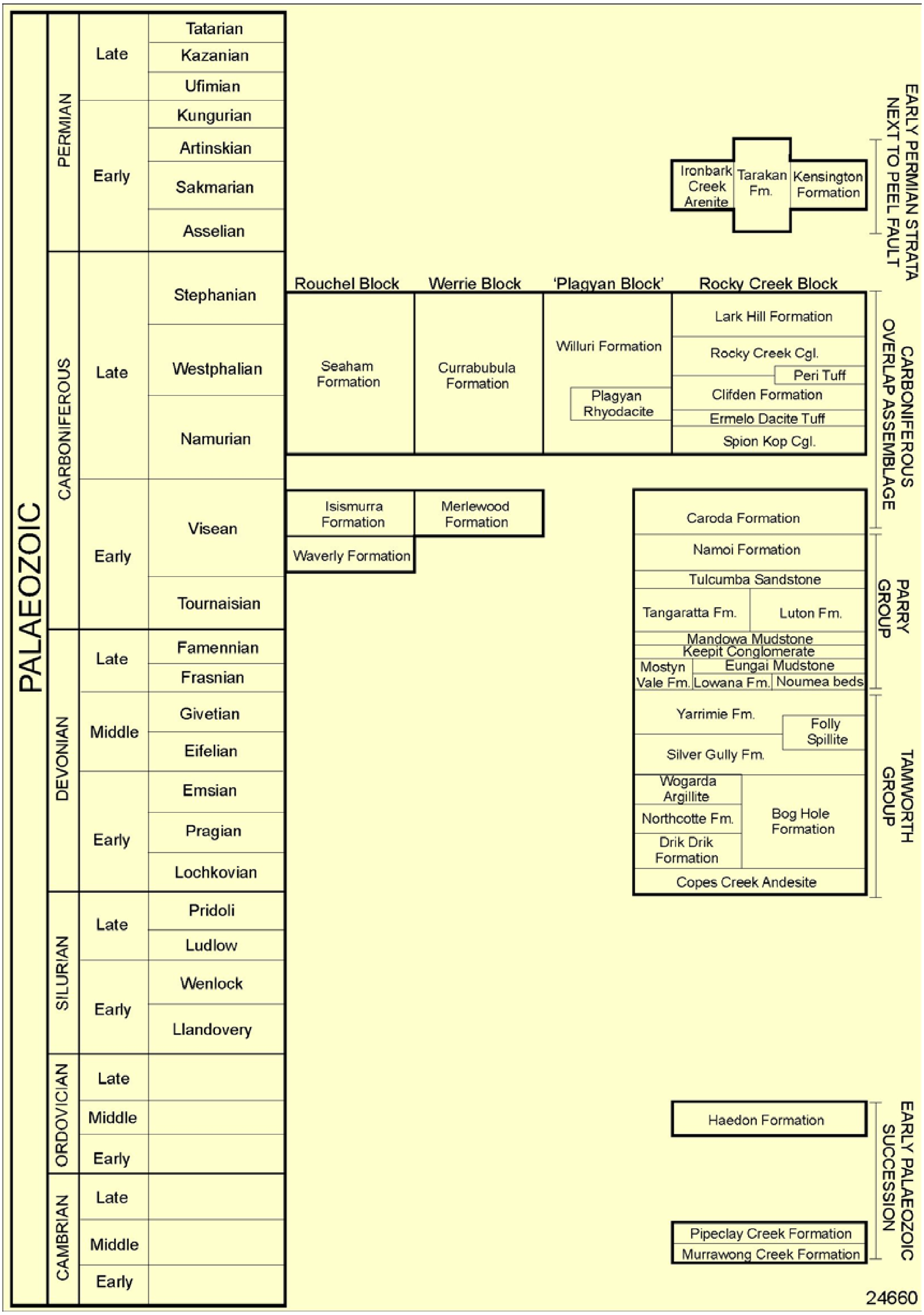


Figure 3-M. Stratigraphy of the Tamworth Belt in the Nandewar study area.

3.3.2 Early Palaeozoic succession

A thin sequence of Middle Cambrian to Middle Ordovician deep marine sedimentary rocks occurs in a narrow north-south trending belt from Chaffey Dam to east of Loombrah. Cawood (1980) recognised three units in this early Palaeozoic succession. These units are the Middle Cambrian Murrawong Creek and Pipeclay Creek Formations, and the Middle Ordovician Haedon Formation. Overall, the early Palaeozoic succession shallows from a base of slope fore-arc complex (Murrawong Creek Formation), to carbonate bank and submarine canyon deposits (Haedon Formation). Rock types in this early Palaeozoic succession consist of cherty siltstone, sandstone, granule to boulder conglomerate and limestone. Volcanic input ranges from mafic in the Murrawong Creek and Pipeclay Creek Formations to intermediate in the Haedon Formation (Cawood, 1982). Conglomerates within the Haedon Formation contain both extraformational clasts (granite, limestone, jasper and green argillite) with varying degrees of roundness (Photograph 3-J), and intraformational clasts (andesitic volcaniclastics) that are angular (Photograph 3-K). A low-angle unconformity observable between the Pipeclay Creek and Haedon Formations infers deformation of the sequence between the Middle Cambrian and Middle Ordovician (Gilligan and Brownlow, 1986).

3.3.3 Tamworth Group

The Tamworth Group consists of a series of intermediate volcanics and volcaniclastics, red breccias and limestones that developed in a submarine to emergent island arc setting in the Early to Middle Devonian. Within the Nandewar study area, the Tamworth Group consists of two roughly north-south trending belts, each up to 15 kilometres across. The eastern belt extends from north of Attunga to east of Nundle and is developed unconformably on the early Palaeozoic succession. The western belt occurs 20 kilometres west of Nundle in the north to Timor in the south. In this area, the Tamworth Group is in faulted contact with the Parry Group to the east, and the base of the sequence is not observed.

In the Nundle area, the Early Devonian part of the Tamworth Group can be divided into two parts that have different depositional and intrusive relationships. These two parts are separated by the north-south trending Sandy Creek Fault (Morgan, 1997). The basal unit of the Tamworth Group on the western side of the Sandy Creek Fault is the Drik-Drik Formation (Crook, 1961b), and includes the Copes Creek Andesite. Typically, the Drik-Drik Formation is dominated by haematite-pigmented andesitic volcaniclastic breccia (Photograph 3-L) that is interstratified with red fine sandstone and siltstones. The Copes Creek Andesite comprises a series of both coherent and brecciated, fine-grained intermediate intrusions and volcanics. The intermediate magmas of the Copes Creek Andesite intrude both the early Palaeozoic succession and the lower Drik-Drik Formation (Morgan, 1997). Overlying the Drik-Drik Formation is the Northcotte Formation, which is comprised of green sandstone and siltstone, and which hosts the Nemingha Limestone (Photograph 3-M) of Crook (1961b). Stratigraphically above the Northcotte Formation is a sequence of green-grey argillites and mudstone as defined by Crook (1961b) called the Wogarda Argillite.

Photograph 3-J. Polymictic boulder conglomerate from the Haedon Formation near Chaffey Dam. Clasts include granite, limestone, jasper and argillite. GR 320890 6530610.

Photograph 3-K. Sedimentary breccia of the Haedon Formation near Chaffey Dam. Angular clasts of andesitic sandstone, with a mudstone infill. GR 320910 6530610.

To the east of the Sandy Creek Fault is the Bog Hole Formation (Cawood, 1980). Lithologies in the Bog Hole Formation include laminated argillite, fine-grained tuffaceous sandstone and medium- to coarse-grained crystal lithic sandstone. A series of brecciated to coherent, discontinuous intermediate intrusions also occur within deep-water mudstone and sandstone units of the Bog Hole Formation (Morgan, 1997). Work by Cawood (1980) demonstrated that the Bog Hole Formation is equivalent to the sequence from the Drik-Drik Formation to the lower Silver Gully Formation on the western side of the Sandy Creek Fault.

Deposition of intermediate volcaniclastics in the Tamworth Group continued during the Middle Devonian with the development of the Silver Gully and Yarrimie Formations. The Silver Gully comprises intermediate volcanolithic sandstones and conglomerates and occurs between two fine-grained units of the Wogarda Argillite (below) and the Yarrimie Formation (above). The Yarrimie Formation consists of green, grey, black and white cherty argillites and fine mudstone. Both of the Yarrimie and Silver Gully Formations contain limestone blocks that are both autochthonous (carbonate reefs that have developed *in-situ*), and allochthonous (carbonate reefs that have dropped off the edge of the marine shelf to the ocean floor) (Photograph 3-N). In the Attunga region, the limestone blocks are called the Sulcor and Moore Creek Limestones (Crook, 1961b) while in the Loombrah and Timor region the limestone blocks are called the Loombrah and Timor Limestones respectively (Crook, 1961b). Mafic intrusions and altered basalts (spillites) comprising the Folly Volcanics intrude and are interbedded with the Silver Gully and Yarrimie Formations. The dolerite sills of the Folly Volcanics are quite thick and occur in the area immediately to the southeast of Nundle.

Photograph 3-L. Haematitic breccia of the Drik-Drik Formation. Photo taken near Loombrah. GR 315010 6546500.

Photograph 3-M. Fossiliferous limestone from the Nemingha Limestone Member of the Wogarda Argillite. Photo taken near Loombrah. GR 314640 6546330.

Photograph 3-N. Sulcor Limestone member of the Yarrimie Formation resting conformably on bedded andesitic sandstone and mudstone. Attunga limestone deposit, Attunga. GR 295520 6576670.

3.3.4 Parry Group

Within the Nandewar study area, the outcropping members of the Parry Group extend in a north-northwest trending belt from Timor in the south to Warialda in the north. Overall, the group comprises a thick sequence of Late Devonian to Early Carboniferous, intermediate to felsic rocks that are all marine in character. The base of the group conformably and unconformably overlies the Early to Middle Devonian rocks of the Tamworth Group. Nomenclature for the Parry Group has been adopted from various authors, principally Crook (1961a), White (1964), and McKelvey and White (1964).

Referred to previously as the Baldwin Formation (Crook, 1961a), the lowermost units of the Parry Group are the Noumea beds, Lowanna Formation, Eungai Mudstone, and Mostyn Vale Formation (McKelvey and White, 1964; Brown, 1982). These units represent a sequence of deep-marine intermediate and mafic volcanic and volcaniclastic rocks deposited in the early Late Devonian. The Noumea beds, Lowanna Formation and Eungai Mudstone occur as a belt of rocks extending from near Nundle to Warialda and comprise a sequence of upward fining intermediate volcanics and volcaniclastics (Photographs 3-O and 3-P). The Mostyn Vale Formation occurs to the west of Keepit Dam and consists of reworked andesitic volcanics and basalts. New work as part of this study has subdivided the Mostyn Vale Formation into two members based on a consistent radiometric change.

The Keepit Conglomerate (a regional scale marker unit) defined by White (1964) represents the lowermost conglomeratic unit of what was previously the Goonoo Goonoo Mudstone (Crook, 1961a). Conglomerates constituting the base of the Keepit Conglomerate rest both unconformably (Bective Unconformity; White, 1964) and conformably (Russell, 1979) on the lower units of the Parry Group and upper Tamworth Group. The Mandowa Mudstone of White (1964) consists of fine sandstones and mudstones, and conformably overlies the Keepit Conglomerate. Scattered Late Devonian limestone bodies occur within the Mandowa Mudstone indicating a marine shelf depositional environment. The Kiah Limestone of Crook (1961a) is the most extensive of these limestone bodies, and occurs as a series of semicontinuous limestone lenses.

Conformably overlying the Late Devonian Mandowa Mudstone is the Early Carboniferous Tangaratta Formation. Lithologies in the Tangaratta Formation are dominated by mudstone and fine sandstone with minor thin, laterally continuous sandstone and conglomerate members. Mapped members of the Tangaratta Formation include the Scrub Mountain Conglomerate, Gowrie Sandstone and Garoo Conglomerate. The overlying Tulcumba Sandstone of White (1964) consists of a basal conglomerate fining upwards into sandstones and limestones towards the top of the unit (H. Henley, DMR Armidale, *pers. comm.*). A laterally extensive and fossiliferous limestone (the Rangrai Limestone Member; Campbell and Engel, 1962) occurs within the upper sandstone members of the Tulcumba Sandstone. In the Keepit Dam area, the Tulcumba Sandstone rests unconformably (Onus Creek Unconformity; White, 1964) on the Mandowa Mudstone, implying erosion of the Tangaratta Formation and upper Mandowa Mudstone during the Early Carboniferous. The Luton Formation occurs to the north of Barraba and is broadly equivalent to the Tangaratta Formation and Tulcumba Sandstone.

Photograph 3-O. Elongate angular clasts of fine sandstone in a coarse sandstone matrix (Noumea beds), with minor quartzose sigmoidal tension veins. Photo taken near Manilla. GR 285570 6609830.

Photograph 3-P. Shallowly dipping, interbedded sandstone and mudstone (Noumea beds). Photo taken near Bingara. GR 266240 6666890.

Within the Nandewar study area, the stratigraphically highest members of the Parry Group are the Namoi and Waverly Formations which contain olive-green to olive-brown siltstone, mudstone, sandstone, limestone and conglomerate. These units conformably and unconformably overlie the Luton Formation, Tangaratta Formation and Tulcumba Sandstone. The base of the Namoi Formation marks the introduction of felsic volcanics from a continental arc to the west as compared to the dominantly intermediate volcanics in the lower units of the Parry Group. Lithologies include limestone, conglomerate, andesite, sandstone and mudstone. In the Rangrai area, a conglomerate at the base of the Namoi Formation (the Pallal Conglomerate) contains angular sedimentary blocks up to three metres in diameter and is interpreted by McKelvey and White (1964) to have formed in a submarine canyon.

3.3.5 Carboniferous overlap assemblage

In the Tamworth Belt a ‘group’ of late Early to Late Carboniferous rocks overlie the Parry Group. At the time of going to press this ‘group’ had not yet been named and has been informally referred to as the “Carboniferous overlap assemblage” in this study. Geographically, the Carboniferous overlap assemblage occurs on the eastern edge of the Tamworth Belt, extending from Murrurundi to Gravesend. Within the Nandewar study area, this Carboniferous overlap assemblage consists of two broadly equivalent sequences of rocks. The lower of these sequences is a late Early Carboniferous marine to terrestrial transitional sequence, and the upper is a Late Carboniferous terrestrial (predominantly fluvioglacial) sequence. Within the Nandewar study area, the nomenclature used for the unnamed Carboniferous overlap assemblage of the Tamworth Belt can be broken into four separate geographic areas:

- Rocky Creek Block; north of Keepit Dam and to the east of the Plagyan and Kelvin Thrusts (McKelvey and White, 1964).
- Werrie Block; south of Keepit Dam and north of the Waverly Fault (Whetten, 1965; Manser, 1965)
- Rouchel Block; south of the Waverly Fault (Roberts and Oversby, 1974)
- Plagyan Block; west of the Kelvin and Plagyan Thrusts [the nomenclature used is currently reserved by Emeritus Professor John Roberts (School of Biological, Earth and Environmental Sciences, UNSW, Sydney) as a series of current stratigraphic names with Geoscience Australia]

In the Nandewar study area, the marine to terrestrial transition sequence consists of limestone, andesite, dacite, conglomerate, sandstone, and siltstone with rare coal. Minor differences within this sequence occur geographically and consequently representations of this sequence have been given different stratigraphic names for each block. These units are the Caroda Formation (Rocky Creek Block), Merlewood Formation (Werrie Block) and Isismurra Formation (Rouchel Block). Intermediate and felsic volcanics occur in this sequence, the Ermelo Dacite Tuff and the Kingsmill's Peak Andesite being examples of these.

Overlying the marine to terrestrial transition sequence is a Late Carboniferous terrestrial sequence. This sequence was deposited in a fluvioglacial environment and consists of tuff, felsic-ignimbrite, conglomerate, sandstone, siltstone and mudstone. Again, there are minor differences in this sequence between the four blocks in the Nandewar study area and so different stratigraphic names have been adopted for this sequence. These units are the Seaham Formation (Rouchel Block), Currabubula Formation (Werrie Block), Willuri Formation (Plagyan Block), Spion Kop Conglomerate, Clifden Formation, Rocky Creek Conglomerate, and Lark Hill Formation (Rocky Creek Block).

McKelvey and White (1964) noted that the sequence in the Rocky Creek Block represents two periods of glacial retreat during the Late Carboniferous. Expressions of these glacial retreats are manifest as the Spion Kop Conglomerate (Photograph 3-Q) and Clifden Formation for the early glacial retreat and the Rocky Creek Conglomerate (Photograph 3-R) and Lark Hill Formation for the later glacial retreat. Felsic volcanics are associated with the fluvioglacial sequences in the Rocky Creek Block, the Peri Rhyodacite Tuff and the Hell Hole Pyroclastic Member being examples of these.

The Currabubula Formation was first named by Whetten (1965) and comprises all of the Late Carboniferous sedimentary rocks above the Merlewood Formation. There are many ignimbrite and tuff members within the Currabubula Formation that have been both formally and informally named. Examples of these units include the Cana Creek Ignimbrite Member, Iventure Ignimbrite Member, Piallaway Trig Ignimbrite Member and Taggarts Mountain Ignimbrite Member.

New mapping by Emeritus Professor John Roberts in the Tulcumba Ridge area has been incorporated into the upgraded geological coverage of the Nandewar study area geology. Consequently, all of the sedimentary rocks between the Kelvin-Plagyan and Hunter-Mooki thrusts are now informally named the Willuri Formation. Previously mapped units in this area followed the stratigraphy of McKelvey and White (1964). A feature of this unit is the higher number of felsic ignimbrites and tuffs compared to the Rocky Creek Block. Within the Willuri Formation, fourteen ignimbrite members have been associated with the Birken Head Rhyolite and three with the Penryn Rhyolite.

3.3.6 Early Permian strata next to Peel Fault

Within the Nandewar study area, a series of narrow (usually less than one kilometre wide) fault slivers that contain Early Permian marine rocks occur immediately west of the Peel Fault. Units that comprise this ‘group’ include the Kensington Formation, Ironbark Creek Arenite, Tarakan Formation, as well as part of the Manning Group in the Chaffey Dam area. These units comprise interbedded sandstones, orthoconglomerates, siltstones, and limestones that deposited in nearshore marine and possibly terrestrial environments.

Photograph 3-Q. Matrix-supported polymictic conglomerate (diamictite). Spion Kop Conglomerate. Photo taken near Caroda. GR 238700 6672790.

Photograph 3-R. Clast-supported polymictic conglomerate. Rocky Creek Conglomerate. Photo taken near Caroda. GR 240560 6673710.

3.3.7 Geophysical interpretation

Over half of the Tamworth Belt is covered with regional geophysics in the Nandewar study area. However, none of the lower Tamworth Group and early Palaeozoic Succession has, at present, been covered with adequate geophysics and therefore can't be described in this study. All of the unnamed Carboniferous overlap assemblage shows a strong magnetic response with magnetic lineaments parallel to the strike of the sequence. Units that have a moderate to strong magnetic response in the Parry Group are the Mostyn Vale Formation, Keepit Conglomerate and parts of the Noumea beds. The radiometric response of the Parry Group below the Namoi Formation and the upper Tamworth Group is characterised by moderate to low potassium, low thorium and low uranium. This is a typical radiometric response of all the intermediate volcanic and volcaniclastic rocks in the New England Fold Belt. The Carboniferous overlap assemblage and Namoi Formation however are dominated by felsic volcanics and volcaniclastics and have moderate to high potassium, thorium and uranium radiometric responses.

3.4 NEW ENGLAND BATHOLITH

NEW ENGLAND BATHOLITH
Covers an area of approximately 16 000 square kilometres and incorporates all the granitoids of the Southern New England Fold Belt;
Is represented in the Nandewar study area by the Moonbi, Uralla and Clarence River I-type supersuites and the S-type Bundarra Supersuite;
Predominantly intrudes sediments of the Central Block and locally the Tamworth Belt (in the south of the study area) therefore dominating the eastern portion of the New England Fold Belt;
Causes extensive contact metamorphism of the Central Block sediments into which it intrudes;
Formed in response to a major thermal disturbance in the earths crust associated with the Carboniferous to Permian convergent tectonic regime in eastern Australia;
Is easily identified and delineated using recent geophysical surveys;
Is composed of individual intrusions that were emplaced at shallow levels in the earths crust and were derived from the melting of igneous material and immature sediments.

3.4.1 Introduction

The New England Batholith covers an area of approximately 16 000 square kilometres, incorporating all the granitoids in the southern New England Fold Belt of northeastern New South Wales and southern Queensland (Bryant, 2001). The batholith is covered in part by sedimentary basins as well as Tertiary volcanics and sediments.

In 1982, Shaw and Flood divided the New England Batholith into five suites, now redefined as supersuites (Bryant, 2001), that include two Late Carboniferous-Early Permian S-type (Bundarra and Hillgrove) and three Late Permian-Early Triassic I-type supersuites (Moonbi, Uralla and Clarence River). The distribution of the New England Batholith within the Nandewar study area can be observed in Figure 3-N.

Granites are subdivided according to chemistry, enabling useful classification and discrimination of these rocks. The chemistry of granites has an enormous influence on its constituent minerals, enabling the recognition of source rocks that have melted to produce the magmas, and their ability to produce economic resources. Granites of the New England Batholith fit into two geochemical groups, I- and S-type granites. I-type granites are derived from melting in the crust of igneous material, whilst S-types are derived from melting of sedimentary material in the crust. Within these subdivisions the granites may be characterised by a number of geochemical features that provide further information about source and conditions during melting and ascent of the magma.

Fractionation is a term used to describe the preferential extraction of certain mineral phases from the magma during melting and ascent. Magmas that have undergone changes in bulk chemistry due to this process are called “fractionated”. The process of fractionation is essential in ore formation for many mineral resources derived from granitic rocks, for example tin.

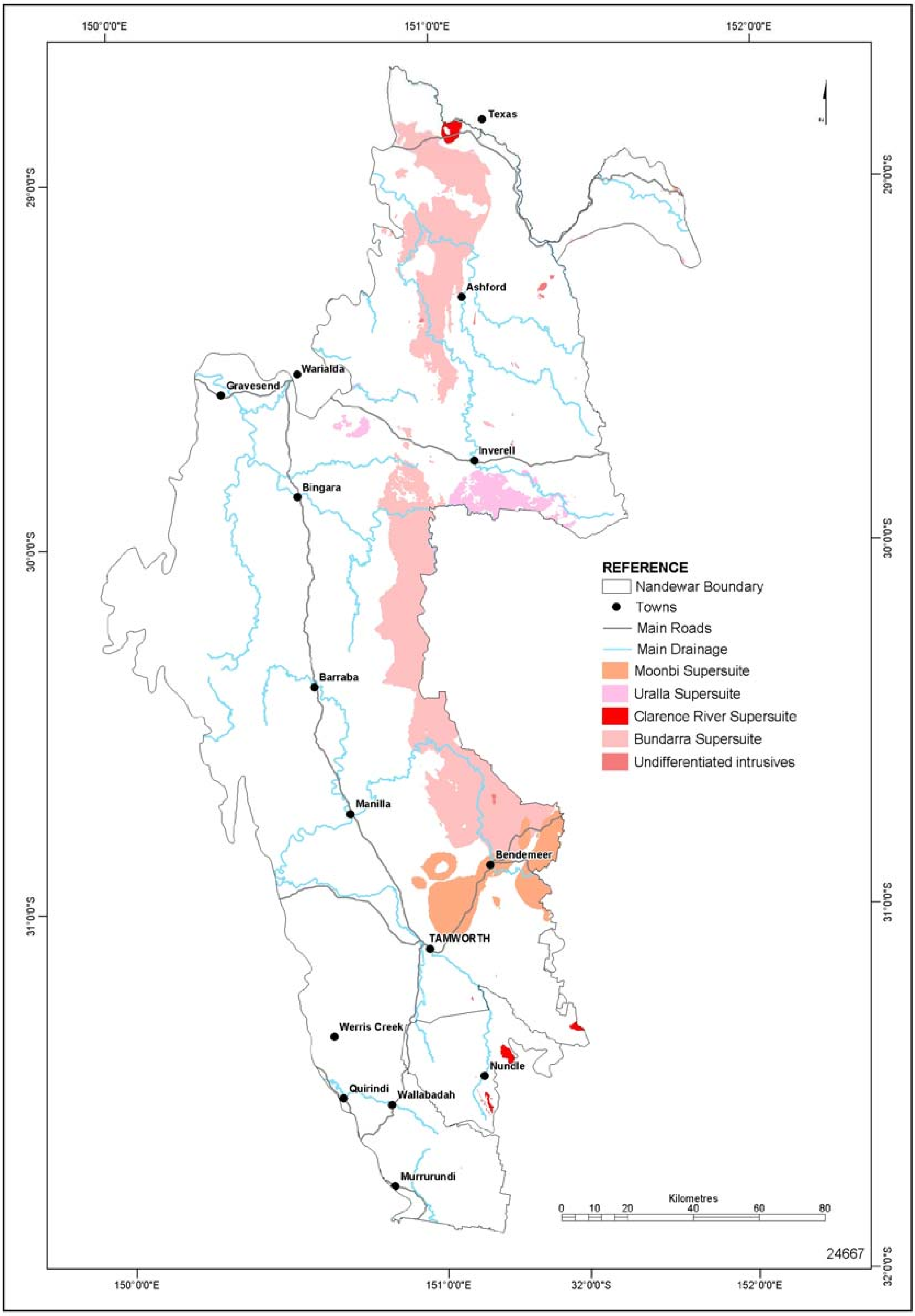


Figure 3-N. Surface distribution of the New England Batholith in the Nandewar study area.

Granites may be classified as being reduced or oxidised. This refers to the amount of oxygen available during crystallisation of the magma. The oxidation state of the magma is a product of that of the source material, interaction with country rocks during ascent, and conditions during crystallisation. It is dependent on a number of complex variables and will partially control the mineral phases and chemistry of the granite. The oxidation state of a granite is measured by the Fe_2O_3/FeO ratio and is reflected in mineralogy by the presence of different iron oxide phases that include ilmenite, magnetite and titanite. In general terms, S-type granites are reduced and produce minerals with higher cation: oxygen ratios, for example, ilmenite, and I-type granites range according to the source rocks from weakly reduced to oxidised. Oxidised granites will tend to include magnetite in their mineral assemblage.

3.4.2 Bundarra Supersuite

The Bundarra Supersuite (Photograph 3-S) is immediately recognisable within the Nandewar study area as a north-south elongate belt of coarse-grained, equigranular to porphyritic granitic rocks. It is unusual in the New England Batholith in that it forms a large, continuous belt, contrasting to the more common ovoid, discrete plutons that comprise the other supersuites. The Bundarra Supersuite is an aggregate of individual plutons forming a compositionally coherent group of S-type affinity. These S-type granites are derived from melting of sedimentary rocks within the crust in response to a major thermal event. They contain a number of diagnostic minerals such as muscovite, cordierite and rare garnet that indicate derivation from an aluminium-rich source (typically sediments). Shaw and Flood (1982) proposed that the Bundarra Supersuite is derived from the melting of sediments similar to, but younger than, the Texas-Sandon association of the Central Block. K-Ar and Rb-Sr dating of whole rock and mineral samples from the Bundarra Supersuite has been compiled by Brown *et al*. (1992) and provides a coeval model for supersuite formation at 286-277 Ma. The Bundarra Supersuite is reduced and unfractionated, and it is largely due to the latter that there is an apparent scarcity of mineralisation associated with it.

Geophysical imagery, particularly radiometrics, reveals heterogeneities within the Bundarra Supersuite that, except for the southerly extent of the supersuite, have not been previously mapped. In regional magnetic images the Bundarra Supersuite produces a prominent uniform low magnetic response, which is in fact the lowest in the New England Fold Belt, consistent with its S-type chemistry. Magnetic imagery reveals a distinct contact aureole (thermal alteration of surrounding sediments) along the western margin that extends for up to four kilometres (Brown, 2003). The Bundarra Supersuite is easily recognisable as a bright, north-south elongate belt in radiometric images defined by sharp boundaries with structural control, particularly on its western margin. Individual intrusions within the southerly bulge include the Pringles, Banalasta and Glenclair monzogranites, recognised previously by mapping. These intrusions are clearly identified using radiometric imagery; unit boundaries are identifiable and have been significantly refined (Brown, 2003).

The Bundarra Supersuite is geographically subdivided into two portions. The southerly extent is by far the largest and includes that part of the supersuite from north of Tamworth to west of Inverell, whilst the northerly part stretches from northwest of Inverell to the Queensland border (Figure 3-O). The northerly and southerly extents of the Bundarra Supersuite produce very different radiometric responses, the northerly portion apparently more potassic than the southerly portion. Within the Nandewar study area, radiometric imagery is useful for discriminating the Bundarra Supersuite from other supersuites of the New England Batholith as it has lower overall abundances of radioelements but has higher K than Th and U.

Photograph 3-S. Bundarra Supersuite at Macintyre Falls weathering to pavements and prominent tors. GR 302160 6773190.

3.4.3 Clarence River Supersuite

The Nundle Suite in the south and the Boxwell Granodiorite in the extreme north represent members of the Clarence River Supersuite within the Nandewar study area. This supersuite is chemically the most diverse of the New England Batholith, ranging from gabbro through to monzogranite compositions, although tonalitic and granodioritic compositions dominate. Within the Nandewar study area, granodiorite with minor trondhjemite and monzogranite intrusions are prevalent. Clarence River intrusions are typically fine- to medium-grained, unfractionated and moderately oxidised. In terms of major element abundances, the Clarence River Supersuite is geochemically distinct from other I-type supersuites within the New England Batholith (Bryant *et al.,* 2002). Kimborough *et al*. (1993) has dated the Barrington Tops Granodiorite, a member of the Nundle Suite, using the SHRIMP (Sensitive High Resolution Ion MicroProbe) method at 273 and 281 Ma, Early Permian age. Prior to this, the Nundle Suite has been dated by whole rock Rb-Sr methods at 264-273 Ma (Hensel *et al.,* 1982). New geophysical surveys do not extend to those parts of the Nandewar study area in which members of the Clarence River Supersuite outcrop. Hence, recognition based on radiometric and magnetic response could not be established.

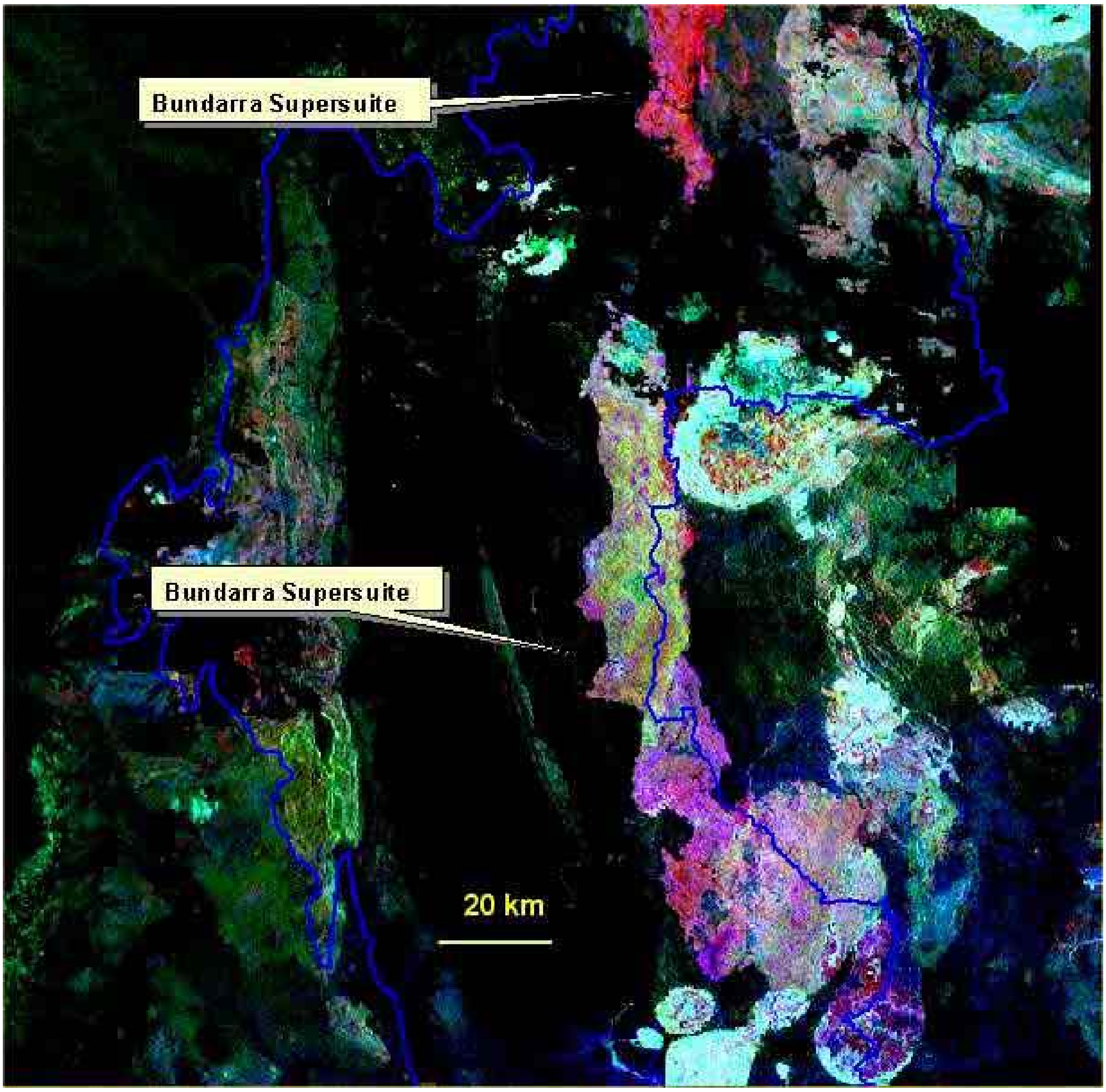


Figure 3-O. Contrasting radiometric responses from the northerly and southerly portions of the Bundarra Supersuite.

3.4.4 Uralla Supersuite

The Tingha Monzogranite is the only recognised member of the centrally located I-type Uralla Supersuite outcropping within the Nandewar study area. The Gilgai, Mole, Elsmore, Webbs Consols and Dumboy-Gragin granites form part of the unclassified "leucoadamellite" suite of Shaw and Flood (1981), however Bryant *et al*. (2002) have tentatively reclassified these plutons as belonging to the Uralla Supersuite. For the purposes of this report however, these leucogranites will be treated separately.

As with the Clarence River Supersuite, the Uralla Supersuite is compositionally diverse. Compositions range from gabbro and diorite through to monzogranite (47-77% SiO_2) (Bryant *et al.,* 2002). The average composition of the Uralla Supersuite is more mafic (that is, lower SiO_2 abundance), contains fewer fractionated plutons and is more reduced than the Moonbi and Clarence River supersuites. In general, within the New England Batholith the Uralla Supersuite composition is transitional between I- and S-type compositions, indicating possible sedimentary influence with respect to the source of these granites (Bryant *et al.,* 2003). Although suites are not recognised within the Uralla Supersuite, four groups have been defined with strong geographical control (Bryant *et al.,* 2002). Members are typically equigranular to weakly porphyritic and are white in colour.

The Tingha Monzogranite (Photograph 3-T) represents a more felsic member (that is higher SiO_2 abundance) of the supersuite that does not fit into any of the four groups recognised. It is characterised by moderate to large K feldspar crystals within a gradational groundmass that includes biotite and hornblende, typical of I-type granites. The Tingha Monzogranite is intruded by the Gilgai Granite where its western, northern and eastern margins are complex contacts that indicate transitional rock type varieties (Stroud, 1989). Stroud (1989) reported a K-Ar age of 237 Ma and a Rb-Sr age on biotite of 249 Ma (Shaw and Flood, 1991) has also been reported.

Photograph 3-T. Tingha Monzogranite, a felsic member of the Uralla Supersuite. GR 345420 6690440.

A very small proportion of the Tingha Monzogranite outcrops in the Nandewar study area. It produces a uniform low magnetic response (Figure. 3-P) and a variably moderate to high radiometric response (Figure. 3-Q). The radiometric response is complicated by the interaction between the Tingha and Gilgai intrusions and by overlying regolith and cover sequences. The Tingha Monzogranite and Gilgai Granites are clearly distinguished by the universally higher radioelement abundance of the Gilgai Granite in radiometric imagery and by the uniform low magnetic response of the Tingha Monzogranite.

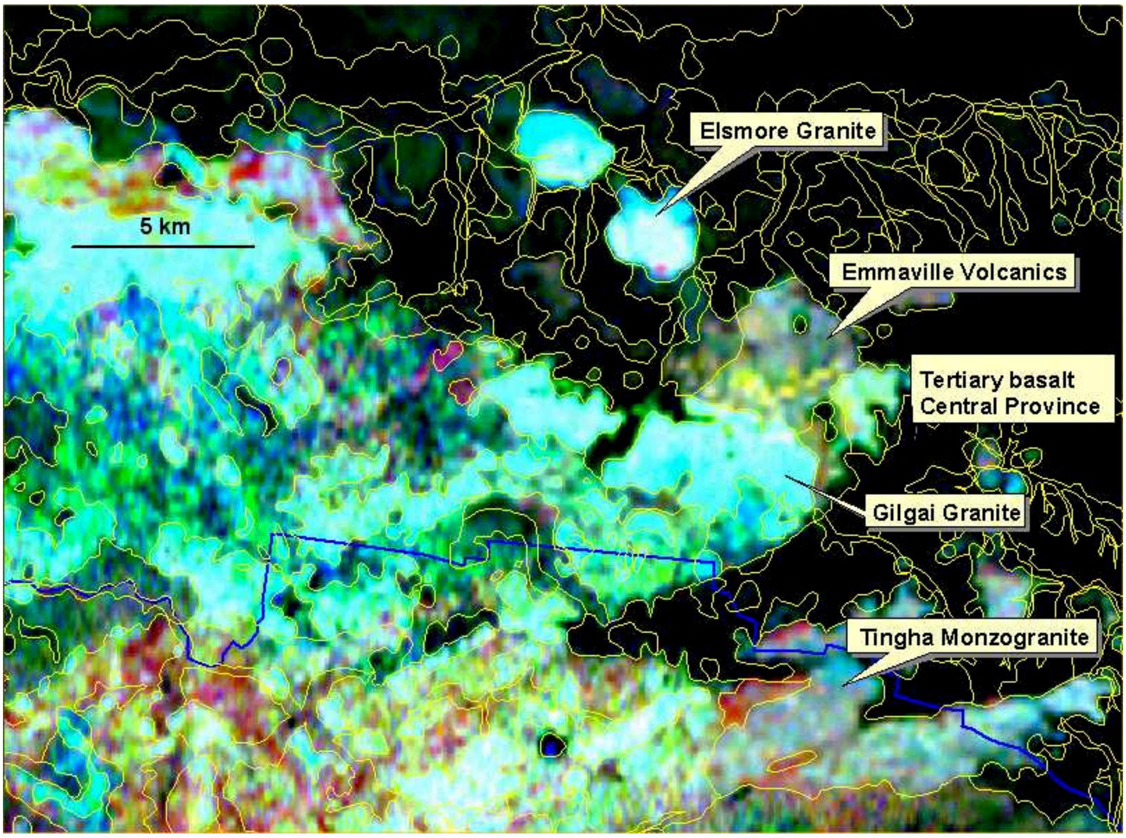


Figure 3-P. Radiometric image highlighting differences between the Tingha Monzogranite and the Gilgai Granite. The mottling effect is due to regolith and/or cover development on top of the granitoids.

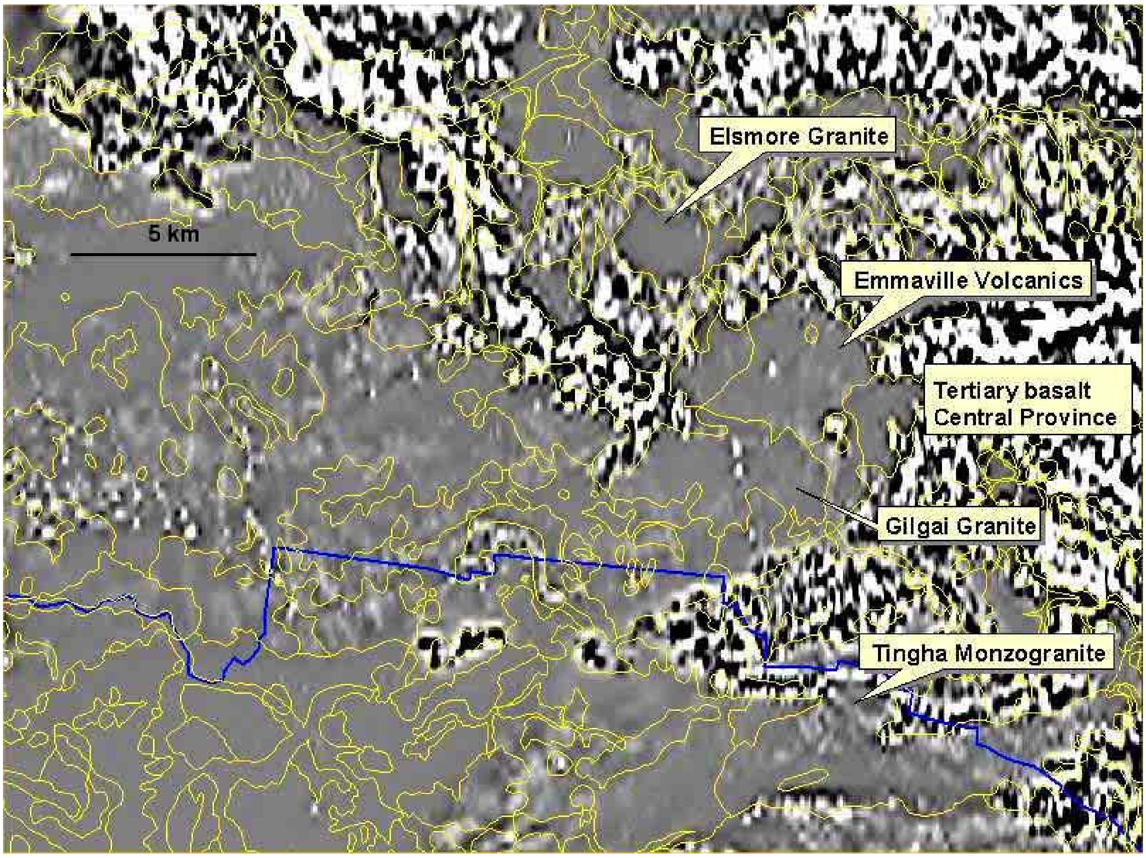
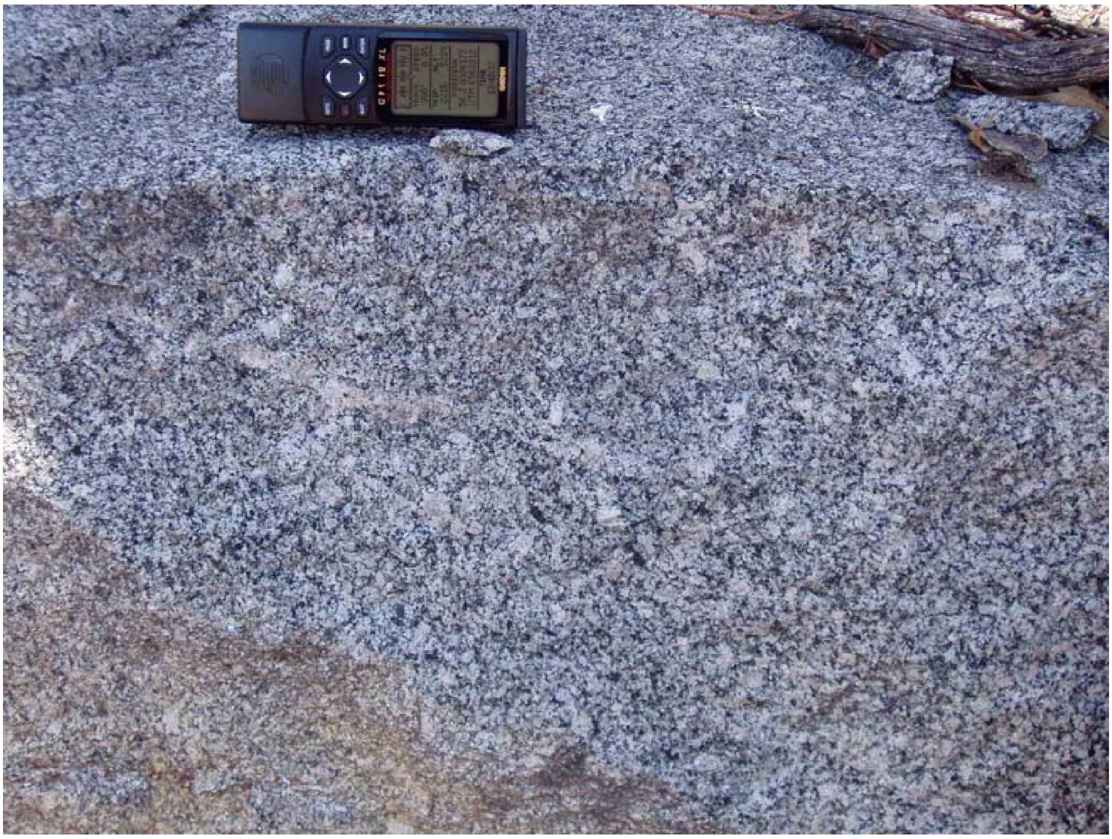


Figure 3-Q. First vertical derivative of the reduced to pole magnetic image showing the contrast between the granitoids and the Tertiary basalts.

3.4.5 Moonbi Supersuite

Bryant (2001) has subdivided the I-Type Moonbi Supersuite into two supersuites; the Northern Moonbi Supersuite (NMSS) and the Southern Moonbi Supersuite (SMSS). Members of the SMSS outcropping within the Nandewar study area include the Inlet Monzonite, Attunga Creek Monzogranite, Moonbi Monzogranite, Bendemeer Monzogranite, Limbri Leucomonzogranite, Walcha Road Monzogranite, Back Creek Tonalite, Congi Creek Monzogranite, Campbells Hill Monzogranite, Standbye Monzogranite and Looanga Monzogranite, all of which are situated northeast of Tamworth. Of those intrusions belonging to the Northern Moonbi Supersuite, the Clive Monzogranite is the only member outcropping within the Nandewar study area.

Members of the SMSS are medium- to coarse-grained with prominent pink K feldspar crystals (phenocrysts) (Photograph 3-U) and minor titanite and magnetite grains (Bryant, 2001). These plutons are moderately to strongly oxidised, are geochemically diverse and are more mafic (contain less SiO_2) than their northern counterparts. They are generally less fractionated than members of the NMSS and hence have reduced metallogeny, although W and minor Mo-Cu prospects are recognised in the granites of the Tamworth area (Bryant *et al.,* 2003). Members of the SMSS in the Nandewar study area are generally unfractionated, although the Looanga Monzogranite is an exception.



Photograph 3-U. Moonbi Monzongranite showing pink K feldspar phenocrysts. GR 306060 6563720.

Very little dating of Moonbi Supersuite granitoids has taken place. Kent (1993) quoted K-Ar ages from Cooper *et al.* (1963) from the Inlet Monzonite as 253±5 Ma (hornblende) and 250±5 Ma (biotite), and 248±5 Ma (K-Ar age on biotite) from the Attunga Creek Monzogranite.

Radiometric and magnetic imagery (Figures 3-R and 3-S) identifies SMSS members as largely ovoid bodies with complex internal structure, as outlined by Brown (2003). Geophysical imagery has delineated concentric zonation within most plutons, expressed in both the magnetic and radiometric images, a feature largely diagnostic of the SMSS. Previously unrecognised zoning has been identified in the Attunga Creek Monzogranite as well as concentric zoning in the Bendemeer Monzogranite (Brown, 2003). Radiometric imagery indicates a diverse range of radiometric responses from uniform, very high K, Th and U in the Limbri Leucomonzogranite to the mottled, high K with lower Th and U response in the Walcha Road Monzogranite. Complex jointing is also identified within this body in both magnetic and radiometric imagery, as are regolith effects, producing a U-rich, deep blue smear.

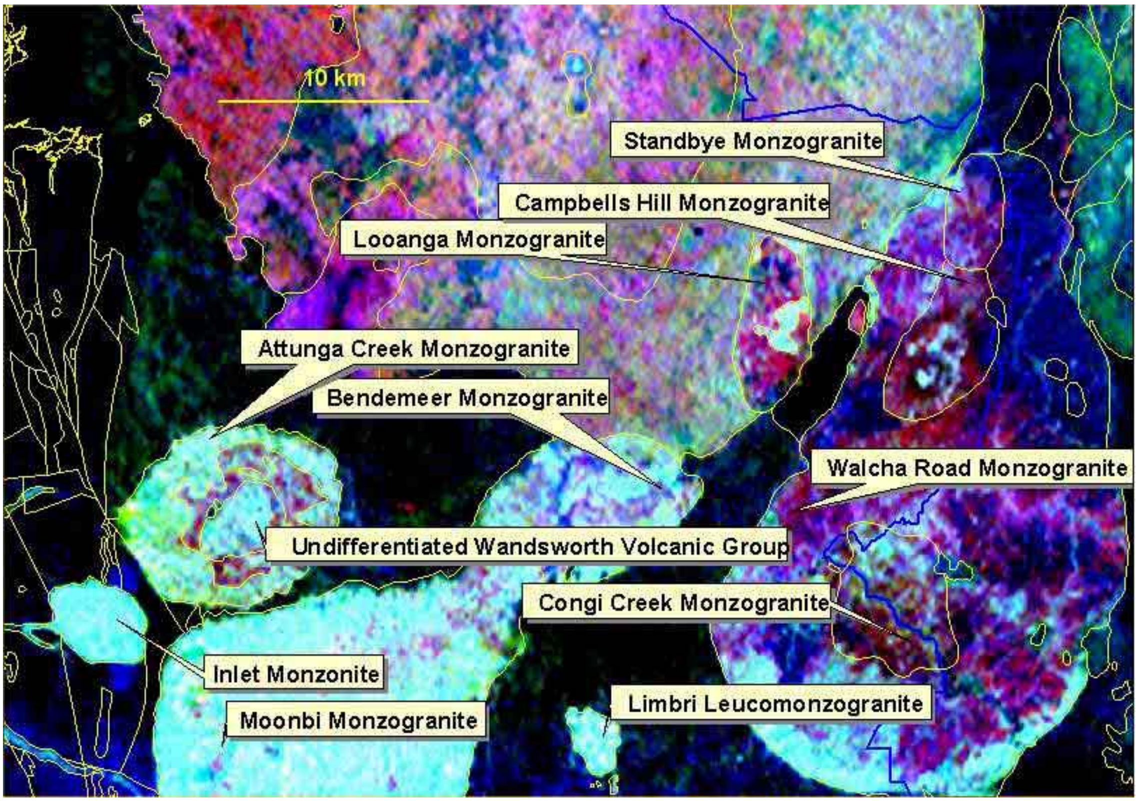


Figure 3-R. Radiometric image of ovoid, zoned granitoids of the Southern Moonbi Supersuite.

3.4.6 'Leucogranites'

In addition to the five suites identified within the New England Batholith by Shaw and Flood (1981), a group of highly fractionated granites informally termed "leucoadamellites" was recognised. Bryant *et al*. (2002) have subsequently reclassified many of these leucogranites into the above mentioned supersuites. In the Nandewar study area the following leucogranites outcrop: The Mole Granite, Webbs Consols Granite, Elsmore Granite, Gilgai Granite and Dumboy-Gragin Granite. These granites form part of a group named by Bryant (2001) as being Western Leucogranites. Due to their highly fractionated chemistry, these granites have been difficult to classify and are tentatively placed within the Uralla Supersuite.

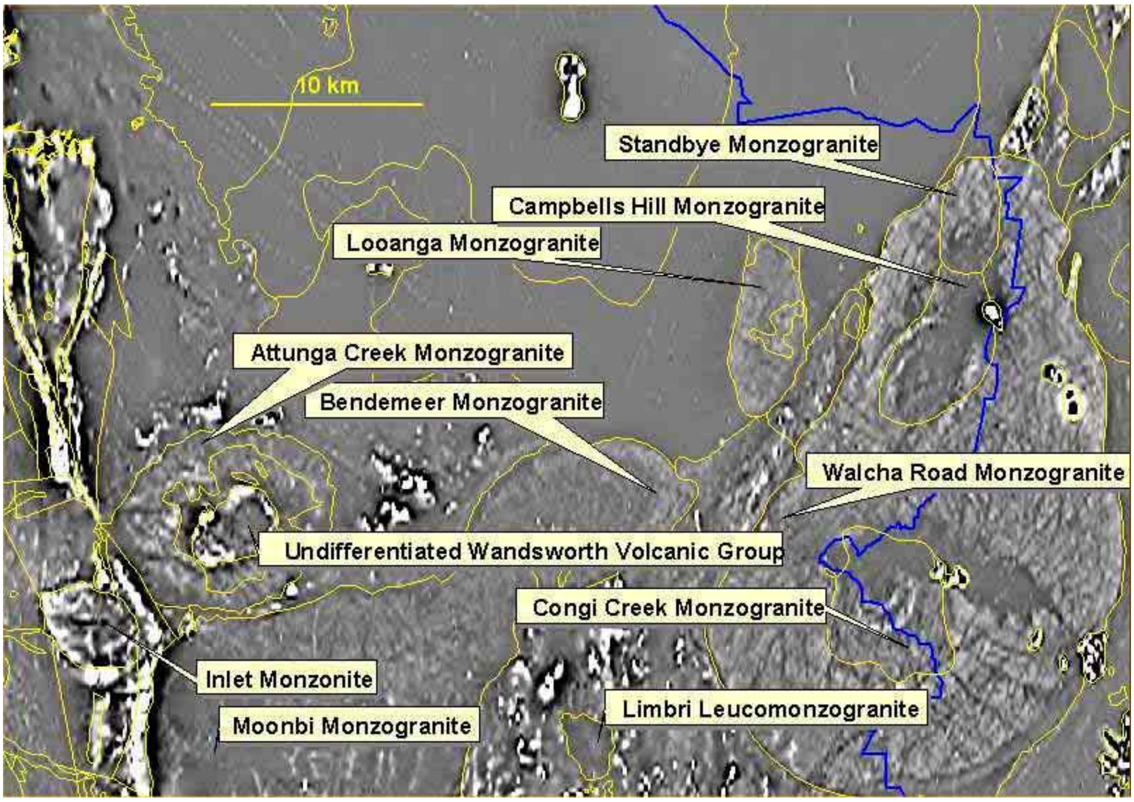


Figure 3-S. First vertical derivative of the reduced to pole magnetic image showing granitoids of the Southern Moonbi Supersuite. Note complex crosscutting jointing within the granitoids and magnetic zoning within the Inlet Monzonite and Attunga Creek Monzogranite.

The leucogranites are I-type, reduced and very felsic in nature (74-77% SiO_2). Their chemistry approximates minimum melt compositions (that is the composition produced from the minimum amount of melt required to produce a magma). Another important feature of these granites is extreme textural variability from fine- to very coarse-grained varieties and an abundance of miarolitic cavities, indicating the presence of a magmatic volatile phase during crystallisation (Bryant, 2001).

The leucogranites in the Nandewar study area are highly mineralised, a product of extreme fractionation of the crystallising magma. These granites were emplaced to a shallow crustal level where they concentrated magmatic fluids, degassed, and hydrothermally altered the granite. The fluids are commonly rich in metals such as tin, tungsten, copper, lead, silver, and arsenic and may produce gem quality topaz, beryl and emerald.

Leucogranites share distinctive geophysical properties. They are all extremely rich in radioelements, producing a white radiometric response reflecting high K, Th and U, which clearly distinguishes them from the less fractionated granites belonging to the Uralla, Moonbi and Bundarra supersuites (Figure 3-T). The leucogranites are reduced, and hence contain ilmenite rather than magnetite in their mineral assemblage. Because of this, the granites are magnetically non-responsive. There is an important exception to note; the Gilgai Granite has a highly variable magnetic signature that is difficult to explain.

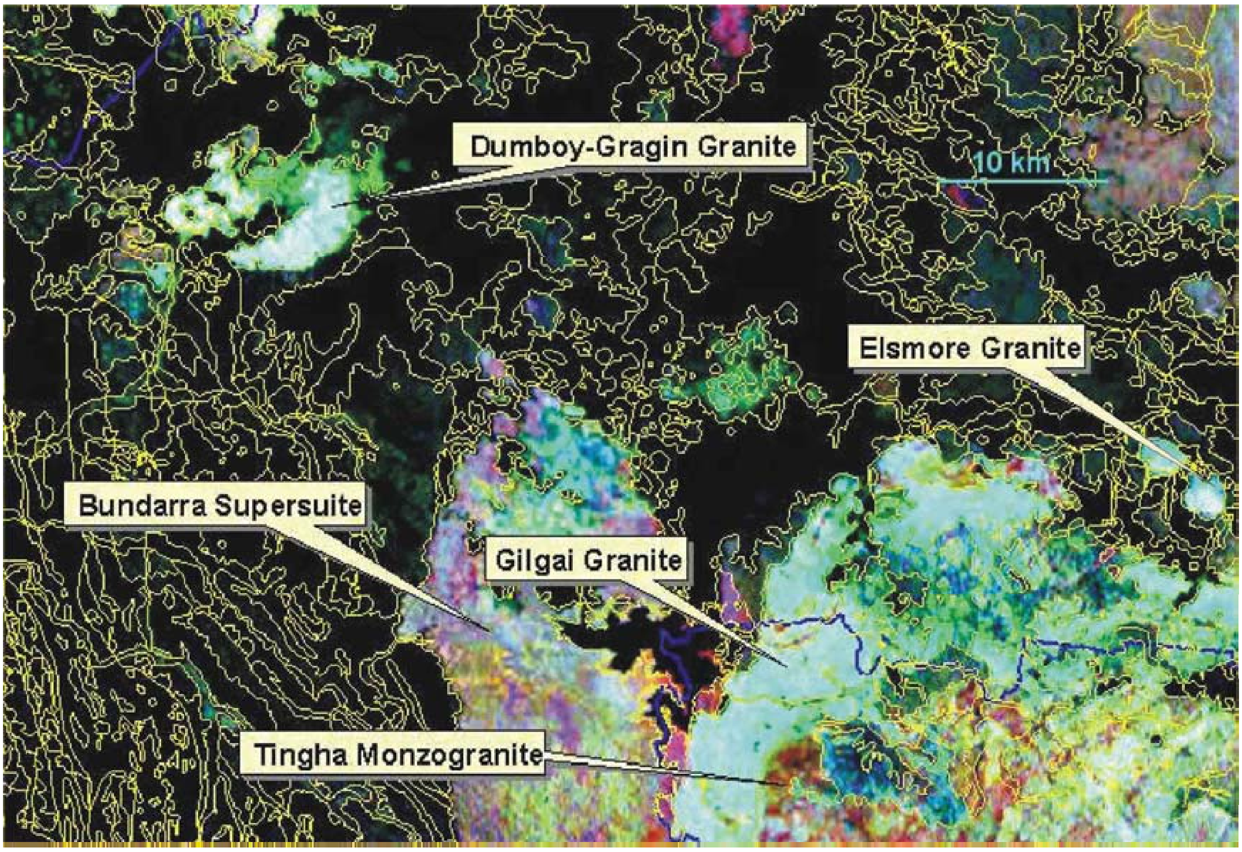


Figure 3-T. Contrasting radiometric signatures of the leucogranites (Gilgai, Elsmore and Dumboy-Gragin) with nearby Bundarra Supersuite and Tingha Monzogranite of the Uralla Supersuite.

3.4.7 Unclassified intrusive rocks

Unclassified intrusive rocks that form part of the New England Batholith are generally small outcropping bodies of limited extent that have been mapped previously, or are newly recognised bodies on the basis of their geophysical signatures. Unclassified bodies range in composition from granitoid to gabbro and are scattered throughout the study area. Granitic bodies are more abundant in the northern portions of the study area where they intrude basement rocks such as the Carboniferous Texas Beds. In the southern portions of the Nandewar study area small gabbroic bodies have been identified that intrude Devonian Tamworth Group sediments.

Two small, highly conspicuous bodies have been identified by recent geophysical surveys in the northern and central portions of the Nandewar study area. These are the informally named “Fox Tor Diorite” and “Willowie Diorite” and have been described by Brown (2003) and Brown (in press). The Fox Tor Diorite has intruded into the Pringles Monzogranite of the Bundarra Supersuite north of Tamworth. It is tentatively classified as being part of the Moonbi Supersuite by Brown (in press) on the basis of geochemistry, magnetic susceptibility and a K-Ar date that reveals an Early Triassic age of 239.7±6.7 Ma. It is poorly distinguished from the Pringles Monzogranite on the basis of radiometric imagery, producing a similar K-Th-U-rich response. The northerly Willowie diorite also intrudes along the western margin of the Bundarra Supersuite southwest of Ashford and is petrographically similar to the Fox Tor Diorite, though geochemical analysis has not yet been undertaken on this intrusive rock. It produces a pale green radiometric response indicating moderate radioelement abundance with Th greater than K and U. The Willowie and Fox Tor diorite bodies produce intense magnetic highs that indicate plug-like structures for both intrusive bodies.

3.5 PERMO-TRIASSIC BASINS

PERMO-TRIASSIC BASINS

In the Nandewar study area includes the Sydney-Bowen Basin, the Werrie Basin and the Warialda Trough;

The Sydney-Bowen Basin:

- Includes the Gunnedah Coalfield and the Hunter Coalfield;
- The Permian comprises early felsic and mafic volcanics, overlain by later, terrestrial and marine sediments that contain coal-bearing horizons
- Triassic depositional environments include braided stream, deltaic and lacustrine environments;
- Was locally disrupted during the latest Permian to Early Triassic by the Hunter Bowen Orogeny proximal to the Hunter-Mooki Thrust System;
- Originated as an Early Permian rift basin in a back-arc setting.

Werrie Basin:

- Comprises a succession of Early to Late Permian sedimentary and igneous rocks;
- Is dissected by the east-west oriented Murrurundi Fault;
- Unconformably overlies sediments of the Tamworth Belt;
- Bounded to the west by the Hunter-Mooki Thrust;
- Comprises sediments and volcanics that were deposited in a range of environments that include terrestrial, shallow marine and lacustrine.

Warialda Trough:

- Middle to Late Triassic in age;
- Unconformably overlies basement rocks of the New England Fold Belt;
- Unconformably overlain by Surat Basin sediments and Tertiary volcanics;
- Comprises sediments that were deposited in high-energy valley-fill and braided stream environments.

3.5.1 Introduction

The Early Permian and Middle Triassic saw those rocks on the western side of the of the New England Fold Belt subject to periods of extension and compression with a resulting development of thick sedimentary basins. Structural elements of three such Permo-Triassic basins are contained within the Nandewar study area – the Sydney-Bowen Basin, Werrie Basin, and the Warialda Trough (Figure 3-U). Figure 3-V is a detailed correlation chart comparing the stratigraphies of the Sydney-Bowen and Werrie Basins as well as the Warialda Trough.

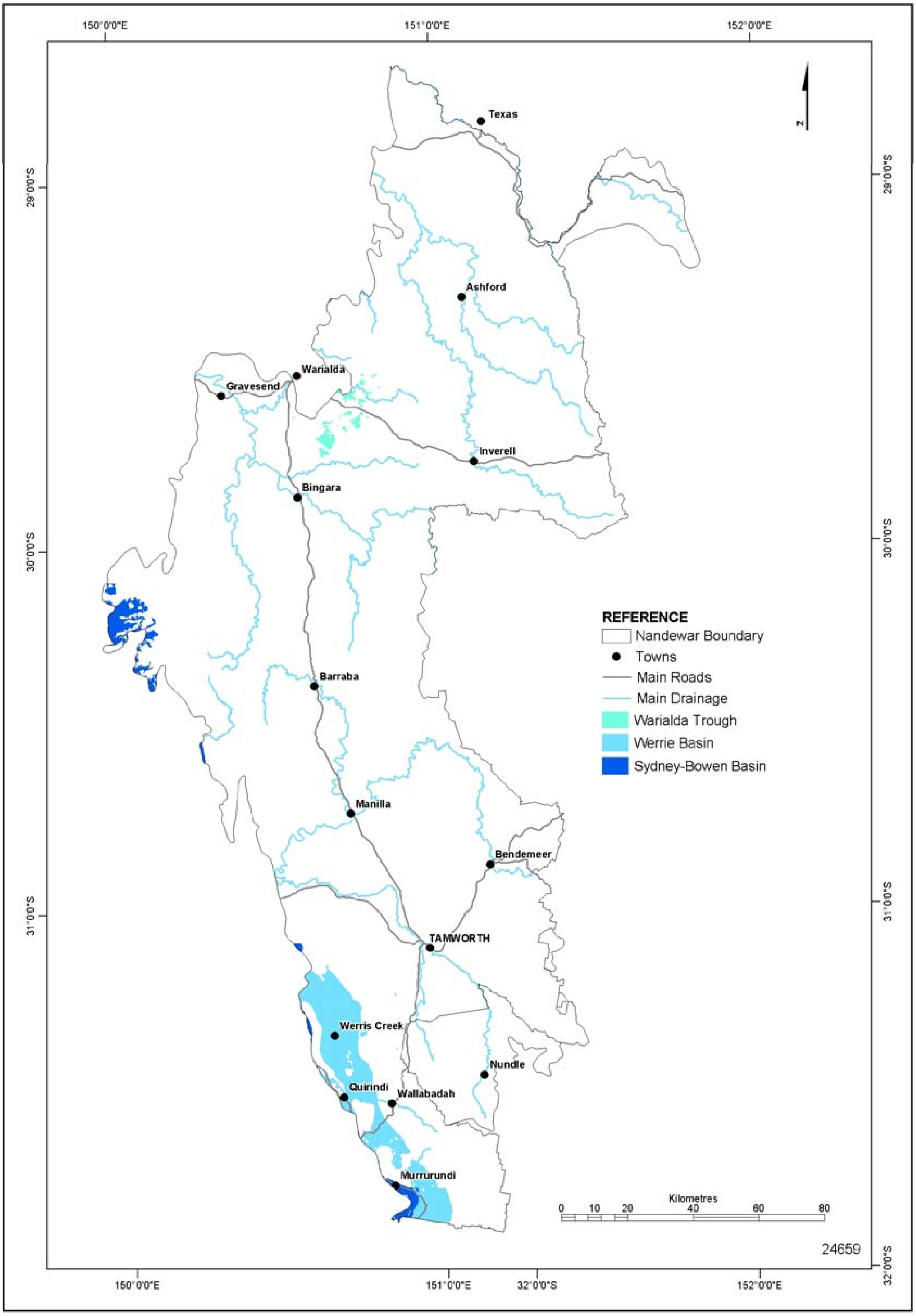


Figure 3-U. Surface distribution of Permo-Triassic basins in the Nandewar study area.

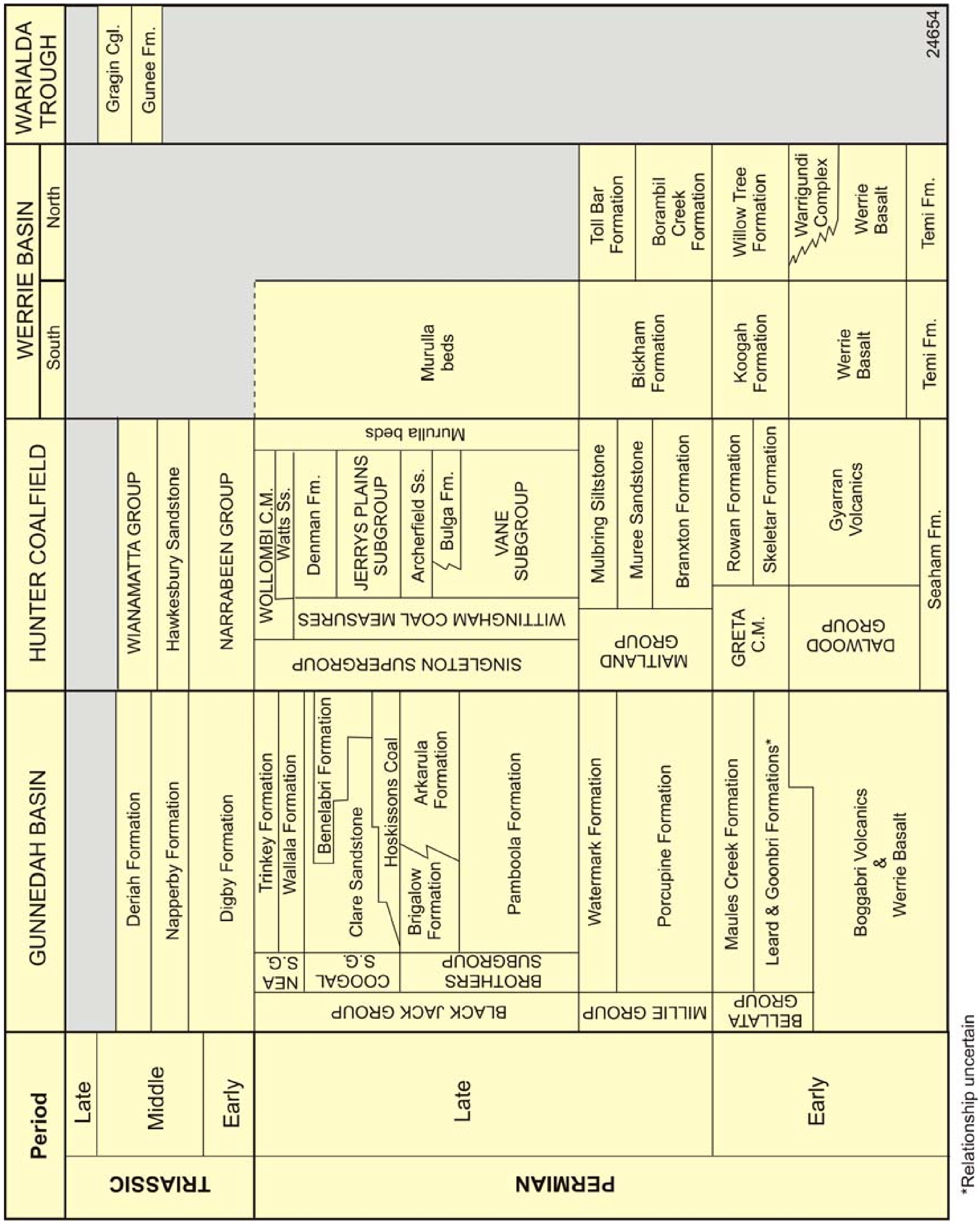


Figure 3-V. Stratigraphic correlation chart for the Sydney-Bowen and Werrie Basins, and the Warialda Trough.

3.5.2 Sydney-Bowen Basin

Gunnedah Coalfield

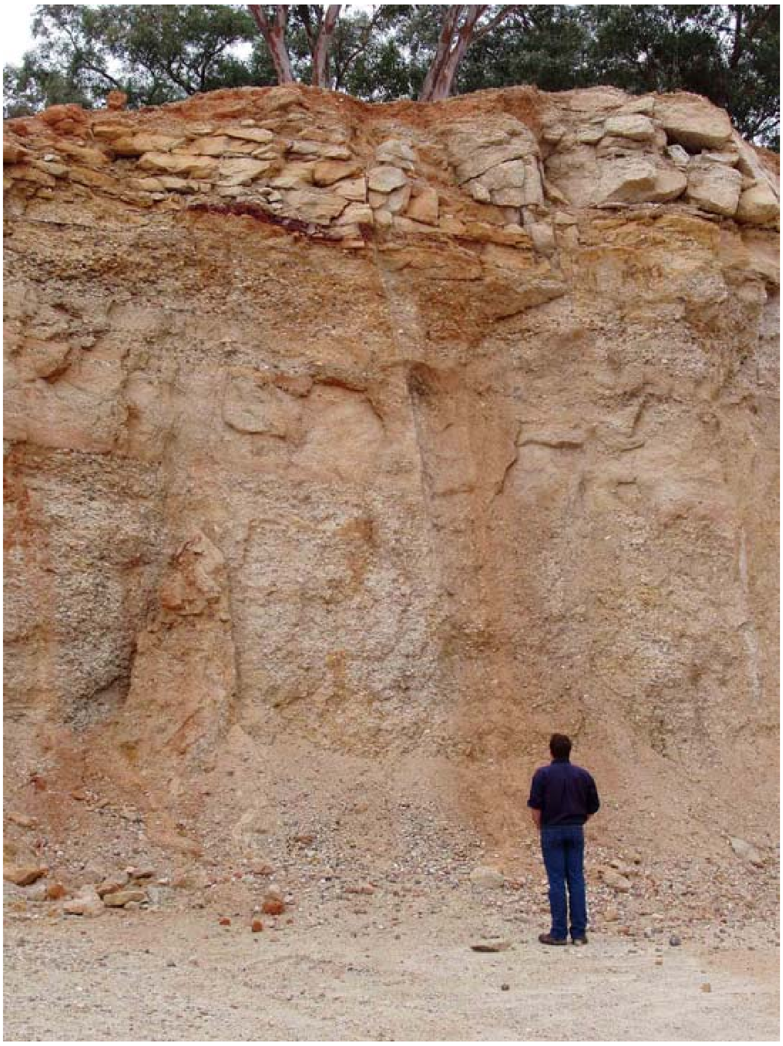
Development of the Gunnedah Coalfield began with the extrusion of felsic to intermediate volcanics (Boggabri Volcanics; Hill, 1986) in the early Early Permian. Mafic volcanics (Werrie Basalt; Branagan, 1969) are interbedded towards the top and overlie the Boggabri Volcanics in the Gunnedah Coalfield. A late Early Permian deep weathering profile and colluvial deposits consisting of kaolinitic clayrocks [Leard Formation; coal-bearing sequence (Brownlow, 1980)] developed on the Boggabri Volcanics and Werrie Basalt. A series of lacustrine to prograding delta deposits (Goonbri Formation; Etheridge, 1986) were then deposited on top of the Leard Formation. Conglomeratic braided stream (alluvial fan) deposits of the Maules Creek Formation (coal-bearing sequence) overlie the Leard and Goonbri Formations.

In the early Late Permian, a marine transgression turned the Sydney-Bowen Basin into a palaeo-sea. The manifestations of this on the Gunnedah Coalfield are the marine conglomerates and sandstones of the Porcupine Formation. These are overlain by the shallow marine siltstones and mudstones of the Watermark Formation, deposited during the regression of the palaeo-sea. The late Late Permian Black Jack Group (coal-bearing sequence) displays a range of depositional settings with influxes of sediment from the New England Fold Belt and Lachlan Fold Belt. The variations extend from deltaic deposits (Hoskissons Coal; Pamboola Formation), to shallow marine deposits (Arkarula Formation), to braided and meandering stream deposits (Wallala Formation, Clare Sandstone), to tuffaceous coal swamps (Trinkey Formation) (Tadros, 1993; Pratt, 1998).

Movement along the Hunter-Mooki thrust associated with the Hunter-Bowen Orogeny during the latest Permian and Early Triassic had a marked effect on the depositional regime in the Gunnedah Coalfield. Thrusting is manifest as an angular unconformity between the Permian part of the Gunnedah Coalfield and the Triassic Digby Formation in the Nandewar Range and Willow Tree areas (Hill, 1986). The Early to early Middle Triassic Digby Formation (Beckett *et al.,* 1983) consists of lower conglomerates (Bomera Conglomerate; Photograph 3-V) fining upwards into a series of cross bedded sandstones toward the top (Ulinda and Wollar Sandstone). The Middle Triassic Napperby Formation (Russell and Middleton, 1981) conformably overlies the Digby Formation and comprises fine sandstone and mudstone that typify the lacustrine and delta front depositional regime for this unit. Finally, the Middle Triassic Deriah Formation (Hill, 1986) near the Nandewar Ranges marks the end of deposition in the Gunnedah Coalfield.

Only a small part of the far-eastern portions of the Gunnedah Coalfield occur within the Nandewar study area. Most of the coalfield that does outcrop in the study area occurs beneath the Nandewar Ranges. The rest exists as small slivers on the edge of the study area. The Boggabri Ridge, a north-northwest trending basement high, effectively divides the Gunnedah Basin into two sub-basins, the Mullaley Sub-basin to the west and the Maules Creek Sub-basin to the east.

The Maules Creek Sub-basin is located east of the Boggabri Ridge, and is bounded to the north by basalts of the Nandewar Range, to the east by the Hunter-Mooki Thrust Fault System, and to the south and west by basal volcanics of the Boggabri Ridge. The Maules Creek Sub-basin contains sediments that onlap the Boggabri Ridge to the west and thicken eastward to greater than 1000 metres. The eastern boundary of the sub-basin is the east dipping Hunter-Mooki Thrust Fault, beneath which Permian sedimentary rocks are thought to occur. Up to 25 correlated coal seams ranging in thickness from 0.3 to 3.5 metres are found in the sub-basin (Table 3-A). These seams, part of the Maules Creek Formation, generally thicken in the western part of the sub-basin (Wiles, 1996).



Photograph 3-V. Quarry face showing shallowly dipping Bomera Conglomerate (Digby Formation). Photo taken at Willow Tree tip. GR 283230 6494300.

The Mullaley Sub-basin extends the length of the Gunnedah Basin, from Moree in the north to the Liverpool Range in the south. The western limit of Permian rocks is the Rocky Glen Ridge while the Boggabri Ridge forms the eastern boundary. As with the Maules Creek Sub-basin, the Mullaley Sub-basin basement consists of the Werrie Basalt and Boggabri Volcanics. Overlying the volcanics are the Early Permian Leard, Goonbri and, Maules Creek Formations. These units are then overlain by the Late Permian Porcupine and Watermark Formations and the Black Jack Group. The Triassic Digby and Napperby Formations overlie the Permian strata. In the Mullaley Sub-basin, there are a number of correlated coal seams (Table 3-B). These seams occur in the Black Jack Group and generally thicken to the south of the Mullaley Sub-basin (Murrurundi Trough).

Table 3-A. Coal seam nomenclature for the Maules Creek Sub-Basin, after Wiles (1996).

MAULES CREEK SUB-BASIN	
Maules Creek nomenclature	**Vickery nomenclature**
Herndale seam	Tralee seam
Onavale seam	Gundawarra seam
Teston seam	Welkeree seam
Thornfield seam	Kurrumbede seam
Braymont seam	Shannon Harbour Upper seam
Jeralong seam	Shannon Harbour Lower seam
Merriown seam	Stratford seam
Velyama seam	Blue Vale seam
Nagero seam	Cranleigh seam
Upper Northam seam	
Lower Northam seam	
Therribri seam	
Flixton seam	
Tarrawonga seam	
Templemore seam	

Table 3-B. Coal seam nomenclature for the Mullaley Sub-basin, after Wiles (1996).

MULLALEY SUB-BASIN	
Southern Mullaley Sub-basin	**Northern Mullaley Sub-basin**
Doona seam	
Springfield seam	
Clift seam	
Breeza seam	
Howes Hill seam	
Caroona seam	
Hoskissons Coal	Hoskissons Coal
Melvilles Coal Member	Melvilles Coal Member

Hunter Coalfield

Although the Hunter Coalfield extends from the Liverpool Ranges to east of Singleton, in the Nandewar study area it only outcrops in the extreme south around the town of Murrurundi. The two units outcropping are the late Late Permian Murulla beds and the Early Triassic Narrabeen

Group. North of Scone, the Singleton Supergroup (Black Jack Group equivalent) lacks the prominent marker beds farther to the south (examples of which include the Watts Sandstone, Denman Formation, Bayswater Seam, Archerfield Sandstone and Bulga Formation). Consequently, the Singleton Supergroup to the north of Scone has been grouped by Manser (1968) and named the Murulla beds. From field and drillcore inspection (Wancol Murrurundi DDH1, Elecom Scone-Murrurundi DDH1), the Murulla beds can be divided into three sequences. These sequences are a lower sandstone sequence, an upper conglomeratic sequence, and, a relatively thin tuffaceous and coaly interval approximately 300 metres above the base of the conglomerate.

Overlying the Murulla beds are the thick, braided-stream conglomerate and sandstone deposits of the Narrabeen Group (Joplin *et al.,* 1952). The boundary between the Murulla beds and the Narrabeen Group is difficult to identify, although Pratt (2000) suggests that the boundary occurs at the top of the tuffs, coal or carbonaceous claystones in the Murulla beds. Deep (greater than 500 metres) beneath the Murulla beds and Narrabeen Group in the Murrurundi area the lower units of the Hunter Coalfield are assumed to occur (although no drilling has yet intersected these rocks). These units are the Dalwood Group (Boggabri Volcanics and Werrie Basalt equivalent), Greta Coal Measures (Bellata Group equivalent), and Maitland Group (Millie Group equivalent).

3.5.2 Werrie Basin

Almost wholly contained within the Nandewar study area, the Werrie Basin unconformably overlies the Tamworth Belt, with the western boundary defined by the Hunter-Mooki Thrust, while the southern boundary was previously defined by the Murrurundi Fault (Carey, 1934). New mapping in this study has outlined a southern extension of the primary Werrie Basin that extends approximately 20 kilometres to the south of the Murrurundi Fault. Two stratigraphies exist for the Werrie Basin: that defined by Offenberg (1968) north of the Murrurundi Fault; and that defined by Manser (1968), south of the Murrurundi Fault. The stratigraphies of the northern and southern parts of the Werrie Basin are shown in Figure 3-V.

Werrie Basin – North

The Werrie Basin north of the Murrurundi Fault, contains a series of Early to Late Permian sedimentary and igneous rocks. Units comprising the northern part of the basin include the Temi Formation, Warrigundi Igneous Complex, Werrie Basalt, Willow Tree Formation, Borambil Creek Formation, and the Toll Bar Formation. The Temi Formation (Photographs 3-W and 3-X) marks the beginning of sedimentation in the Werrie Basin and is up to 220 metres thick (McPhie, 1984). Terrestrial conglomerates and coarse sandstones of the lower Temi Formation (>100 metres thick) give way to fine sandstone, siltstone, carbonaceous shale and coal in the upper part of the unit (>100 metres thick). As well as coal deposits, oil shale deposits have been reported (Lishmund, 1971) towards the base of the Temi Formation. A series of mafic to felsic volcanic and volcaniclastic rocks of the Werrie Basalt and Warrigundi Igneous Complex intrude and overlie the Temi and Currabubula Formations with conformable and unconformable relationships respectively. The Werrie Basalt is up to 1500 metres thick and is comprised dominantly of basalt (Branagan, 1969). Tuffs, agglomerates, conglomerates and sandstones are interbedded with the basalt flows and are apparently marine in origin (Hanlon, 1948). Dolerite dykes and sills up to five metres thick, coeval with the Werrie Basalt, are commonly observed intruding the Currabubula and Temi Formations in the Werrie Basin. The Warrigundi Igneous Complex is made up largely of extrusive andesites, dacites and rhyolites that are in part interbedded with the Werrie Basalt.

Photograph 3-W. Boundary of the Temi Formation (top) and the Currabubula Formation (bottom). Photo taken at Quipolly Dam spillway. GR 281310 6521280.

Overlying the Werrie Basalt is the late Early Permian Willow Tree Formation (Bellata Group equivalent). This unit outcrops in two areas five kilometres south of Werris Creek, and immediately to the west of Willow Tree. Branagan (1969) describes the Willow Tree Formation as consisting of shales, sandstones, grits, conglomerates and bands of concretionary ironstone. The early Late Permian marine sedimentary rocks of the Borambil Creek Formation (Porcupine Formation equivalent; Photograph 3-Y) and Toll Bar Formations (Watermark Formation equivalent) are consistently fossiliferous and consist of conglomerate, sandstone, mudstone and limestone.

Photograph 3-X. Clast-supported conglomerate, Temi Formation. Elecom Scone-Murrurundi DDH4.

Photograph 3-Y. Matrix-supported conglomerate, Borambil Creek Formation. Photo taken near Willow Tree. GR 284540 6494190.

Werrie Basin - South

The proposed southern extension of the Werrie Basin (south of the Murrurundi Thrust Fault) contains the Temi Formation, Werrie Basalt, Koogah Formation, Bickham Formation and Murulla beds. Figure 3-W shows the geology and extent of the southern Werrie Basin. The lowermost units are the same as those to the north of the Murrurundi Fault (Temi Formation and Werrie Basalt). The late Early Permian (coal bearing strata) Koogah Formation overlies the Werrie Basalt and comprises three distinctive and contrasting facies. The lower facies [Leard Formation equivalent (Beckett *et al.,* 1983)] consists essentially of kaolinitic and flint clays and hosts the 'G' seam (Table 3-C) of the Bickham Coal Proposal area. Drillcore inspection in this study (Wancol Blandford DDH1) has defined a sequence of lacustrine to delta front deposits up to 75 metres thick, containing the 'F' coal seam (Table 3-C). This unit could be tentatively correlated with the Goonbri Formation of Etheridge (1986) in the Gunnedah Coalfield. The upper facies (Maules Creek Formation equivalent) is composed almost entirely of quartz-lithic sandstones and conglomerates up to 200 metres thick and hosts the 'E' to 'A' coal seams (Table 3-C). The early Late Permian Bickham Formation [Porcupine and Watermark Formation equivalent (Photograph 3-Z)] overlies the Koogah Formation and consists of lithic conglomerates and sandstones of marine origin. Above the Bickham Formation is the late Late Permian, terrestrial coal sequence of the Murulla beds (Black Jack Group equivalent). From field and drillcore inspection (Wancol Murrurundi DDH1, Elecom Scone-Murrurundi DDH1), the Murulla beds can be divided into three sequences. These sequences are a lower sandstone sequence, an upper conglomeratic sequence, and, a relatively thin tuffaceous and coally interval approximately 300 metres above the start of the conglomerate.

Overall, the Werrie Basin is a synclinal structure, laterally compressed and folded internally into a western anticline along the leading edge of the Hunter Mooki Fault and an eastern syncline. Dips on the edge of the margins of the basin are generally moderate to steep. Domes and saddles within the basin provide the largest areas of outcrop of the gently dipping to sub-horizontal Temi Formation (Rio Tinto Pty Ltd & Werrie Gold Ltd 1997).

Table 3-C. Coal seam nomenclature, thickness, and ash for the Koogah Formation, Southern Werrie Basin.

Seam	Thickness	Ash
A	3 m	15.00%
B	*	*
C	2 - 2.75 m	>30%
D	0.5 m	16%
E	6.4 - 7.6 m	7.2 - 9.6%
F	1.25 m	6.1 - 9.4%
G	6.2 - 11.5 m	4 - 5.9%
* No Data available		

Photograph 3-Z. Matrix-supported conglomerate, Bickham Formation. Wancol Blanford DDH1.

3.5.3 Warialda Trough

The Warialda Trough is a Middle Triassic sedimentary sequence that unconformably overlies the New England Fold Belt and the Bowen Basin, 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 (Barnes *et al.,* 2002). These sediments comprise terrestrial coarse to fine clastic sediments that range in thickness up to 200 metres. Warialda Trough sediments nonconformably overlie the Early Triassic Dumboy-Gragin Granite, from which they are largely derived, and so it is estimated that in excess of 1000 metres of New England Fold Belt rocks have been eroded in less than 20 million years (Barnes *et al.,* 2002). The trough sediments comprise the Middle Triassic Gunnee Formation and Gragin Conglomerate that were deposited in a high-energy valley-fill and braided stream environment (Bourke, 1980; quoted in Barnes *et al.,* 2002).

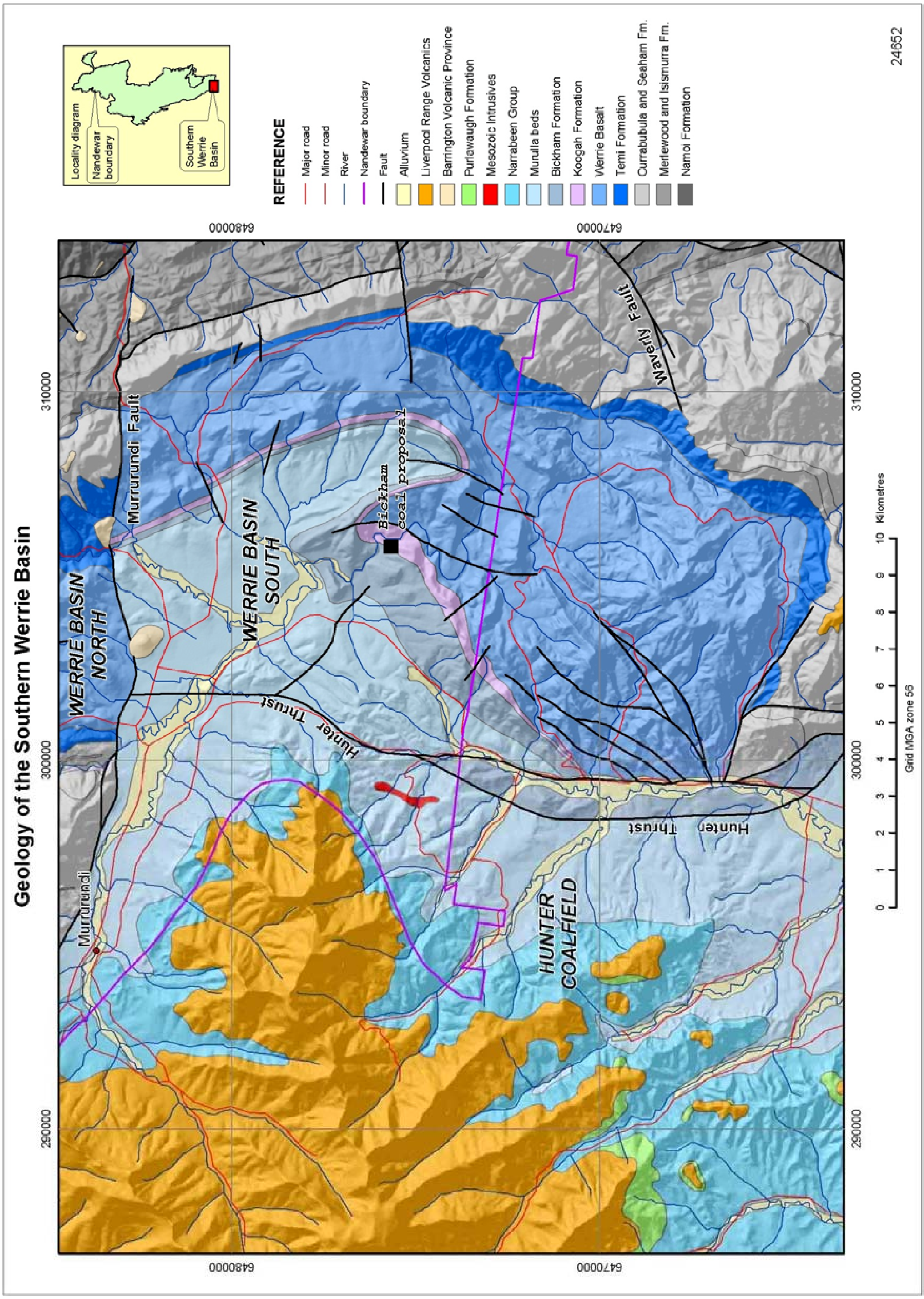


Figure 3-W. The geology of the Southern Werrie Basin.

The Gunnee Formation comprises coarse arkosic arenite with finer grained interbeds of arenite and argillite (Stroud, 1989), locally grading into paraconglomerate (Photograph 3-AA). The lithologies are immature, particularly near the underlying contact with the Dumboy-Gragin Granite, the provenance of a significant proportion of the unit. Plant macro and microfossils have been recorded that place the age of the unit as Middle Triassic (Bourke et al., 1977; quoted in Stroud, 1989). The geophysical signature of the Gunnee Formation reflects the provenance of these rocks, that is derivation from a radioelement rich, strongly fractionated granite. Despite the obvious similarities, the Gunnee Formation can be distinguished from the nearby Dumboy-Gragin Granite by its slightly lower radiometric response. The magnetic response is essentially identical to the Dumboy-Gragin Granite.

The Gragin Conglomerate overlies the Gunnee Formation and comprises a thick sequence of moderately well sorted orthoconglomerates with minor interbeds of arenite (Stroud, 1989). Clasts are pebble to conglomerate, well rounded, and are dominated by felsic volcanics with minor sedimentary clasts that include chert and quartzite (Photograph 3-BB). The provenance of the Gragin Conglomerate differs from that of the underlying Gunnee Formation, the latter lacking felsic volcanic clasts (Stroud, 1989). Macro and micro fossil data place the age of the Gragin Conglomerate as Middle Triassic (Bourke *et al.,* 1977; quoted in Stroud, 1989). Like the Gunnee Formation, the Gragin Conglomerate can be distinguished from the nearby Dumboy-Gragin Granite by its slightly lower radiometric response. The radiometric and magnetic responses of the Gragin Conglomerate cannot be distinguished from those of the Gunnee Formation and the Dumboy-Gragin Granite.

Photograph 3-AA. Outcrop of clast-supported paraconglomerate (Gunnee Formation). Photo taken near Warialda. GR 276060 6711600.

Photograph 3-BB. Outcrop of a clast-supported orthoconglomerate (Gragin Conglomerate). Photo taken near Warialda. GR 284170 6728540.

3.6 SURAT BASIN

SURAT BASIN

Comprises sediments of Early Jurassic to Early Cretaceous age;

Forms part of the Great Australian Basin;

Unconformably overlies the Sydney-Bowen Basin, Warialda Trough and the New England Fold Belt in the Nandewar study area;

Is overlain by Tertiary volcanics and Quaternary sediments;

Comprises sediments that were deposited in a continental basin containing early fluvial sediments and terrestrial volcanics with later sequences typical of a cyclic marine transgressive and regressive environment;

Comprises the following stratigraphic units that outcrop within the Nandewar study area (from base):

- Hutton Sandstone, Walloon Coal Measures, Purlawaugh Formation, Pilliga Sandstone, and the Rolling Downs Group.

3.6.1 Introduction

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–Early Cretaceous continental basin and contain early fluvial sediments and terrestrial volcanics and later marine transgressive-regressive sequences that have been folded into very gentle regional anticlines and synclines. Overlying these basin sediments are Tertiary sediments and volcanics. The stratigraphy of the Surat Basin in the Nandewar study area can be observed in (Figure 3-X). 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 (Figure 3-Y).

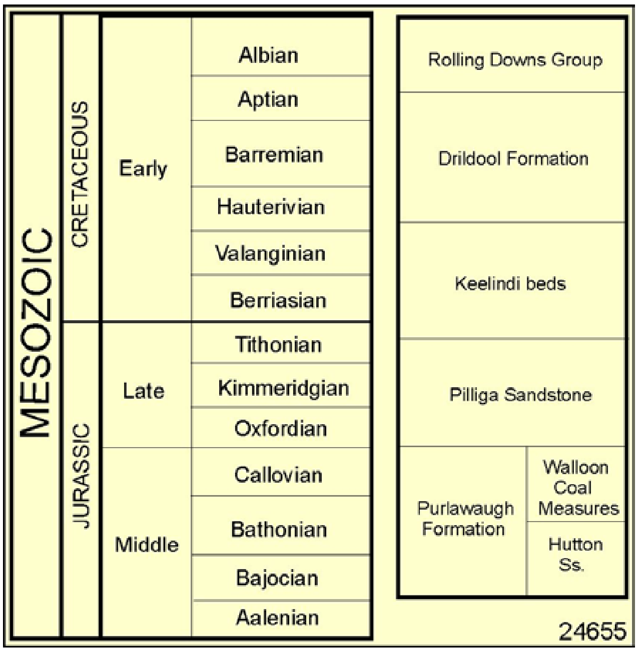


Figure 3-X. Stratigraphy of the Surat Basin in the Nandewar study area.

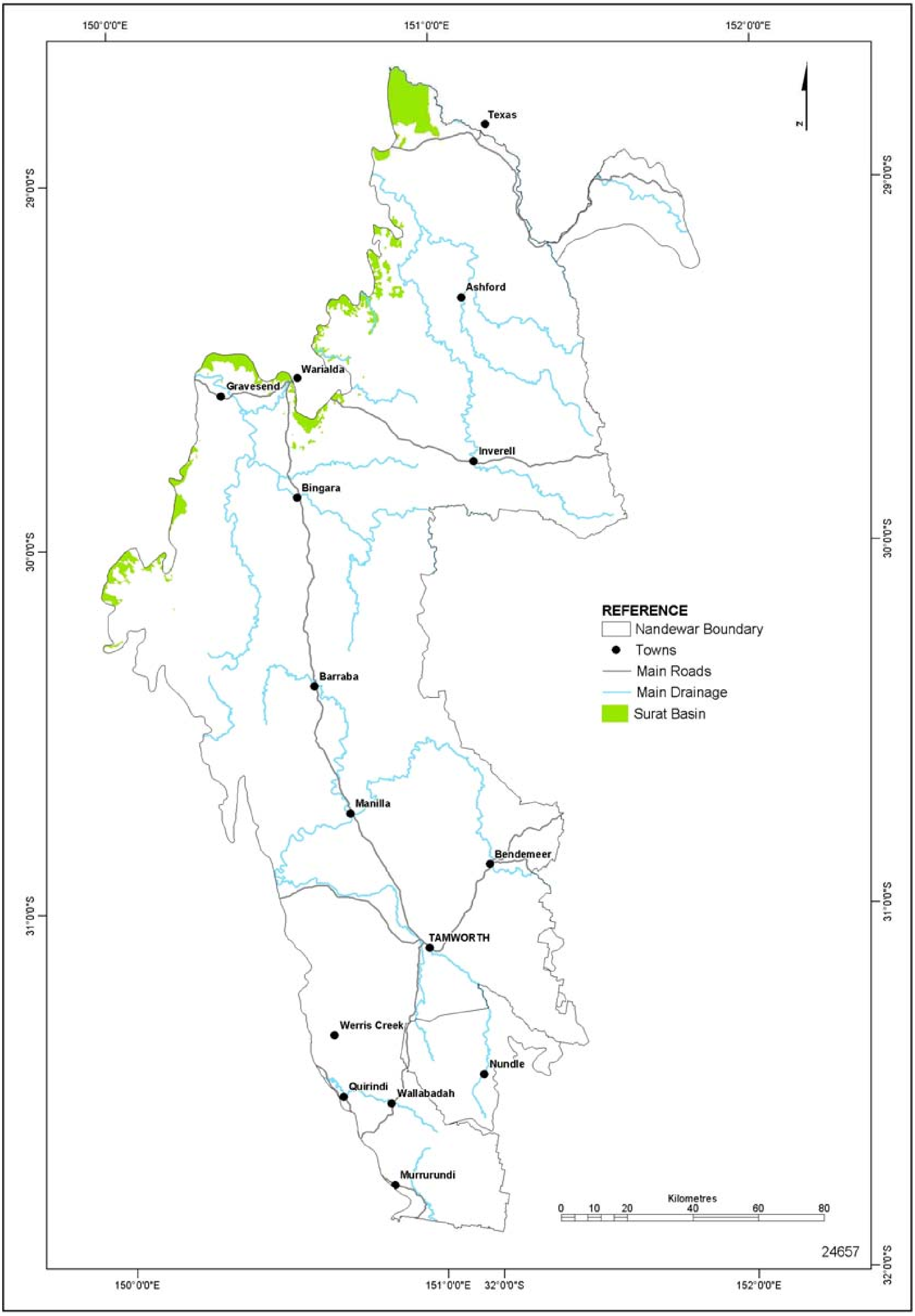


Figure 3-Y. Surface distribution of the Surat Basin in the Nandewar study area.

3.6.2 Stratigraphy

In the Nandewar study area, the Hutton Sandstone (Mollan *et al.,* 1972) outcrops in the Warialda area and in a north-south elongate strip from near Terry Hie Hie to the west of Gravesend. The unit is wedge shaped and increases in thickness to the north and west of Warialda. The Hutton Sandstone is dominantly composed of medium- to coarse-grained quartzose sandstone (Photograph 3-CC). Other minor lithologies in the Hutton Sandstone include conglomerate, fine sandstone, siltstone, mudstone, carbonaceous shale and coal. Bourke (1980) divided the Hutton Sandstone into three sub-units: two coarse-grained sub-units (upper and lower) that are separated by a mudstone, siltstone and coal sub-unit.

The Walloon Coal Measures (Exon, 1976) conformably overly the Hutton Sandstone, and are in turn overlain by the Pilliga Sandstone. Lithologies for the Walloon Coal Measures include a lower portion that consists of coarse- to medium-grained lithic sandstone, and an upper portion that contains fine sandstone, siltstone, shale and coal. This unit was deposited in a series of swamps and lakes during a period of volcanism (Bourke, 1980). However, Bourke (1980) was unsure of the source of the volcanics.

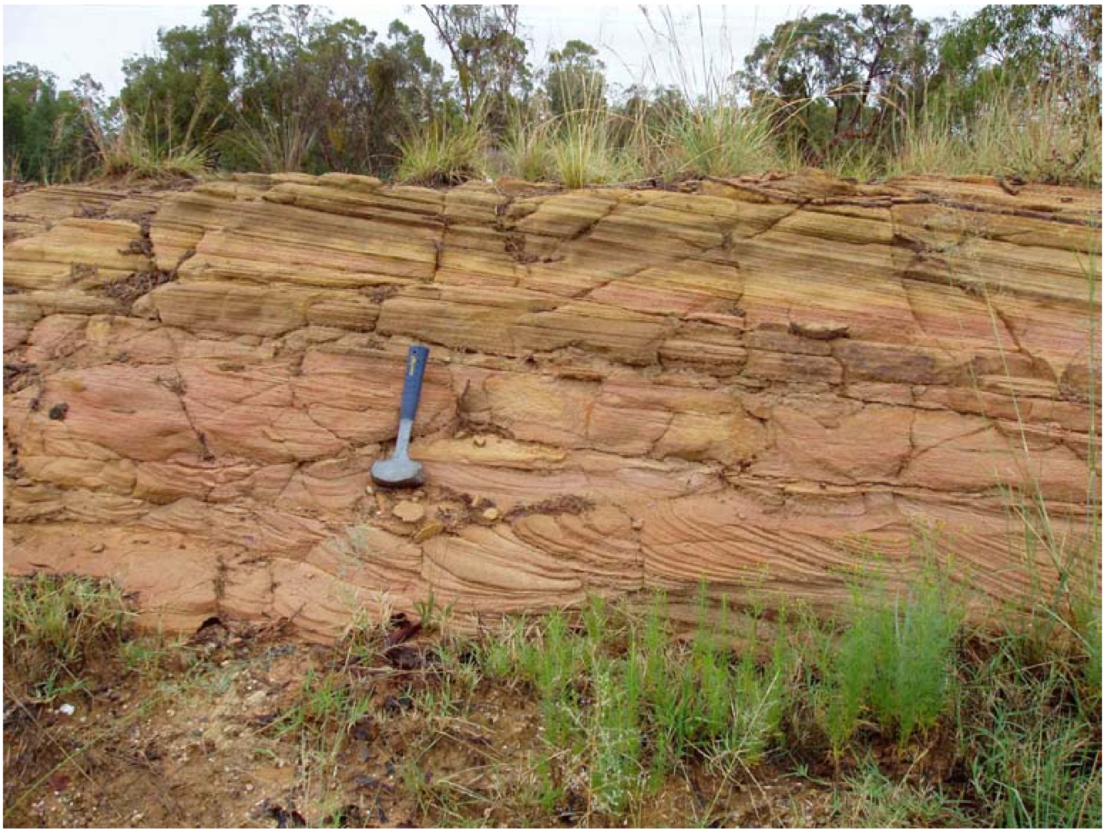
The Middle Jurassic Purlawaugh Formation (Dulhunty, 1973) can be broadly correlated with the Hutton Sandstone and Walloon Coal Measures and is dominated by smectic and kaolinitic clayrocks with minor sandstone, coal and fossil wood. Outcrop of the Purlawaugh Formation in the Nandewar study area occurs on the old New England Highway northwest of Murrurundi (Dulhunty, 1939). In this area, the Purlawaugh Formation rests unconformably on the Narrabeen Group (Arditto, 1980), and is unconformably overlain by the Tertiary Liverpool Range Volcanics. Environments of deposition of the Purlawaugh Formation include lacustrine (Dulhunty and Eadie, 1969), meandering stream and as valley fill (Loughnan and Evans, 1978).

The Late Jurassic Pilliga Sandstone (Dulhunty, 1939), a major freshwater aquifer in the Warialda district (Bourke, 1980), conformably overlies the Walloon Coal Measures and unconformably rests on the Tamworth Belt. Lithologies comprise a series of monotonous coarse- to medium-grained cross-bedded quartzose sandstone with a kaolinitic matrix (Photograph 3-DD). Minor lithologies in the Pilliga Sandstone include conglomerate ‘lags’, fossil wood horizons and ferruginised 'ironstone' layers. The Pilliga Sandstone was deposited as a fluvial braided stream sequence (Arditto, 1980).

Overlying the Pilliga Sandstone is the late Late Jurassic to Early Cretaceous Keelindi beds (Hawke and Cramsie, 1984). The Keelindi beds comprise the Orallo Formation, Mooga Sandstone and the lower Bungil Formation and consist of fine sandstone, siltstone, claystone, carbonaceous shale and coal. Environments of deposition for the Keelindi beds are fluvial and lacustrine (Hawke and Cramsie, 1984).

The Early Cretaceous Drildool Formation (Hawke and Cramsie, 1984) does not outcrop in the Nandewar study area, although it is expected to occur beneath the Rolling Downs Group. This unit was deposited in a shallow marine-shoreline environment and comprises the upper part of the Bungil Formation (Reiser, 1969).

Photograph 3-CC. Outcrop of the Hutton Sandstone showing massive quartzose sandstone. Photo taken west of Gravesend. GR 232130 6729340.



Photograph 3-DD. Outcrop of the Pilliga Sandstone showing cross bedding. Photo taken east of Warialda. GR 272000 6725120.

Rocks constituting the Early Cretaceous Rolling Downs Group in the Nandewar study area occur just to the north of the Nandewar Ranges. This unit is marine in character and contains claystone and siltstone.

South of Terrie Hie Hie, a group of unnamed Triassic to Jurassic sedimentary rocks, resting on the Tamworth Belt is overlain by the Pilliga Sandstone. Lithologies for this unit consist of lithic coarse-sandstone and polymictic conglomerate. Although more research is required to clearly define possible relationships with this unit, the conglomeratic member looks similar to the Digby Formation (Gunnedah Coalfield).

3.6.3 Geophysics

All of the sedimentary rocks within the Surat Basin have little or no magnetic response, but other geophysical responses (for example gamma ray data) can vary quite significantly (Hawke and Cramsie, 1984). The radiometric responses from airborne geophysical surveys for units within the Nandewar study area are as follows:

- Hutton Sandstone; low K, low Th, moderate to high U,
- Walloon Coal Measures; moderate to high K, low to moderate Th, low to moderate U
- Purlawaugh Formation; low K, low Th, low U
- Pilliga Sandstone; low K, moderate to high Th, low U
- Keelindi beds; moderate K, low Th, low U
- Rolling Downs Group; low K, low to moderate Th, low U (this may be related to regolith formation on the Rolling Downs Group).

3.7 MESOZOIC INTRUSIVES

MESOZOIC INTRUSIVES
A number of small unnamed plug-like centres within the Nandewar study area, in the central west and south;
Intrude sediments of the Tamworth Belt;
Includes a small intrusion at Ruby Hill south of Bingara that contains garnet-rich eclogitic xenoliths;
Produces prominent bright blue radiometric and high magnetic responses.

Mesozoic intrusives are widely scattered in the southern portion of the Nandewar study area, outcropping in three localities; Ruby Hill just south of Dinoga along the Fossickers Way, approximately 12 kilometres north of Upper Horton and approximately ten kilometres southeast of Murrurundi. These intrusions are small circular to ovoid plug-like structures less than one kilometre in width. The two northerly intrusions produce prominent bright radiometric responses that contrast markedly with the surrounding Noumea beds and Luton Formation of the Parry Group (Figure 3-Z). Magnetics similarly produce an intense, magnetic high that is easily differentiated from the surrounding magnetically subdued sediments (Figure 3-AA).

A small intrusion at Ruby Hill comprises basaltic breccia with abundant inclusions of garnet-rich eclogite and granulite (Brown, 1986). Several east-west trending alkali olivine basalt dykes have intruded this plug-like structure. Palaeomagnetic studies indicate a Jurassic age for the intrusion, which has been confirmed by K-Ar dating of a sanidine megacryst (Brown, 1986).

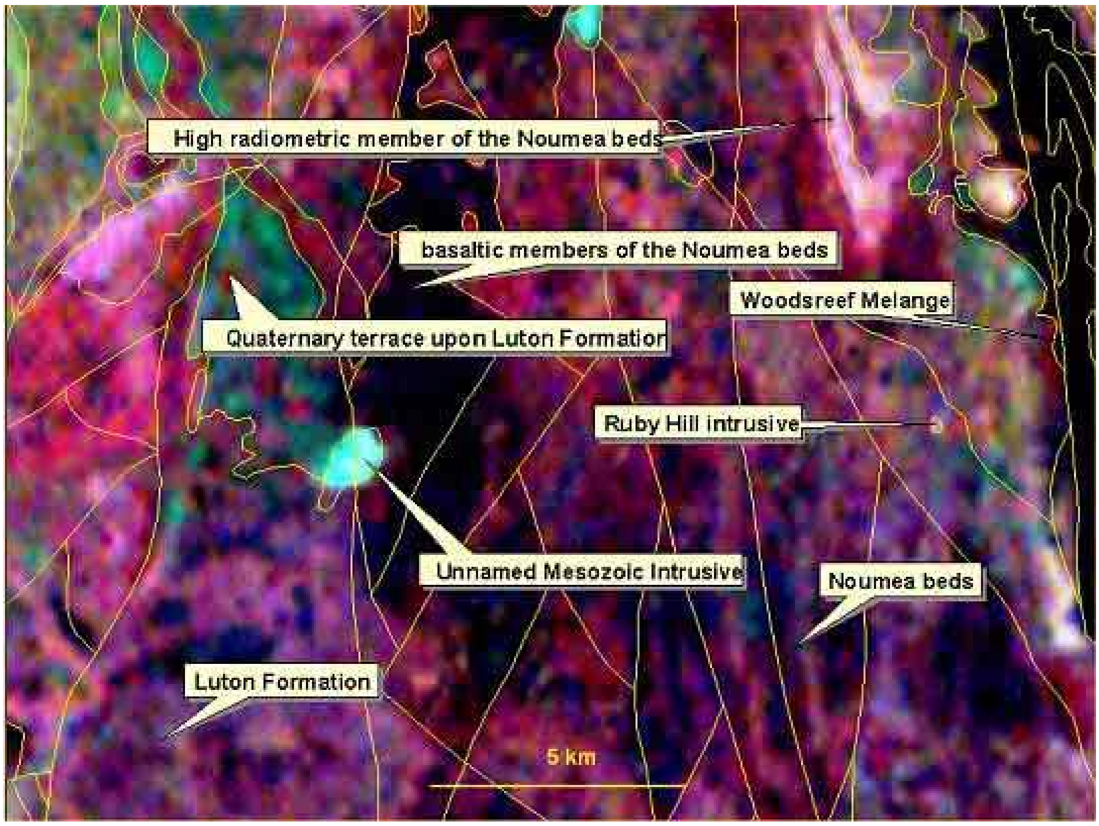


Figure 3-Z. Prominent high radiometric response of the unnamed Mesozoic intrusive.

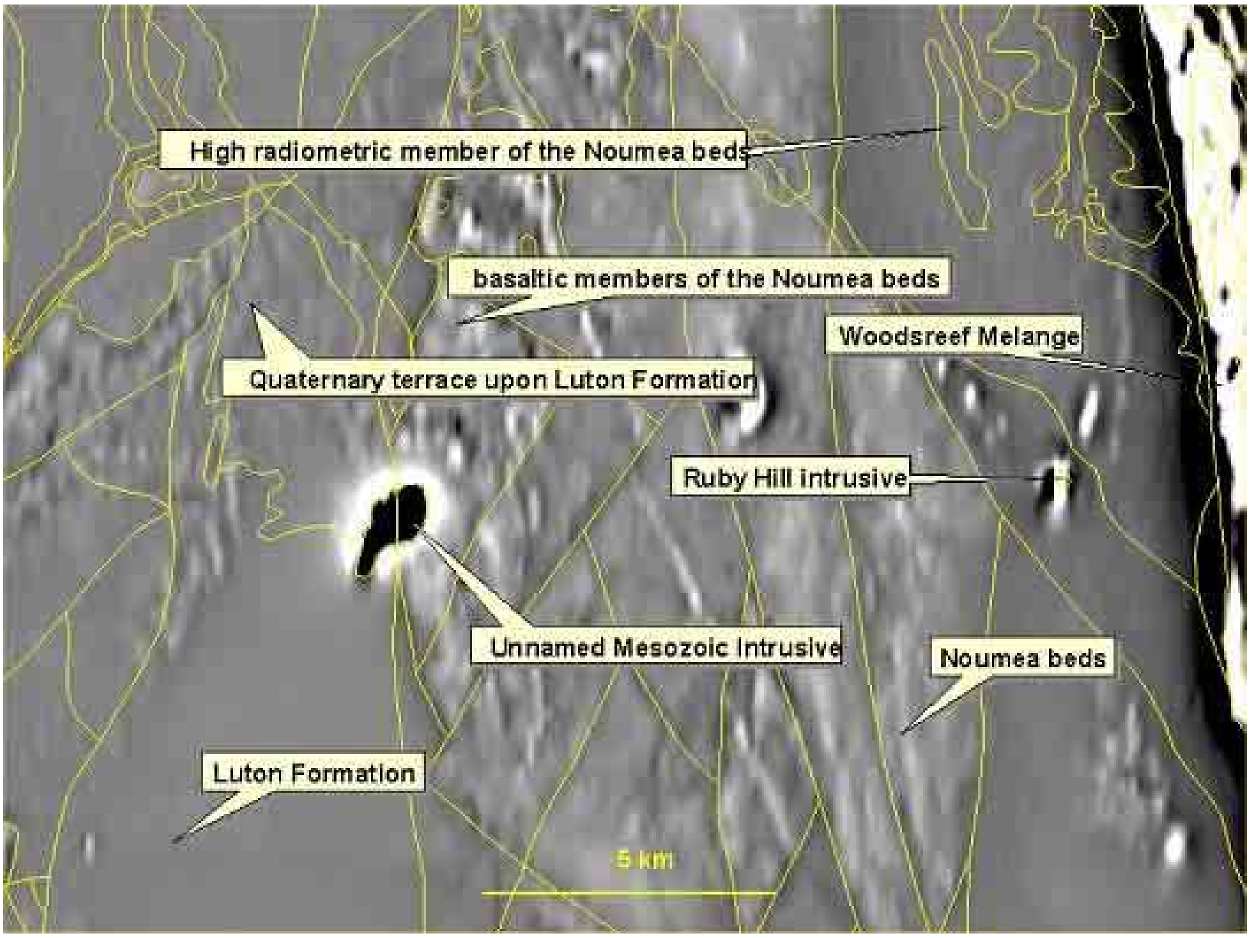


Figure 3-AA. First vertical derivative of the reduced to pole magnetic image showing the intense magnetic anomalies associated with the Mesozoic intrusives.

3.8 TERTIARY UNITS

TERTIARY UNITS

Are dominated by basaltic volcanic rocks and associated sediments;

Comprise four distinct volcanic associations within the Nandewar study area:

- Barrington Volcanic Province - of middle Eocene age, dominated by volcanic rocks of alkaline basaltic composition and outcropping in the extreme south of the study area;
- Liverpool Range Volcanics - of late Eocene age in the Nandewar study area, dominated by volcanic rocks of alkaline mafic to ultramafic composition outcropping on the south western margin of the study area;
- Central Province - comprises two suites; an Eocene to Oligocene alkaline association dominated by basaltic lavas with minor phonolitic plugs and early volcaniclastic sapphire-bearing sediments, and a Miocene aged tholeiitic association dominated by basaltic lavas with subordinate volcaniclastic sediments;
- Nandewar Volcanic Province - of early Miocene age, comprising an alkaline association that includes, rhyolitic plugs and flows, trachyte and subordinate mafic flows;

Typically contain coarse clastic sediments at the base of successions that may or may not be associated with volcanism;

Are spatially associated around a central volcanic edifice, except the Central Province tholeiitic association;

Preserve deep lead deposits of diamonds, tin and gold throughout the northern portions of the Nandewar study area;

Are the result of intraplate volcanism in Eastern Australia that stretched from Victoria to Queensland in the Tertiary.

3.8.1 Introduction

Quiescent periods 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). Units constituting the Early Tertiary sediments and subsequent volcanic piles are developed on basement of New England Fold Belt, producing prominent volcanic edifices, the remnants of which are still present today. Lava field provinces produced large flat-topped tablelands in the northern portions of the Nandewar study area. The Tertiary volcanic material is almost always associated with a distinct high frequency magnetic signature. This appears on the magnetic data as "spotty" high and low magnetic values that are due to the highly varying occurrence of magnetite in these rocks. The surface distribution of Tertiary units can be observed in Figure 3-BB.

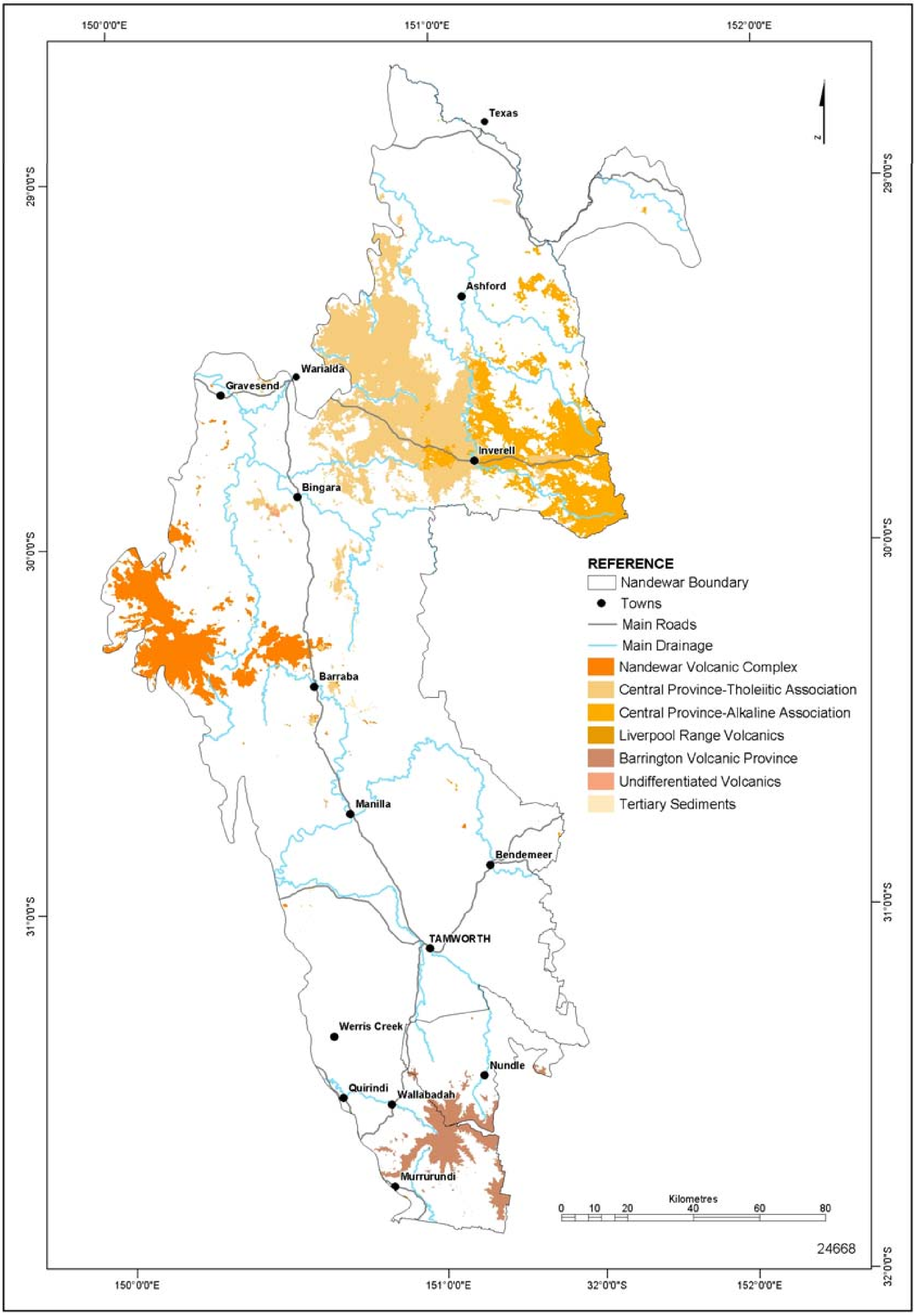


Figure 3-BB. Surface distribution of Tertiary units in the Nandewar study area.

3.8.2 Barrington Volcanic Province (informal)

Tertiary basalts outcropping in the southern portion of the Nandewar study area, northeast of Murrurundi, are tentatively placed within the Barrington Volcanic Province of Sutherland and Fanning (2001), on the basis of field relations and K-Ar dating. The Barrington Volcanic Province is dominated by an alkaline succession of basaltic flows derived from the Barrington and Mt. Royal volcanoes, and possibly includes the older Square Top intrusion (59 Ma), west of Nundle (Wellman and McDougall, 1974; Scheibner and Basden, 1998). Basalts within the Nandewar study area that outcrop between the Square Top intrusion and the Mt. Royal Volcano have been dated at 43 Ma and 53 Ma (Wellman and McDougall, 1974) and are therefore included within the Barrington Volcanic Province. It should be noted that similar petrography and age between the Barrington Volcanic Province and the nearby Walcha Province precludes definite identification of these volcanic rocks of which little petrography is reported. Wellman and McDougall (1974) constrain the age of the Barrington Volcano, based on 15 K-Ar dates, between 55-43 Ma. Sutherland and Fanning (2001) report successively younger ages of gem-bearing eruptions at 57, 43, 38, 28 and 4-5 Ma by zircon fission track dating methods. There are no recent geophysical surveys over this area to further aid identification of these Tertiary volcanic rocks.

3.8.3 Liverpool Range Volcanics

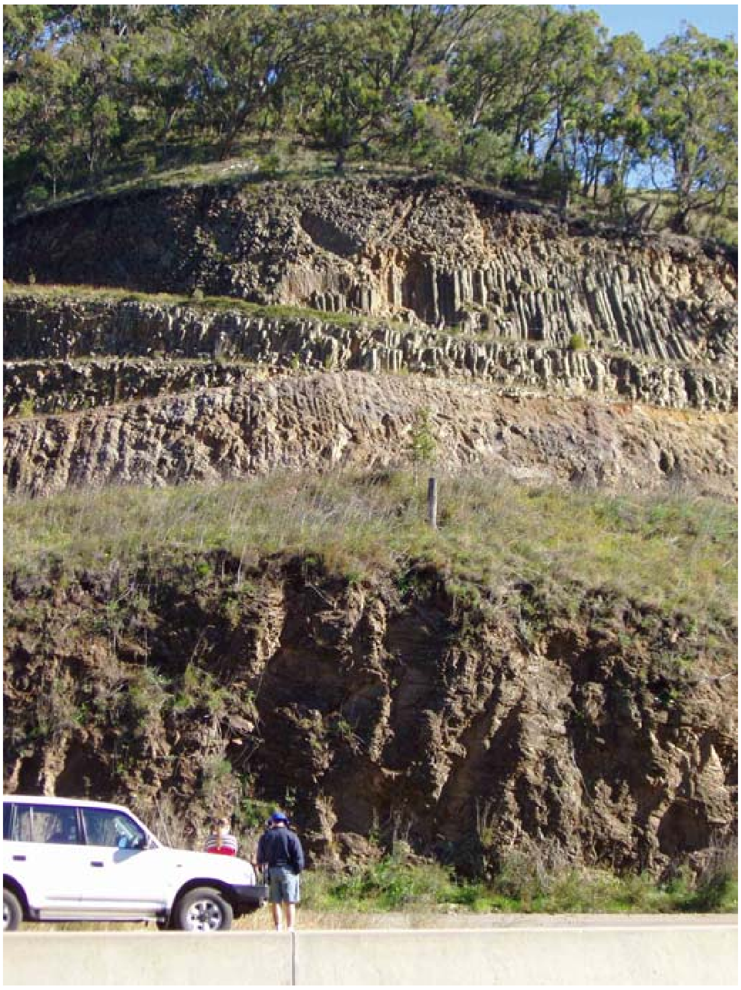
The Liverpool Range Volcanics crop out along the western boundary in the southern portion of the Nandewar study area, south of Murrurundi. Wellman and McDougall (1974) describe the Liverpool Volcano as highly dissected with a present-day thickness of 850 metres. K-Ar dating has led to the separation of the Liverpool Range Volcanics into a late Eocene (38-40 Ma) Eastern volcanic division and an early Oligocene (32-35 Ma) Western division (Schon, 1985). In the Nandewar study area, only rocks of the eastern volcanic division outcrop.

The Eastern volcanic division forms a highly dissected spine less than 400 metres wide and comprises an alkalic undersaturated series of mafic to ultramafic rocks dominated by alkali olivine basalts with rare hawaiites and mugearites (Schon, 1985). Two compositional suites are recognised within the Liverpool Range Volcanics, a nepheline-normative and hypersthene-normative suite, but only the nepheline-normative compositions occur in Nandewar. Composition ranges from up to 17% normative nepheline in basanites to less than 5% nepheline in the more common alkali olivine basalts. Thick flows of columnar jointed basalt are quite common in the eastern volcanic division of the Liverpool Range Volcanics (Photograph 3-EE).

3.8.4 Central Province (informal)

Introduction

Northern portions of the Nandewar study area are dominated geologically by Tertiary basalts and associated volcaniclastics of the Central Province. Radiometric and magnetic imagery has enabled the recognition and clear delineation of two suites of rocks; an older Oligocene-Eocene alkaline association related to the Maybole volcanic centre, and a Miocene aged lava field association of tholeiitic basalts. Previous workers have identified and mapped these associations, for example Coenraads (1991). Recent geophysical surveys conducted by the Department of Mineral Resources have confirmed the validity of this mapping using magnetic and radiometric data. The alkaline association has been well documented, due to the spatial and genetic connection to sapphire occurrence (Oakes *et al.,* 1996; Sutherland *et al.,* 1993; Barron, 1987; T.J. & P.V. Nunan Pty Ltd 1992; Pecover and Coenraads, 1989). Similarly, the tholeiitic association has been studied, due in part to spatial relationships of these basalts to diamond occurrence as deep leads in the Copeton and Bingara districts (Davies *et al.,* 2002).



Photograph 3-EE. Columnar jointed basalt in the Liverpool Range Volcanics, New England Highway, north of Murrurundi. GR 290070 6487830.

Central Province Alkaline association

Basalts

The alkaline association is centred on the Maybole volcano where distribution reflects the radial drainage from the volcanic edifice. Basaltic rocks commonly form linear ridges in the higher country. The alkaline association outcrops over a wide area covering extensive parts of the Glen Innes 1:100 000 and eastern portions of the Inverell 1:100 000 map sheets, obscuring in part the

New England Fold Belt and Mesozoic basin sediments. The alkaline association also includes minor felsic members including phonolite. Potassium-Argon dating has revealed ages between 32.3±0.2 Ma (Smith, 1988; quoted in Coenraads, 1991) to 37±1.5 Ma (Hollis and Sutherland, 1985; quoted in Coenraads, 1991).

The alkaline association produces a dark red/brown radiometric signature, indicating low overall response typical of basalts, but with significantly more K than Th and U (Fig. 3-CC). The radiometric responses are complicated by cover sequences (Tertiary and Quaternary) and deep weathering that has produced a more Th/U-rich signature. The effects of *in-situ* weathering (regolith) development and alluvial/colluvial cover can clearly be seen in the Kings Plains district in the radiometric image where both processes obscure the dark red basaltic material by light blue/green material. In many cases weathering and alluvium/colluvium are difficult to distinguish; further to this, Tertiary volcaniclastics and sediments derived from these rocks are difficult to distinguish using radiometric imagery, both producing a dark green response due to Th being more dominant than the K and U in these rocks.

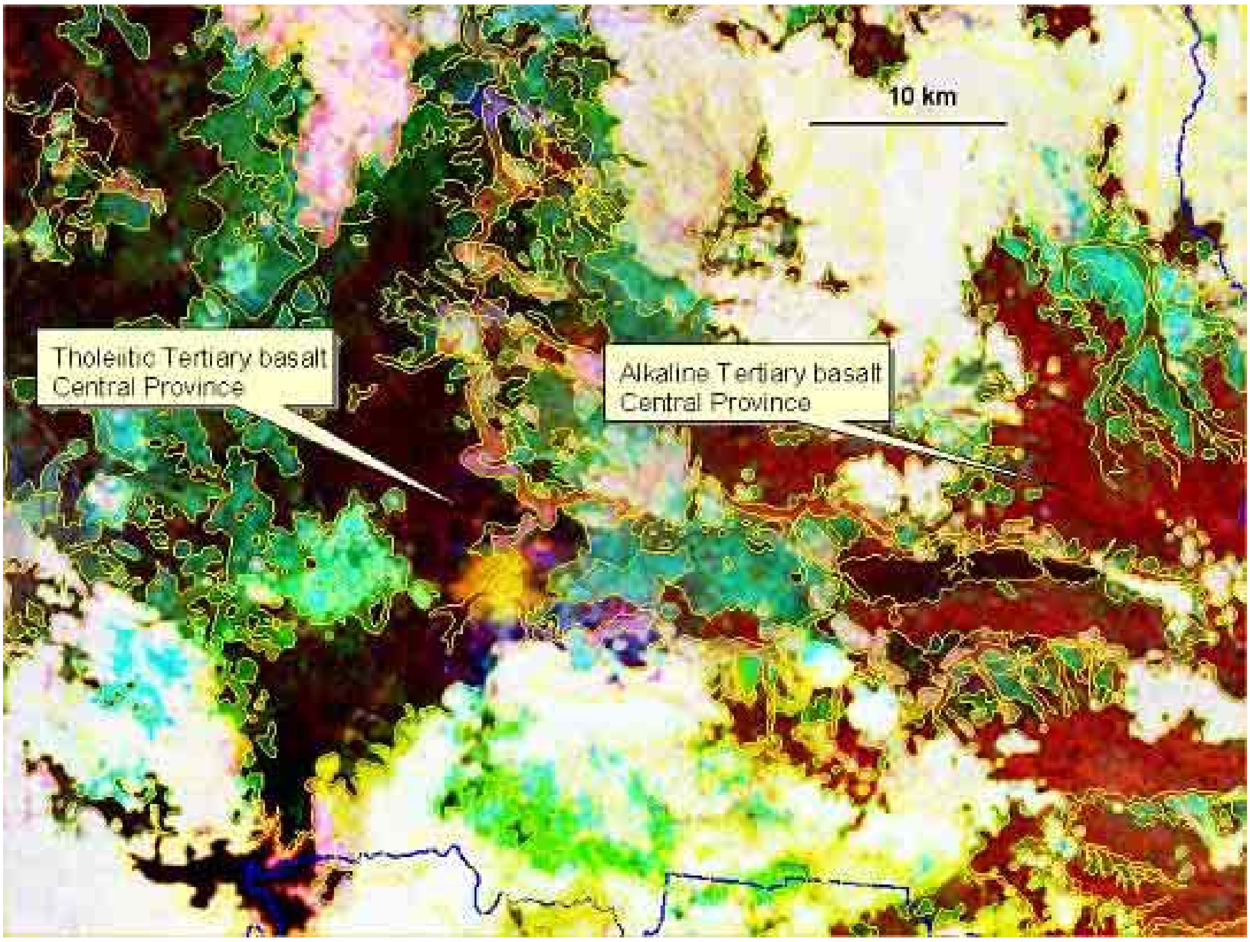


Figure 3-CC. Contrasting radiometric responses of Tertiary alkaline and tholeiitic basalts in the Inverell district.

Volcaniclastic rocks

The alkaline association comprises a sequence of lavas, volcaniclastic rocks (including breccias and tuffs), and sediments derived from the volcanic material. Pecover and Coenraads (1989) postulated several episodes of volcanic eruption followed by erosion and deposition of volcanic-dominated material in a fluvio-lacustrine environment, producing Tertiary gravels, and concentrating sapphires derived from the volcaniclastic material.

Tertiary volcaniclastic rocks are volumetrically minor, outcropping poorly throughout the study area and forming subdued subcrop that produces dark, brick red soils and rarely forms sequences thicker than five metres (Brown and Pecover, 1988a, 1988b). Preservation of volcaniclastic textures is generally poor, though lithic fragments may be readily identified (Photograph 3-FF). The matrix comprises silt to clay sized, strongly ferruginous, clay altered lithic detritus.

Photograph 3-FF. Ferruginous Tertiary volcaniclastic rock. GR 319360 6726340.

Brown and Pecover (1988a) identified two distinct varieties of volcaniclastic rock within the alkaline association; a red lithic volcaniclastic at the base of the volcanic pile, and a white, largely epiclastic volcanogenic rock at, or tens of metres above, the base of the volcanic pile. Barron (1987) identified and classified the alkaline volcaniclastic rocks according to colour (red or white), abundance and type of lithic fragments, and degree of contamination with the basement geology (predominantly Texas beds). He grouped the lithic components as belonging to five "suites", namely basaltic, rhyolitic, granitic, sedimentary and metasedimentary, and organic.

Central Province Tholeiite association

The tholeiitic lava field association is prevalent west of Inverell, forming broad flat plains dotted with small plug-like structures, for example Gragin Peak, northwest of Delungra. There is no obvious central edifice from which these rocks erupted, and they are therefore interpreted as the products of small vent structures and/or fissure eruptions (Duggan, 1972). The tholeiitic rocks produce a black, mottled radiometric signature that stretches west and north, obscuring in part the New England Fold Belt, Warialda Trough sediments and Surat Basin sediments.

Tholeiitic rocks are clearly distinguished from the older alkaline rocks to the east by their radiometric and magnetic signatures. The tholeiitic rocks produce a black signature in radiometric imagery, reflecting lower K abundance than the alkaline rocks. Weathering and/or cover, producing extensive mottling of the radiometric signature commonly obscure the tholeiitic rocks. This effect is amplified by poor outcrop (Photograph 3-GG), corresponding to land that is extensively cropped, pasture improved or cleared for livestock. Tholeiitic volcaniclastic rocks produce a dark green signature due to the Th concentration being higher relative to K and U, similar to their alkaline counterparts. This makes it difficult to distinguish radiometrically from colluvium. In both associations volcaniclastic rocks outcrop poorly and are commonly deeply weathered and ferruginised (Stroud, 1990).

Photograph 3-GG. Typical low lying outcrop of Tertiary basalt of the Central Province. GR 291200 6711630.

Geochemistry

During the geological upgrade process using GIS and new geophysical data, two distinct suites of Tertiary basalt in the Central Province were recognised on the basis of radiometric and magnetic data. These suites were correlated to the eastern, older Oligocene-Eocene alkaline association and the western, younger Miocene tholeiitic association. Coenraads (1991) indicated the approximate boundary between these suites as being the north-south oriented Gwydir River, north of Inverell. This boundary is confirmed by geophysical data.

The integrated use of geophysics with new geochemical data has significantly improved the geological mapping of these associations. A number of basalts were sampled to test the relationship between the radiometric response and chemistry, comprising 23 samples from the Central Province and six samples from a location west of Bingara. Sample locations are shown in Figure 3-DD, and descriptions and geochemical analyses are provided in Appendix 2 and 3.

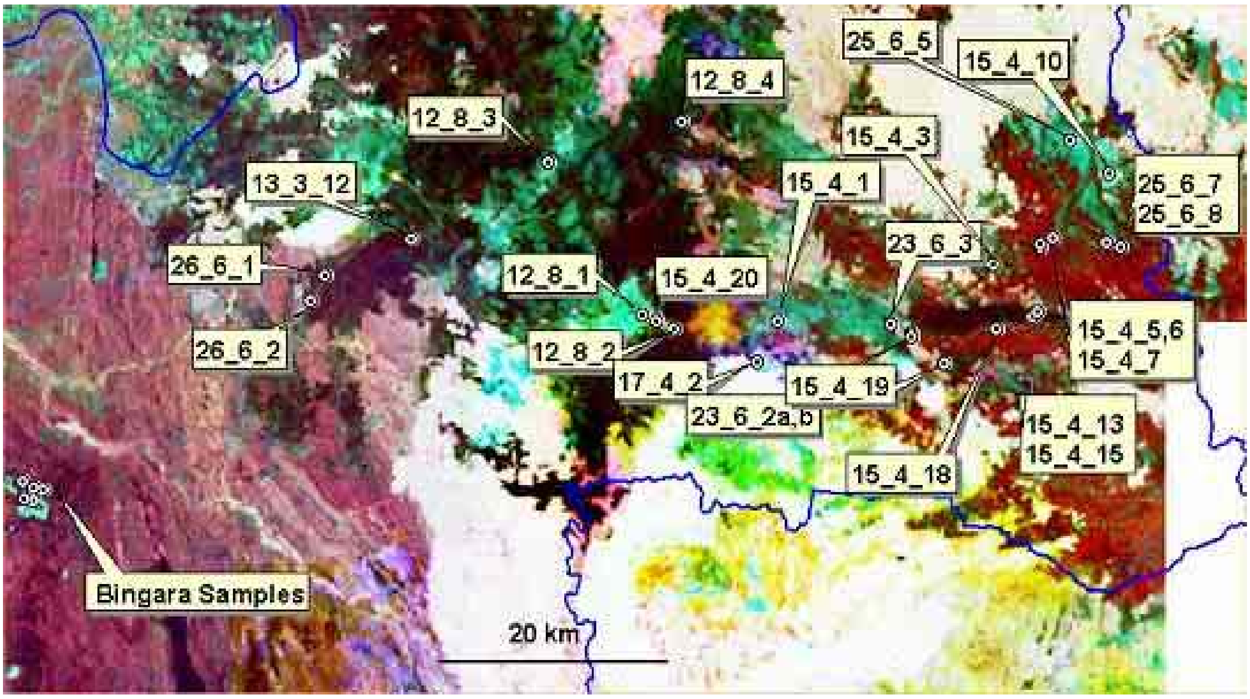


Figure 3-DD. Radiometric image showing sample locations for basalt geochemical analysis in the Inverell district.

Volcanic rocks are broadly separated into two groups on the basis of their chemistry; namely alkali and sub-alkali. Sub-alkali rocks are further separated into high aluminium calc-alkali and low potassium tholeiite rocks, of which only the latter occur in the Central Province. The major difference between these basalts is expressed by the chemical composition (Figure 3-EE). Alkali and tholeiitic rocks are commonly formed in different tectonic settings by melting of different portions of the upper mantle by numerous geological processes. These rocks are derived from different melting events and have different sources. The alkali rocks in the Cental Province are genetically related to sapphire occurrence, so the accurate spatial distribution of these rocks is essential to sapphire explorers.

The geochemical plots of Figure 3-EE show the different basalt groups sampled as part of this study. The samples have been separated on the basis of their radiometric signature. An exception is the Bingara samples, which have been separated on a geographical basis. The red dots represent those samples that produce a dark red radiometric signature, the black diamonds represent basalts that produce the very dark radiometric signature. A further suite of basalts has been identified by radiometrics and is characterised by a bright blue response. These samples are treated separately and uniformly called "blue" basalts. The "blue" basalts plot in fields that overlap the alkali rocks, clearly indicating this chemical affiliation. It can be shown from the plots that these basalts can be consistently and clearly differentiated on the basis of radiometric signature.

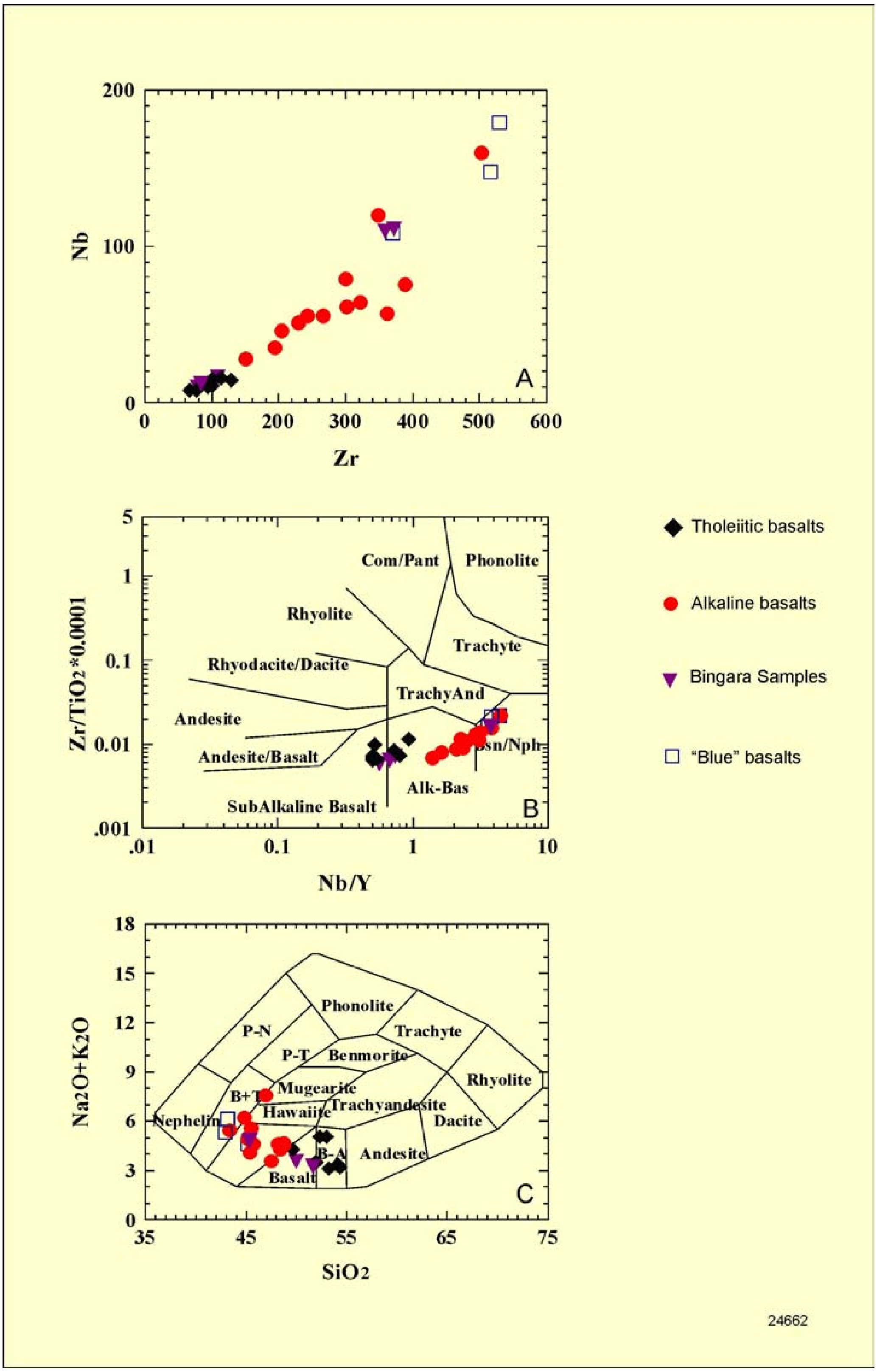


Figure 3-EE. Geochemical plots of the Central Province basalts and basalts west of Bingara. Diagram A indicates extreme enrichment of Nb and Zr (incompatible elements) that is typical of alkali basalts. Diagrams B and C clearly discriminate the tholeiitic and alkali suites and confirm the alkaline affinity of the "blue" basalts. The Bingara samples have representatives of both suites.

The Bingara basalt samples are not included in the Central Province, and the purple triangles that represent them have both tholeiitic and alkaline geochemical affinities that fall along the same trends as the Central Province basalts, indicating a similar source.

3.8.5 Nandewar Volcanic Province

The Nandewar volcano and associated products are situated in the extreme central west of the Nandewar study area, forming a northwest trending elongate belt covering an area of 50 by 30 kilometres, the majority of which is included within the study area. The Nandewar complex comprises 800 metres of thickness of preserved volcanic material and contains two main eruptive centres, the Killarney Gap volcano (20-21 Ma) and the Mount Kaputar volcano (16-18 Ma). The Killarney Gap volcano is composed mostly of rhyolite plugs and flows whilst the Mount Kaputar volcano is composed of more mafic rocks (Pratt, 1998; quoted in Barnes *et al.,* 2002). Central portions of the volcano comprise alkali rhyolite and minor trachyte plugs and domes dated at 20.5 Ma (Wellman and McDougall, 1974) whilst lavas display a range in composition that includes hawaiite, trachyandesite, tristanite to trachyte and comendite (Stolz, 1985). These lavas have dates of eruption between 18.0-17.2 Ma (Wellman and McDougall, 1974). Ewart (1985) postulated that crystal-liquid fractionation and convective fractionation processes controlled the evolution of the Nandewar complex, and Stolz (1985) concluded that differential partial melting of the source and liquid-state differentiation processes were also important in producing the rock types present in the area.

3.8.6 Unassigned Tertiary volcanics

Unassigned Tertiary volcanics are scattered throughout the Nandewar Bioregion and include small outcropping areas that are spatially remote to, or have not been assigned to any of the above mentioned associations. Most importantly this includes tholeiites and minor alkaline rocks west of Bingara (Photograph 3-HH), tholeiitic rocks immediately west of Barraba dated at 14.9 Ma (Wellman and McDougall, 1974) and tholeiitic rocks east of Upper Bingara.

3.8.7 Tertiary sediments

Tertiary sediments in the Nandewar study area comprise a variety of lithologies and associations. Many are well preserved underneath basaltic flows, where they form deep leads or interflow units. Less commonly, Tertiary sediments are mapped in areas of little Tertiary volcanism, for example Photograph 3-II. Sediments commonly consist of sand, gravel, silt, clay, diatomite, and crystal tuff; variably lithified, with detritus that includes quartz, chert, jasper and other locally derived lithologies. Within sediments at the base of volcanic piles, deep lead sediments may contain gold, tin, diamonds, sapphires and zircon (Brown *et al.,* 1992). Silcrete, or ‘Grey Billy’, is a common Tertiary sediment on the Bingara and Inverell 1:100 000 maps where it forms prominent, massive, siliceous outcrop commonly marginal to extensive areas of basaltic material.

Diamond-bearing deep lead sediments west of Bingara and in the Copeton area consist of unconsolidated gravels and sands with diamonds; derivation is interpreted from different sources (MacNevin, 1972). The relationship between the Bingara and Copeton deep leads is unclear, as are the relative ages of these leads (Stroud, 1990).

Photograph 3-HH. Columnar jointed basalt west of Bingara. GR 257260 6688990.

Tertiary gravels proximal to the Gwydir River on the Bingara 1:100 000 map sheet are interpreted to be the sedimentation products of the juvenile river system (Stroud, 1990). These sediments are prominent as low lying, rounded hills up to 500 metres away from the current river system (Photograph 3-JJ). Tertiary gravels are also prominent in an extensive area south of Upper Bingara, developed upon the Bobs Creek Formation and in close spatial association with, in part, Tertiary basalts. These gravels are matrix-supported, partially to well consolidated and contain sub-rounded clasts of quartz, jasper, argillite, minor basalt and rare wood fragments. The matrix is silt to sand sized, poorly sorted and is commonly white in colour.

Photograph 3-II. Tertiary gravels unconformably overlying Noumea beds. GR 233810 6736240.

Photograph 3-JJ. Flat-topped, low-lying hill of partially consolidated pebble conglomerate, about 500 metres from the current Gwydir River. GR 250570 6707160.

3.9 QUATERNARY

QUATERNARY
Include gravels, sand and silt that have been deposited along major flood plains of significant drainage systems in the Nandewar study area;
Can be delineated along major drainage systems such as the Gwydir and Peel river systems with the use of radiometric imagery;
Occupy only a small proportion of outcrop area as valley-fill and river terrace material.

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 and valley fill alluvium and scree (Photograph 3-KK) with associated alluvial terraces (Photograph 3-LL) are the dominant Quaternary systems in the study area.

For the Quaternary sediments of the Nandewar study area, the morphostratigraphic grouping proposed by Grimes (1984) has been broadly adopted. In this system, the morphological types are grouped according to broad depositional systems and these groups are further subdivided into individual features with a distinctive morphology. The features are also grouped by relative age whenever possible, as well as radiometric signature, a valuable reflection of the provenance of the sediments. The system of nomenclature adopted for the Quaternary in this study, is the same as that used in the Brigalow Belt South Bioregion Assessment (Barnes *et al.,* 2002). This publication should be referred to for more information.

A significant finding from this study is the delineation of alluvial terraces on the Peel and Gwydir river systems by the use of radiometrics. For the Gwydir River system, bedrock in the Gravesend to Bingara area is comprised mostly of intermediate volcanic and volcaniclastic rocks of the Tamworth Belt that have moderate to high potassium, low thorium and low uranium radiometric responses (See section 3.3.7 of this volume). The alluvial terraces that overlie bedrock in this area have low potassium, moderate thorium and low uranium radiometric responses. Figure 3-FF shows an example of this change in radiometric response. Similarly, the Peel River system shows the same radiometric relationships between bedrock and alluvial terraces (that is moderate potassium, low thorium and low uranium for bedrock and low potassium, moderate thorium and low uranium for alluvial terraces). There are, however, some alluvial terraces near the Peel River that have a distinctly different radiometric response (that is moderate to high potassium, moderate to high thorium and moderate to high uranium). These terraces consist of granite clasts and occur near Keepit Dam.

Photograph 3-KK. Thick sequence of Quaternary scree next to Chilcotts Creek. GR 293160 6493920.

Photograph 3-LL. Roadcut showing alluvial terrace material overlying the Tamworth Belt near Somerton. GR 269510 6574490.

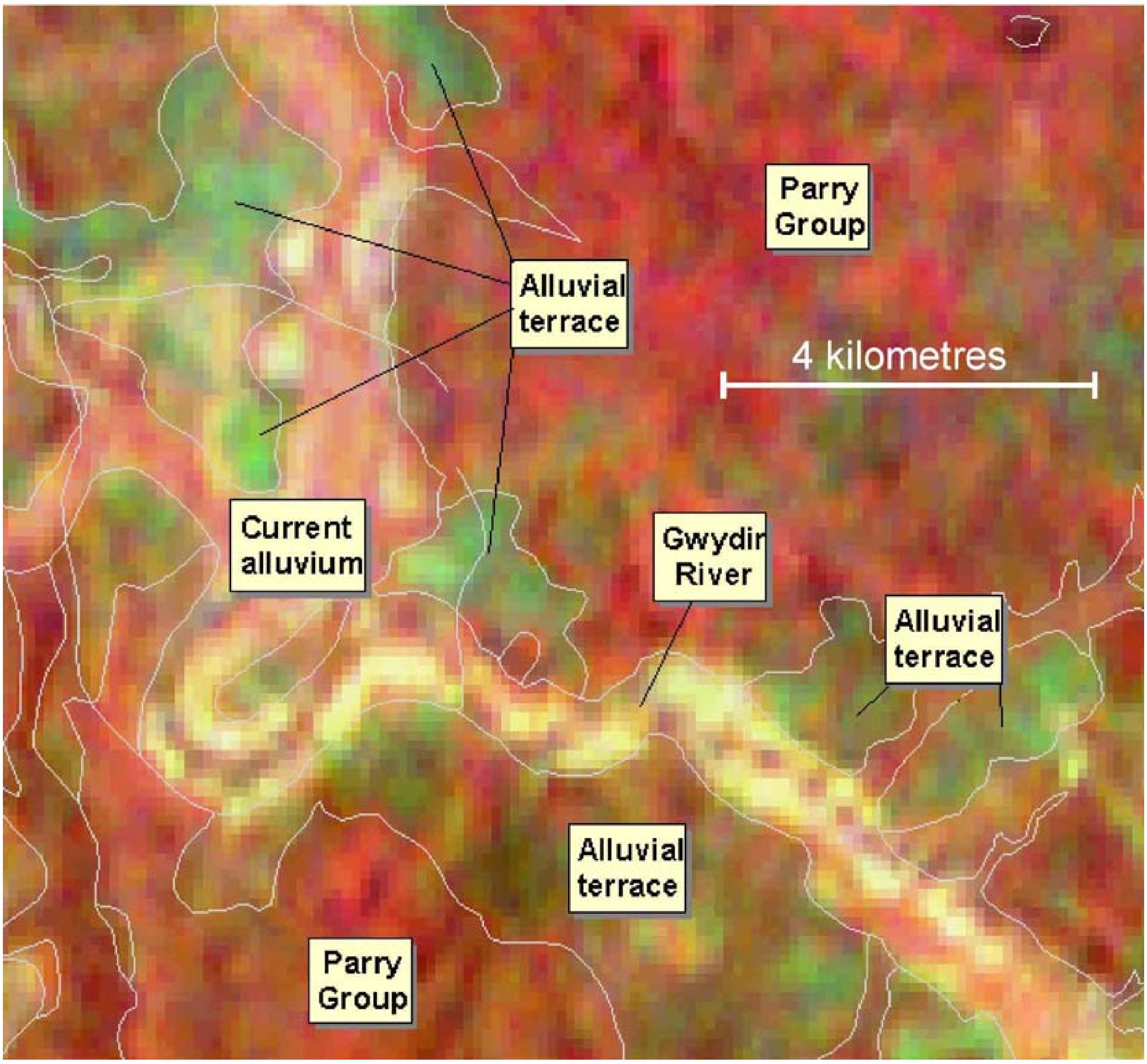


Figure 3-FF. Radiometric image showing the extent of alluvial terraces surrounding the Gwydir River northwest of Bingara.

3.10 STRUCTURE

3.10.1 Introduction

Folding, faulting and metamorphism disrupts the sedimentary and igneous rocks within the Nandewar study area. Many episodes of deformation have been observed from the Ordovician through to the Tertiary. The major deformations are in response to the accretion of the New England Fold Belt onto Gondwanaland. A diagram showing the distribution of mapped faults with respect to the major geological systems in the study area can be observed in Figure 3-GG. Figure 3-HH is a schematic cross-section of the Nandewar study area showing the relationship of structures.

3.10.2 Central Block

Sediments of the Central Block to the east of the Peel Fault are interpreted as an accretionary subduction complex. These sediments formed part of a deep marine sequence that collided with the eastern margin of Gondwana in the Early Permian to Late Triassic (Hunter-Bowen Orogeny). As a result of this collision, the western most sedimentary rocks, the Woolomin Group, underwent intense deformation that produced multiple generations of tight folding and cleavage development (Photograph 3-MM). These sediments were metamorphosed to low to medium grade greenschist facies, in response to the accretionary event. To the east, deformation and metamorphic grade decreases away from the Peel Fault, though moderate deformation within the most easterly Texas and Sandon beds is extensively reported. Minor folding and low to medium grade contact metamorphic effects have been recorded in sediments of the Central Block in response to intrusion of Permian to Triassic granitoids of the New England Batholith. An angular unconformity can be observed between the Early Permian marine sequences and the Silurian to Early Carboniferous terranes.

This unconformity represents a deformation event in the Late Carboniferous to Early Permian consistent with the Kanimblan Orogeny.

3.10.3 Tamworth Belt

The Tamworth Belt represents the western-most portion of the New England Fold Belt. These rocks are interpreted as forming in an intra-oceanic island arc and foreland arc setting (Aitchison et al 1999) and are Middle Cambrian to Early Permian in age. Rocks of the Tamworth Belt have experienced weak to moderate deformation in response to collision and accretion to the eastern margin of Gondwana, and later accretion of the Central Block in the latest Devonian and Late Permian to Early Triassic, respectively.

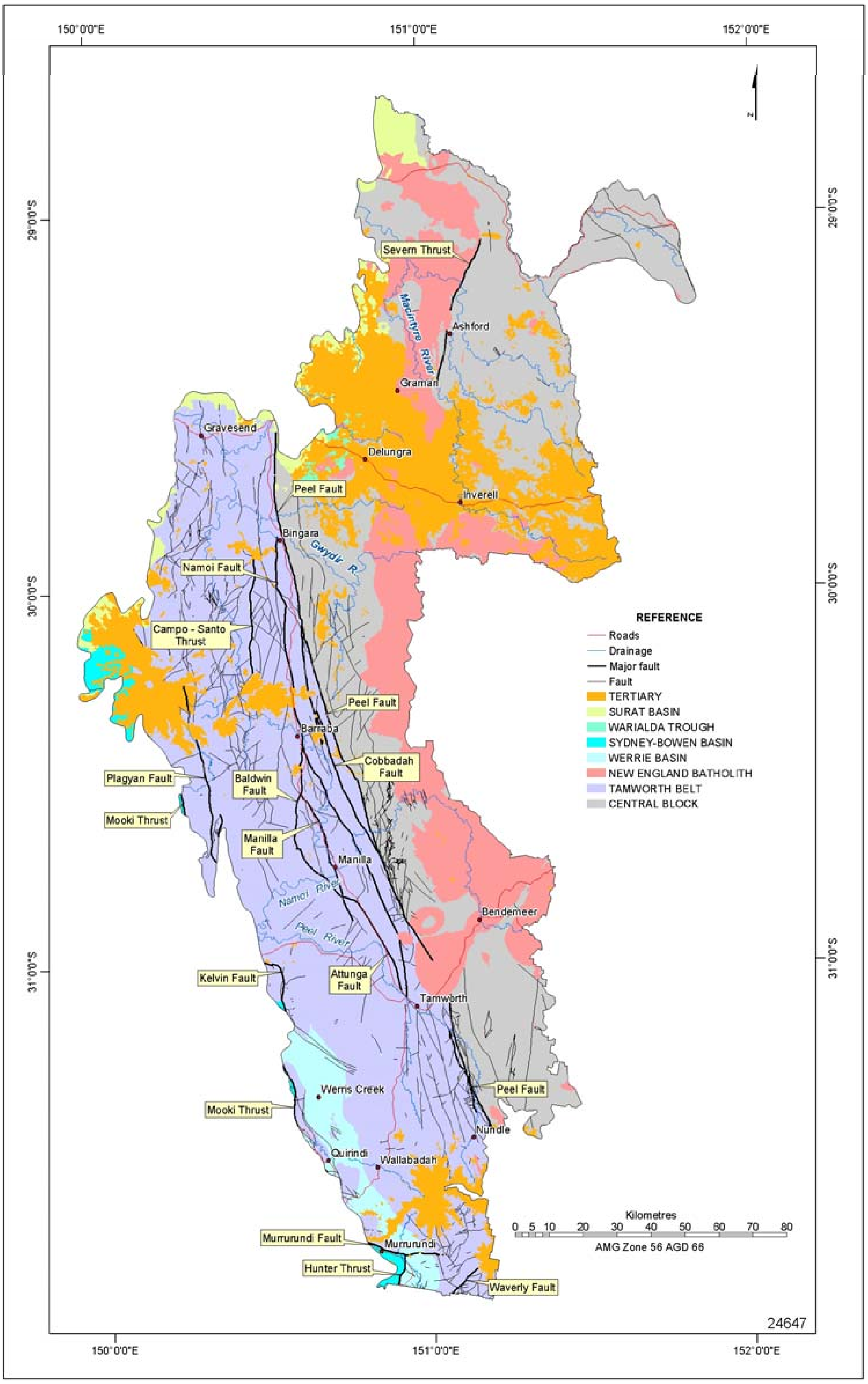


Figure 3-GG. The distribution of faults with respect to major geological provinces in the Nandewar study area.

Tamworth Belt sediments are deformed into a series of asymmetrical north-northwest oriented gentle folds that include the Rocky Creek Syncline, Klori Anticline, Appleby Syncline, Manilla Syncline and Yarramanbully Anticline. The Rocky Creek Syncline is the western most of these folds and extends for over 120 kilometres, from south of Keepit Dam to approximately 15 kilometres south of Gravesend.

Major north-northwest oriented thrusts and faults form an anastomosing fault set that disrupts the Tamworth Belt stratigraphy and causes local truncation of the sequence. These faults include the Kelvin, Namoi, Campo-Santo and Cobbadah faults that formed in response to major east-west compression associated with subduction. The Kelvin Fault places Devonian over Carboniferous sediments in the west, similarly the Cobbadah Fault places Devonian over Carboniferous sediments in the east. These structures are largely interpreted as being compressional (Glen and Brown, 1993). The Campo-Santo Thrust juxtaposes Carboniferous and Devonian sequences of the Parry Group in the northern portions of the Tamworth Belt. Intensity in deformation within the Tamworth Belt increases eastwards towards the Peel Fault system. In the west, folds are open and cleavage, where developed, is weak and NW trending. Glen and Brown (1993) postulated that this cleavage developed in response to post-thrust shortening. In contrast to this, sediments of the Parry Group east of the Namoi Fault are more intensely deformed. Chevron folds and two well developed subvertical cleavages trending northwest and northeast are defined, the latter interpreted as the result of strike-slip movement along the Peel Fault (Glen and Brown, 1993).

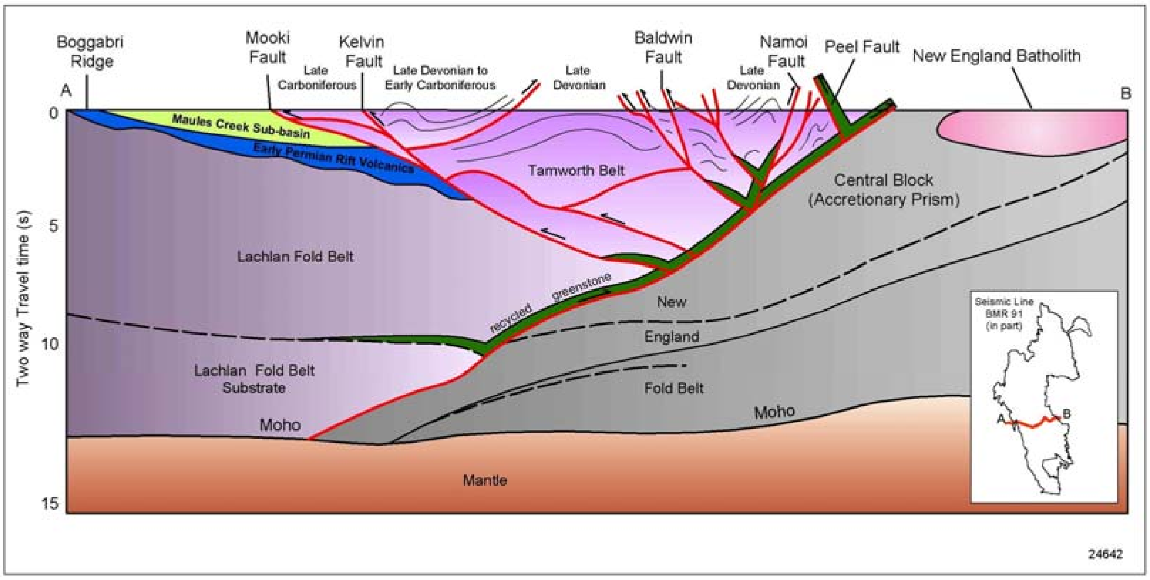


Figure 3-HH. Schematic cross-section of the Nandewar study area interpreted from seismic survey (BMR91.GO1) from Boggabri (west) to Manilla (east), after Korsch et al (1999).

3.10.4 Permo-Triassic Basins

The most significant deformation episode to affect the Permo-Triassic Basins is the Hunter-Bowen Orogeny during collision of the New England Fold Belt with Gondwanaland during the Late Permian and Early Triassic. Structure in the Werrie Basin is manifest as two sets regional synclines and anticlines. These two sets of synclines are approximately at right angles and combine to form domes (for example the Quirindi Dome) and basins. The best example of large-scale folding is the Werrie Syncline, which extends from Murrurundi in the south to near Carrol in the north. An open- to closed-anticline occurs to the immediate east of the Hunter-Mooki Thrust. In this area subvertical dips can be observed, indicating strong deformation in the hanging wall of the thrust. The best exposures of these steep dips are along Borambil Creek and at the Willow Tree Tip. A comprehensive study of structure in the Werrie Basin was undertaken by Carey (1934).

Deformation of the Sydney-Bowen Basin is most intense near the Hunter-Mooki Thrust. Manifestations of this deformation are subvertical dips of the Maules Creek Formation, Porcupine Formation and Werrie Basalt in the area beneath the Nandewar Ranges. An angular unconformity between the Permian and Triassic rocks of the Sydney-Bowen Basin can be observed at the Willow Tree Tip, and in the area beneath the Nandewar Ranges. This angular unconformity can be attributed to the Hunter-Bowen Orogeny. This contact between the Permian and Triassic becomes conformable to the west towards the centre of the basin.

The sedimentary rocks of the Warialda Trough were deposited after the Hunter-Bowen Orogeny and therefore, do not show the same deformation as the Sydney-Bowen and Werrie Basins.

Photograph 3-MM. Deformed Woolomin Group metasediments from near Dungowan GR 311200 6553320.

3.10.5 Surat Basin

Deformation within the Surat Basin is manifest as minor faulting and gentle warping. This occurred in the Middle Cretaceous during the closing of sedimentation of the Surat Basin. Near

Warialda, the deformation is manifest as gently dipping Walloon Coal Measures and Pilliga Sandstone. Cross-sections showing the deformation of the in the northern Nandewar study area can be found in Bourke (1980).

3.10.6 Tertiary Units

Minor reactivation of older faults occurred during the Tertiary. An example of this is the Murrurundi Fault near Ardglen, where Tertiary Basalts of the Liverpool Range Volcanics are faulted against the Carboniferous Currabubula Formation (Photograph 3-NN).

Photograph 3-NN. Tertiary Basalt (right) faulted against Carboniferous Currabubula Formation (left). Photo taken along the trace of the Murrurundi Fault near Murrurundi GR 290800 6486130.

a Appendix

APPENDIX 1: BIBLIOGRAPHY AND LIST OF REFERENCES

Aitchison, J.C. & Ireland, T.R. 1995, 'Age profile of ophiolitic rocks across the late Palaeozoic New England Orogen, New South Wales: implications for tectonic models', *Australian Journal of Earth Sciences*, vol. 42, pp. 11-23.

Aitchison, J.C., Flood, P.G. & Spiller, F.C.P. 1992, 'Tectonic setting and palaeoenvironment of terranes in the southern New England Fold Belt, eastern Australia as constrained by radiolarian biostratigraphy', *Palaeogeography, Palaeoclimatology, Palaeoecology*, vol. 94, pp. 31-54.

Arditto, P.A. 1982, 'Deposition and diagenesis of the Jurassic Pilliga Sandstone in the southeastern Surat Basin, New South Wales', *Journal of the Geological Society of Australia*, vol. 29, pp. 191-205.

Barnes, R.G. & Willis, I.L. 1989, The geology of the Grafton and Maclean 1:250 000 sheet areas, Geological Survey of New South Wales, Report GS1989/117 (unpublished).

Barnes, R.G., Brown, R.E., Brownlow, J.W. & Stroud, W.J. 1991, 'Late Permian volcanics in New England - the Wandsworth Volcanic Group', *Geological Survey of New South Wales. Quarterly Notes*, no. 84, pp. 1-36.

Barnes, R.G., Dawson, M.W. & Spiller, F.C.P. 2002, Geology integration and upgrade, Brigalow Belt South study area Stage 2, Department of Mineral Resources report for Resource and Conservation Assessment Council, Sydney, NSW, Western Regional Assessments, Project no. WRA19, 156 pp.

Barron, L.M. 1987, Summary of petrology and chemistry of rocks from the sapphire project, Geological Survey of New South Wales, Report GS1987/050 (unpublished).

Beckett, J., Hamilton, D.S.& Weber, C.R. 1983, 'Permian and Triassic stratigraphy and sedimentation in the Gunnedah-Narrabri-Coonabarabran region', *Geological Survey of New South Wales Quarterly Notes*, no. 51, pp. 1-16.

Benson, W.N. 1913, 'The geology and petrology of the Great Serpentine Belt of New South Wales. Part I. Introduction', *Linnean Society of New South Wales, Proceedings*, vol. 38, no. 3, pp. 491-517.

Bourke, D.J. 1980, 'Stratigraphy of the Mesozoic sequence in the Warialda-Goondiwindi area', *Records*, vol. 19, no. 1, Geological Survey of New South Wales, pp. 1-79.

Branagan, D.F. 1969, The Sydney Basin - Northwestern Coalfield, in ‘The Geology of New South Wales’, ed. Packham, G.H., *Journal of the Geological Society of Australia*, vol. 16, no. 1, pp. 444-455.

Brown, R.E. 1986, Preliminary Geological Notes for the Manilla 1:250,000 Sheet, Geological Survey of New South Wales, Report GS1987/003 (unpublished).

Brown, R.E. 1987, ‘Newly defined stratigraphic units from the western New England Fold Belt, Manilla 1:250 000 sheet area’, *Geological Survey of New South Wales Quarterly Notes*, no. 69, pp. 1-9.

Brown, R.E. 2001, ‘Peel discovery 2000 geophysics - providing keys to exploration in the western New England region of New South Wales Exploration NSW’, *Geological Survey of New South Wales Quarterly Notes*, no. 111, 16 pp.

Brown, R.E. 2003, ‘Peel south Exploration NSW geophysics - interpretation of new data for exploration and geological investigations in western New England area of New South Wales’, *Geological Survey of New South Wales Quarterly Notes*, no. 114, 28 pp.

Brown, R.E. (in prep.), ‘Inverell Exploration NSW geophysics - a new tool for exploration and geological investigations in the northern New England area of New South Wales’ *Geological Survey of New South Wales Quarterly Notes*.

Brown, R.E. & Pecover, S.R. 1988a, The geology of the Braemar sapphire field, Geological Survey of New South Wales, Report GS1986/270 (unpublished).

Brown, R.E. & Pecover, S.R. 1988b, The geology of the Kings Plains sapphire deposit, Geological Survey of New South Wales, Report GS1986/271 (unpublished).

Brown, R.E., Brownlow, J.W. & Krynen, J.P. 1992, *Manilla-Narrabri 1:250 000 Metallogenic Map SH/56-9, SH/55-12: Metallogenic Study and Mineral Deposit Data Sheets*, Geological Survey of New South Wales, Sydney, 319 pp.

Brownlow, J.W. 1980, ‘Early Permian sediments in the Maules Creek district, New South Wales’, *Coal Geology Group Journal*, vol. 2, no. 4, pp. 125-160.

Bryant, C.J. 2001, The status of the NEB database and the classification of NEB granites, Presentation to AMIRA Project P515, Igneous Metallogenic Systems of Eastern Australia (unpublished).

Bryant, C.J., Chappell, B.W. & Blevin, P.L. 2002, New England Batholith granites, Provisional final report to AMIRA Project P515, Igneous Metallogenic Systems of Eastern Australia (unpublished).

Bryant, C.J., Chappell, B.W. & Blevin, P.L. 2003, ‘Granites of the southern New England Orogen’, in *Magmas to Mineralisation, The Ishihara Symposium*, eds Blevin, P., Jones, M. & Chappell, B., Geoscience Australia, Record 2003/14, pp. 9-11.

Campbell, K.S.W.& Engel, B.A. 1962, 'The faunas of the Tournasian Tulcumba Sandstone and its members in the Werrie and Belvue synclines, New South Wales', *Geological Society of Australia Journal*, vol. 10, pp. 55-122.

Carey, S.W. 1934, 'The geological structure of the Werrie Basin', *Proceedings of the Linnean Society of New South Wales*, vol. 59, pp. 351-374.

Cawood, P.A. 1980, Geological development of the New England Fold Belt in the Woolomin-Nemingha and Wisemans Arm regions. The evolution of a Palaeozoic fore-arc terrain, PhD thesis, University of Sydney.

Cawood, P.A. 1982, 'Correlation of stratigraphic units across the Peel Fault System', in *Proceeding of the New England Geology, Voisey Symposium,* eds Flood, P.G. & Runnegar, B., Department of Geology, University of New England and AHV Club, Armidale, pp. 53-61.

Coenraads, R.R. 1991, Alluvial sapphires and diamonds of the New England gem fields, New South Wales, Australia, PhD thesis, Macquarie University.

Crook, K.A.W. 1961a, 'Stratigraphy of the Parry Group (Upper Devonian-Lower Carboniferous), Tamworth-Nundle district, N.S.W.', *Journal and Proceedings of The Royal Society of New South Wales*, vol. 94, pp. 189-207.

Crook, K.A.W. 1961b, 'Stratigraphy of the Tamworth Group (Lower and Middle Devonian), Tamworth-Nundle district, N.S.W.', *Journal and Proceedings of The Royal Society of New South Wales*, vol. 94, pp. 173-188.

Davies, R.M., O'Reilly, S.Y. and Griffin, W.L. 2002, 'Multiple origins of alluvial diamonds from New South Wales, Australia', *Economic Geology*, vol. 97, pp. 109-123.

Duggan, N.T. 1972, Tertiary volcanics of the Inverell area. A study of the mineralogy, petrology and chemistry of the basaltic rocks near Inverell, northern New South Wales, BSc Hons thesis, University of New England, Armidale.

Dulhunty, J.A. 1939, 'The Mesozoic stratigraphy of the Merriwa-Murrurundi district and south-eastern Liverpool plains', *Journal and Proceedings of The Royal Society of New South Wales*, vol. 73, pp. 29-40.

Dulhunty, J.A. 1973, 'Mesozoic stratigraphy in central western New South Wales', *Journal of the Geological Society of Australia*, vol. 20, no. 3, pp. 319-328.

Dulhunty, J.A. & Eadie, J. 1969, 'Geology of the Talbragar fossil fish bed area', *Journal and Proceedings of The Royal Society of New South Wales*, vol. 102**,** no. 1, pp. 1-4.

Etheridge, L.T. 1986, 'New stratigraphic and structural data from the Surat and Gunnedah Basins and implications for petroleum exploration', *Geological Survey of New South Wales Quarterly Notes*, no. 66, pp. 1-21.

Ewart, A. 1985, 'Aspects of the mineralogy and chemistry of the intermediate-silicic Cainozoic volcanic rocks of eastern Australia. Part 2: mineralogy and petrogenesis', *Australian Journal of Earth Sciences*, vol. 32, pp. 383-413.

Exon, N.F. 1976, *Geology of the Surat Basin in Queensland*, Bulletin, no. 166, Bureau of Mineral Resources, Australia.

Flood, P.G. & Aitchison, J.C. 1988, 'Tectonostratigraphic terranes of the southern part of the New England Orogen', in *New England Orogen Tectonics and Metallogenesis*, ed. Kleeman, J.D., Proceedings of a symposium held at the University of New England, Armidale, New South Wales, 14-18 November 1988, pp. 7-10.

Gilligan, L.B. & Brownlow, J.W. 1986, *Tamworth-Hastings 1:250 000 Metallogenic Map SH56-13, SH56-14 (plus parts of SI 56-1, SI 56-2), Mineral Deposits Sheets and Metallogenic Study*, Geological Survey of New South Wales, Sydney, 438 pp.

Grimes, K G. 1984, Cainozoic studies in Queensland, Geological Survey of Queensland, Record Series 1984/6.

Hanlon, F.N. 1948, 'Geology of the North-Western Coalfield: Part 2. Geology of the Willow Tree-Temi district', *Journal and Proceedings of The Royal Society of New South Wales,* vol. 81, pp. 280-286.

Hawke, J.M. & Cramsie, J.N. 1984, *Contributions to the Geology of the Great Australian Basin in New South Wales*, Bulletin, no. 31, Geological Survey of New South Wales, 295 pp.

Hensel, H.D., Chappell, B.W., Compston, W. & McCulloch, M.T. 1982, 'A neodynium and strontium isotopic investigation of granitoids and possible source rocks from New England, Eastern Australia', in *New England Geology, Voisey Symposium,* eds Flood, P.G. & Runnegar, B., Proceedings, Department of Geology, University of New England and AHV Club, Armidale, pp. 193-199.

Hill, M.B.L. 1986. 'Geology of the Deriah Forest area - implications for the structure and stratigraphy of the Gunnedah Basin', *Geological Survey of New South Wales Quarterly Notes*, no. 62, pp. 1-15.

Joplin, G.A., Hanlon, F.N.& Noakes, L.C. 1952, *Wollongong N.S.W. 1:250 000 Geological Survey Explanatory Notes*, Bureau of Mineral Resources.

Kent, A.J.R. 1993, 'Palaeozoic magmatic history of the Rockvale region, southern New England Orogen, NSW, Australia', in *New England Orogen, Eastern Australia 1993 Conference Proceedings*, eds Flood, P.G & Aitchison, J.C., University of New England, Armidale, pp 381-390.

Kimborough, D.L., Cross, K.C. & Korsch, R.J. 1993, 'U-Pb isotopic ages for zircons from the Pola Fogal and Nundle granite suites, southern New England Orogen', in *New England Orogen, Eastern Australia 1993 Conference Proceedings*, eds Flood, P.G & Aitchison, J.C., University of New England, Armidale, pp. 403-412.

Lishmund, S.R. 1974, *Oil Shale*, Mineral Industry, vol. 30, Geological Survey of New South Wales, 82 pp.

Loughnan, F.C. & Evans, P.R. 1978, ‘The Permian and Mesozoic of the Merriwa-Binnaway-Ballimore area, New South Wales’, *Journal and Proceedings of The Royal Society of New South Wales*, vol. 111, pp. 107-119.

MacNevin, A.A. 1972, Sapphires in the New England district, New South Wales, *Records*, vol. 14, no. 1, Geological Survey of New South Wales, pp. 19-35.

Manser, W. 1965, *Geological Map of New England, 1:100 000 Series, Gunnedah Sheet (no. 320)*, University of New England Press, Armidale.

Manser, W. 1968, *Geological Map of New England, 1:100 000 Series, Wingen Sheet (no. 359),* University of New England Press, Armidale.

McKelvey, B.C.& White, A.H. 1964, *Geological Map of New England, 1:100 000 Series, Horton Sheet (no. 290)*, University of New England Press, Armidale.

McPhie, J. 1984, ‘Permo-Carboniferous silicic volcanism and palaeogeography on the western edge of the New England Orogen, north-eastern New South Wales’, *Australian Journal of Earth Sciences*, vol. 31, no. 1, pp. 133-146.

Mollan, R.G., Forbes, V.R., Jensen, A.R., Exon, N.F. & Gregory, C.M. 1972, *Geology of the Eddystone, Taroom and Western Part of the Mundubbera Sheet Areas, Queensland*, Report, vol. 142, Bureau of Mineral Resources, Australia, 137 pp.

Morgan, E.J. 1997, ‘Early Devonian subaqueous andesitic volcanism in the New England Fold Belt, eastern Australia’, *Australian Journal of Earth Sciences*, vol. 44, no. 2, pp. 227-236.

Murray, C.G. 1997, ‘From geosyncline to fold belt: a personal perspective on the development of ideas regarding the tectonic evolution of the New England Orogen’, in *Tectonics and Metallogenesis of the New England Orogen*, Special Publication 19, eds Ashley, P.M. & Flood, P.G., Geological Society of Australia, pp. 1-28.

Oakes, G.M., Barron, L.M. & Lishmund, S.R. 1996, ‘Alkali basalts and associated volcaniclastic rocks as a source of sapphire in eastern Australia’, *Australian Journal of Earth Sciences*, vol. 43, pp. 289-298.

Offenberg, A.C. 1968, *Tamworth H56-13 1:250 000 Provisional Edition,* Geological Survey of New South Wales.

Pecover, S.R. & Coenraads, R.R. 1989, ‘Tertiary volcanism, alluvial processes and the origin of sapphire deposits at Braemar, near Elsmore, north eastern New South Wales’, *Geological Survey of New South Wales Quarterly Notes*, vol. 77, pp. 1-23.

Pratt, W. 1998, Notes to accompany the 1:100,000 scale Gunnedah Coalfield regional geology (north and south) maps, Geological Survey of New South Wales, Report GS1998/505, (unpublished).

Reiser, R.F. 1969, *Surat, Queensland, 1:250 000 Geological Series Explanatory Notes. Sheet SG/55-16*, Bureau of Mineral Resources, Australia, 22 pp.

Rio Tinto Pty Ltd & Werrie Gold Ltd 1997, First and final six monthly coal exploration report, EL 5285, 5124, 4925, 5309, 5310, 5311, Quirindi, Hunter Coalfield, Geological Survey of New South Wales, CR97/4060 (unpublished).

Roberts, J. & Oversby, B.S. 1974, *The Lower Carboniferous Geology of the Rouchel District, New South Wales*, Bulletin, no. 147, Bureau of Mineral Resources, Australia.

Russell, T.G. 1979, 'A reappraisal of the Late Devonian Bective unconformity', *Journal and Proceedings of The Royal Society of New South Wales*, vol. 112, no. 2, pp. 63-69.

Russell, T.G.& Middleton, M.F. 1981, 'Coal rank and organic diagenesis studies in the Gunnedah Basin: preliminary results', *Geological Survey of New South Wales Quarterly Notes*, no. 45, pp. 1-11.

Scheibner, E. & Basden, H. (eds.) 1996, *Geology of New South Wales – Synthesis. Volume 1 Structural Framework*, Memoir Geology, vol. 13, no. 1, Geological Survey of New South Wales, Sydney, 295 pp.

Schon, R.W. 1985, 'Petrology of the Liverpool Range Volcanics, eastern New South Wales', in *Volcanism in Eastern Australia*, Publication, no. 1, eds Sutherland, F.L., Franklin, B.J. & Waltho, A.E., Geological Society of Australia, NSW division, pp. 73-85.

Shaw, S.E. & Flood, R.H. 1981, 'The New England Batholith, eastern Australia: geochemical variations in time and space', *Journal of Geophysical Research*, vol. 86, pp. 10 530-10 544.

Shaw, S.E. & Flood, R.H. 1982, 'The Bundarra suite: a summary of new data', in *New England Geology, Voisey Symposium*, eds Flood, P.G. & Runnegar, B., Proceedings, Department of Geology, University of New England and AHV Club, Armidale, pp. 183-192.

Stolz, A.J. 1985, 'The role of fractional crystallisation in the evolution of the Nandewar Volcano, north-eastern New South Wales, Australia', *Journal of Petrology*, vol. 26, pp. 1 002-1 026.

Stroud, W.J. 1989, Notes on revised geological compilations, Inverell and Goondiwindi 1:250 000 geological sheets, northern New England, N.S.W., Geological Survey of New South Wales, Report GS1989/351 (unpublished).

Stroud, W.J. 1990, The geology of the Inverell and Goondiwindi 1:250 000 sheet areas (N.S.W. portions), Geological Survey of New South Wales, Report GS1990/083 (unpublished).

Sutherland, F.L. & Fanning, C.M. 2001, 'Gem-bearing basaltic volcanism, Barrington, New South Wales: Cenozoic evolution, based on basalt K-Ar ages and zircon fission track and U-Pb isotope dating', *Australian Journal of Earth Sciences*, vol. 48, pp. 221-237.

Sutherland, F.L., Pogson, R.E. & Hollis, J.D. 1993, 'Growth of the central New England basaltic gem fields, New South Wales, based on zircon fission track dating', in *New England Orogen, Eastern Australia 1993 Conference Proceedings*, eds Flood, P.G & Aitchison, J.C., University of New England, Armidale, pp. 483-491.

T.J. & P.V. Nunan Pty Ltd 1990, Exploration reports, EL 2988 and EL 2989, Emmaville, Inverell area, Geological Survey of New South Wales, File GS1992/091 (unpublished).

Wellman, P. & McDougall, I. 1974, 'Potassium–argon ages on the Cainozoic volcanic rocks of New South Wales, *Geological Society of Australia Journal*, vol. 21, pp. 247-272.

Whetten, J.T. 1965, 'Carboniferous glacial rocks from the Werrie Basin, New South Wales, Australia', *Geological Society of America, Bulletin*, vol. 76, no. 1, pp. 43-56.

White, A.H. 1964, 'The stratigraphy and structure of the upper Palaeozoic sediments of the Somerton-Attunga district, NSW', *Proceedings of the Linnean Society of New South Wales*, vol. 89, no. 2, pp. 203-217.

Wiles, L.A. 1996, *Coal Resource Audit of the Gunnedah Basin*, New South Wales Department of Mineral Resources, Sydney, 319 pp.

Wynne, P. E., Bacchin, M. & Tracey, R. M. 2003, *Australian National Gravity Database 2003*, Geoscience Australia, Canberra.

APPENDIX 2: FIELD LOCATIONS, DESCRIPTIONS AND DETAILS OF SAMPLES COLLECTED FOR GEOCHEMICAL AND PETROGRAPHIC ANALYSIS

Thin sect no	Assay no	Site/field no	AMG_E	AMG_N	Unit	Field description	Location description
T74852	G03/548	13/3_12	291200	6711660	Tctb	Tertiary basalt outcropping along creek edge, massive aphanitic basalt with vesicles and amygdales.	5 km south of Delungra
T74853	G03/549	15/4_1	323280	6704500	Tcab	Alkaline Tertiary basalt containing pale brown (partially weathered) olivine phenocrysts and lathic plagioclase. Fine to medium-grained, coarser than typical basalts in the area. Rare amygdales.	5 km east of Inverell
T74854	G03/550	15/4_3	342080	6709500	Tcab	Tertiary basalt (alkaline), fine to medium-grained (nearly doleritic?) north of Swan Peak. Pale brown olivine phenocrysts and lathic plagioclase abundant, massive, equigranular basalt.	24 km northeast of Inverell
T74855	G03/552	15/4_5	346230	6710920	Tcab	Alkaline Tertiary basalt, fine to medium-grained, similar to 15/4_1.	29 km northeast of Inverell
T74856	G03/553	15/4_6	346330	6711230	Tcab	Basalt, fine-grained vesicular basalt with pale brown olivine phenocrysts, massive outcrop from hill top.	300 m to northeast of sample 15/4_5, 29 km northeast of Inverell
T74857	G03/554	15/4_7	347350	6711850	Tcab	Alkaline Tertiary basalt, aphanitic and vesicular.	1.2 km to northeast of sample 15/4_6, 30 km northeast of Inverell
T74858	G03/555	15/4_10	352380	6717400	Tcabb	Tertiary basalt, fine-grained to aphanitic, massive and equigranular.	10 km southwest of Wellingrove
T74859	G03/556	15/4_13	345590	6704880	Tcab	Tertiary basalt (alkaline). Aphanitic to fine-grained, equigranular massive basalt.	28 km east of Inverell
T74860	G03/557	15/4_15	345940	6705360	Tctb	Tertiary basalt, aphanitic, massive and equigranular.	200 m to northeast of sample 15/4_13, 28 km east of Inverell
T74861	G03/558	15/4_18	342460	6703770	Tcab	Tertiary basalt along road cutting possibly representing multiple flows? Lowest flow is most weathered, vesicular and upper flows are fine-grained, massive and contain mantle xenoliths (olivine, clinopyroxene and magnetite or spinels).	24 km east of Inverell
T74862	G03/559	15/4_19	337820	6700770	Tctb	Tertiary basalt (alkaline). Fine to medium-grained, massive basalt forming low ridge east of Elsmore. Strongly weathered.	20 km east-southeast of Inverell
T74863	G03/560	15/4_20	312690	6704510	Tcabb	Tertiary basalt, west of Inverell on hill top. Fine-grained, vesicular, massive containing olivine phenocrysts. Good outcrop.	6 km west of Inverell
T74864	G03/561	16/4_17	349050	6734640	Pgx	Red/pink intrusive felsic rock within the Emmaville volcanics, outcrop forms prominent low hill. Very weathered rock. Medium-grained, massive, equigranular containing K feldspar>>plagioclase with abundant biotite, amphibole and quartz. Possible sericitic alteration of plagioclase+/- K feldspar. High K radiometric response for I-type.	30 km east of Bukkulla
T74865	G03/562	17/4_2	321440	6700850	Tctb	Tertiary basalt float material, fine-grained massive basalt.	5 km southeast of Inverell

Thin sect no	Assay no	Site/field no	AMG_E	AMG_N	Unit	Field description	Location description
T73413	G03/583	23/6_2a	334930	6703330	Tcav	Dark orange to red, possible vertical ?jointing surfaces, moderately ferruginous clay-rich volcaniclastic with little textural preservation.	Braemar, 3 km northeast of Elsmore
T73414	G03/584	23/6_2b	334910	6703330	Tcav	Grey to white, fine-grained, bleached ?volcaniclastic overlying the above sample. Weak textural preservation including ?vesicles or ?weathered pumice fragments. Volcaniclastic has suffered complete clay replacement due to weathering.	Braemar', 3km northeast of Elsmore
T73415	G03/585	23/6_3	333180	6704260	Tcab	Fine to medium-grained, massive, equigranular black basalt containing lathic plagioclase.	3 km north of Elsmore, old roadside quarry
T73416	G03/586	24/6_2	306160	6756930	Pbg	Fine to medium-grained, massive, seriate granite containing biotite, quartz, white k spar and plagioclase. Sugary texture (nearly aplitic). Minor pale green ?sericitic alteration of feldspars. K feldspar phenocrysts to 2 mm.	10 km northwest of Ashford
T73417 & T73418	Thin Section Only	24/6_8	303490	6768070	Ctl	Two thin sections across the lighter skarn vein material (garnet, olivine veins) and two across the darker host rock. Magnetic susceptibility on the darker host rock is extremely high and suspected to be enriched with secondary magnetite. The skarn veins have very low magnetic susceptibility readings.	18 km northwest of Ashford
T73419	Thin Section Only	24/6_9	303490	6768070	Ctl	Two thin sections across the lighter skarn vein material (garnet, olivine veins) and two across the darker host rock. Magnetic susceptibility on the darker host rock is extremely high and suspected to be enriched with secondary magnetite. The skarn veins have very low magnetic susceptibility readings.	18 km northwest of Ashford
T73420	G03/587	24/6_10	302170	6773200	Pbg	Medium to coarse-grained seriate granite. K feldspar megacrysts to 2 cm. Fine-grained interstitial biotite, dark smoky quartz, white tabular plagioclase.	22 km northwest of Ashford
T73421	G03/588	25/6_5	348840	6720350	Tcab	Dark green to grey, fine-grained, massive, equigranular basalt.	Kings Plains
T73422	G03/589	25/6_7	352000	6711400	Tcab	Dark green to grey, fine-grained, massive, equigranular basalt.	Kings Plains, Waterloo Road
T73423	G03/590	25/6_8	353270	6711020	Tcab	Fine-grained, massive basalt containing amygdales, olivine plus possible pyroxene phenocrysts.	Kings Plains, Waterloo Road
T73424	G03/591	26/6_1	283590	6708540	Tctb	Fine-grained, friable, pale grey, moderately weathered, vesicular basalt. Infilling carbonate or zeolite into amygdales or vesicles.	11 km southwest of Delungra
T73425	G03/592	26/6_2	282400	6706250	Tctb	Aphanitic, massive basalt in new road cut (very fresh). Fewer vesicles than 26/6_1.	13.5 km southwest of Delungra
T73426	G03/593	26/6_7	257190	6690480	Tuab	Aphanitic, massive basalt near contact with underlying Tertiary sediments.	8 km southwest of Bingara, Monte Christo Mine
T73427	G03/594	26/6_8	257190	6690410	Tuab	Fine to medium-grained, massive black basalt containing lathic plagioclase.	8 km southwest of Bingara, Monte Christo Mine
T73428	G03/595	26/6_10	258900	6689760	Tutb	Fine to medium-grained, massive basalt containing olivine, pyroxene and plagioclase.	7 km southwest of Bingara

Thin sect no	Assay no	Site/field no	AMG_E	AMG_N	Unit	Field description	Location description
T73429	G03/596	26/6_13	258220	6689900	Tuab	Dark green to black, fine to medium-grained, equigranular massive basalt.	8 km southwest of Bingara
T73430	G03/597	11/8_1	258140	6688830	Tutb	Fine-grained, massive basalt weathering along sub-parallel foliation (too weathered for sampling).	7 km southwest of Bingara
T73431	G03/598	11/8_2	257270	6688990	Tutb	Fine-grained, massive, equigranular columnar jointed basalt with ?flow textures. Subvertical joint patterns are prominent.	7 km southwest of Bingara
T73432	Thin Section Only	16/4_15	331350	6733570	Pgx	Massive pink porphyry containing abundant phenocrysts of white to pale green, zoned anhedral plagioclase (approx 1 cm). Pale pink, tabular, subhedral K-feldspar to 5 mm. Dark grey to black quartz phenocrysts, anhedral to 3 mm diameter. Irregularly oriented prismatic dark green hornblende to approx 1cm length and minor biotite phenocrysts < 2mm diameter. Groundmass is aphanitic and dominated by ?K-feldspar with subordinate quartz, plagioclase and ferromagnesian minerals.	13 km east of Bukkulla
T73433	G03/599	12/8_1	311460	6705090	Tcabb	Massive, aphanitic basalt, olive green-grey, with olivine phenocrysts.	6 km west of Inverell
T73434	G03/600	12/8_2	314170	6703810	Tcab	Aphanitic, massive basalt with olivine phenocrysts to 1 cm diameter. Minor vesicles with ?zeolite infilling.	3.5 km west of Inverell
T73435	G03/601	12/8_3	303180	6718370	Tcab	Pale green to grey, massive basalt, aphanitic with small olivine phenocrysts to 2 mm diameter, vesicles with infilling (zeolites?).	19 km northwest of Inverell
T73436	G03/602	12/8_4	314930	6722020	Tctb	Fine-grained, massive basalt containing olivine phenocrysts with dark red ? weathered grains (however the olivine appears fresh?).	17.5 km north of Inverell

APPENDIX 3: WHOLE ROCK AND TRACE ELEMENT GEOCHEMISTRY OF SAMPLES COLLECTED

 # Note: SiO_2, TiO_2, Al_2O_3, Fe_2O_3, FeO, MnO, MgO, CaO, Na_2O, K_2O, P_2O_5, SrO, and Al values are in weight percent. All other values are in parts per million.

Sample	rock	DMRNo	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	SrO	Al	Ag	As	Au	Ba	Be	Bi	C	Ca	Cd	Ce	Co
13_3_12	tholeiitic basalt	G03_548	53.22	1.54	14.72	4.41	6.37	0.14	7.09	9.15	2.90	0.22	0.20	0.03	7.79	0.07	0.4	0.01	142	0.57	0.01	0.04	6.35	0.12	19.9	42.9
15_4_1	alkali basalt	G03_549	45.17	2.30	13.99	4.82	8.01	0.21	9.09	10.33	3.71	1.21	1.03	0.14	7.09	0.16	0.7	0.01	901	1.79	0.01	0.01	6.88	0.05	121.0	43.8
15_4_3	alkali basalt	G03_550	47.47	2.23	15.23	3.99	8.12	0.16	9.69	9.05	2.73	0.85	0.41	0.06	7.70	0.06	0.4	0.01	189	1.00	0.01	0.01	6.15	0.04	24.9	47.9
15_4_5	alkali basalt	G03_552	48.73	2.45	15.95	4.08	7.21	0.15	6.86	9.43	3.03	1.50	0.51	0.10	8.09	0.09	0.5	0.01	298	1.27	0.01	0.01	6.31	0.05	36.4	36.8
15_4_6	alkali basalt	G03_553	45.74	2.86	15.45	5.72	7.02	0.18	8.56	8.87	3.60	1.01	0.82	0.18	7.48	0.15	1.0	0.01	373	2.13	0.01	0.01	6.03	0.10	61.5	49.7
15_4_7	alkali basalt	G03_554	44.82	3.14	15.60	4.48	8.89	0.19	7.12	8.32	3.99	2.24	1.02	0.17	8.13	0.13	1.6	0.01	315	2.51	0.01	0.02	5.82	0.11	75.8	40.0
15_4_10	alkali basalt	G03_555	45.50	2.74	15.37	3.47	9.33	0.18	8.19	8.75	3.58	1.97	0.82	0.10	8.01	0.10	1.3	0.01	269	2.16	0.01	0.01	6.11	0.07	61.4	47.1
15_4_13	alkali basalt	G03_556	46.92	2.77	16.14	4.62	7.25	0.17	6.42	7.09	5.83	1.72	0.93	0.13	8.18	0.11	1.3	0.01	333	2.89	0.01	0.43	5.00	0.11	84.1	35.6
15_4_15	tholeiitic basalt	G03_557	49.60	0.93	17.01	1.89	9.64	0.16	8.00	8.25	3.89	0.40	0.20	0.02	8.24	0.06	0.3	0.01	112	0.43	0.01	0.01	5.88	0.08	12.6	46.1
15_4_18	alkali basalt	G03_558	45.42	2.94	15.12	5.92	6.19	0.18	10.27	8.90	3.11	0.99	0.84	0.11	7.63	0.11	0.8	0.01	335	1.89	0.01	0.03	6.17	0.07	60.1	54.6
15_4_19	tholeiitic basalt	G03_559	52.34	0.77	16.21	2.10	8.09	0.15	7.93	7.17	4.33	0.68	0.20	0.02	8.31	0.05	0.6	0.01	184	0.59	0.01	0.38	5.23	0.07	18.0	38.2
15_4_20	alkali basalt	G03_560	42.91	2.44	12.67	8.34	5.63	0.23	9.18	11.42	3.44	1.83	1.66	0.24	6.38	0.24	1.5	0.01	894	3.02	0.02	0.01	7.71	0.10	257.0	42.1
16_4_17	granite	G03_561	66.28	0.55	16.42	2.18	2.43	0.12	0.39	1.57	4.55	5.40	0.10	0.01	7.85	0.03	0.9	0.01	1780	1.32	0.13	0.16	1.20	0.10	141.0	3.0
17_4_2	tholeiitic basalt	G03_562	51.91	1.37	15.28	2.04	8.91	0.16	7.59	9.03	2.98	0.49	0.20	0.03	8.12	0.06	1.3	0.01	150	0.52	0.01	0.05	6.50	0.06	17.2	40.3
23_6_2a	Braemar volcaniclastic	G03_583	8.23	5.57	49.13	35.57	0.63	0.08	0.16	0.09	0.06	0.06	0.39	0.01	18.49	0.04	3.4	0.04	56	0.41	0.08	0.13	0.05	0.05	15.1	16.1
23_6_2b	Braemar volcaniclastic	G03_584	49.72	3.64	42.75	2.20	0.41	0.01	0.15	0.27	0.12	0.06	0.58	0.10	16.07	0.02	3.1	0.02	178	2.72	0.02	0.03	0.17	0.05	38.4	7.6
23_6_3	tholeiitic basalt	G03_585	52.94	0.87	17.20	2.54	8.50	0.15	5.64	6.90	4.44	0.58	0.21	0.03	8.95	0.05	1.5	0.01	181	0.69	0.01	0.65	4.88	0.08	27.8	59.3
24_6_2	aplite	G03_586	76.85	0.08	13.14	0.29	1.59	0.05	0.06	0.25	2.92	4.56	0.20	0.01	6.30	0.09	49.0	0.01	11	1.75	7.45	0.02	0.23	0.05	15.6	1.3
24_6_10	granite	G03_587	74.71	0.25	13.66	0.36	1.93	0.05	0.33	1.30	3.25	4.05	0.10	0.01	6.66	0.06	9.0	0.01	392	2.53	0.55	0.02	0.98	0.12	48.0	3.2
25_6_5	alkali basalt	G03_588	48.78	2.60	16.72	5.10	6.17	0.16	6.23	8.95	3.33	1.35	0.51	0.11	8.76	0.08	1.5	0.01	694	1.56	0.02	0.02	6.19	0.08	53.8	43.7
25_6_7	alkali basalt	G03_589	48.14	2.53	16.15	3.23	8.15	0.16	6.89	9.53	3.00	1.61	0.51	0.09	8.67	0.07	7.0	0.01	274	1.54	0.01	0.03	6.76	0.08	49.5	45.7
25_6_8	alkali basalt	G03_590	48.41	2.36	15.73	3.59	7.86	0.16	7.79	9.22	2.85	1.42	0.51	0.09	8.48	0.11	1.3	0.01	256	1.34	0.01	0.03	6.50	0.09	44.3	48.5
26_6_1	tholeiitic basalt	G03_591	54.35	1.40	14.94	3.78	6.61	0.13	6.83	8.54	2.90	0.29	0.20	0.03	8.31	0.05	0.9	0.01	153	0.52	0.01	0.03	6.21	0.10	20.5	42.3
26_6_2	tholeiitic basalt	G03_592	54.07	1.53	14.88	2.43	7.54	0.14	7.03	8.79	2.94	0.42	0.20	0.03	7.88	0.04	0.8	0.01	168	0.64	0.01	0.03	6.06	0.08	26.3	46.0
26_6_7	Bingara	G03_593	45.42	2.24	13.31	4.83	8.82	0.21	8.82	10.32	4.15	0.70	1.03	0.15	7.05	0.21	1.7	0.01	730	1.93	0.02	0.01	7.11	0.15	178.0	55.6
26_6_8	Bingara	G03_594	45.29	2.25	13.26	5.26	8.43	0.22	8.77	10.53	3.73	1.05	1.03	0.18	7.08	0.22	1.7	0.01	901	1.91	0.02	0.01	7.29	0.15	172.0	54.5
26_6_10	Bingara	G03_595	51.68	1.31	15.43	4.60	7.03	0.16	7.61	8.73	2.90	0.31	0.20	0.03	8.10	0.05	0.5	0.01	143	0.48	0.01	0.01	6.01	0.09	20.6	52.3
26_6_13	Bingara	G03_596	45.23	2.22	13.20	4.22	9.57	0.22	9.17	9.99	3.52	1.51	1.02	0.12	7.31	0.22	1.7	0.01	755	2.08	0.02	0.03	7.16	0.15	174.0	56.1
11_8_1	Bingara	G03_597	49.97	1.47	15.43	3.09	9.10	0.17	8.10	8.87	3.03	0.51	0.21	0.05	8.50	0.05	7.0	0.01	158	0.67	0.01	0.01	6.40	0.09	27.0	56.6
11_8_2	Bingara	G03_598	51.66	1.32	15.50	3.35	8.23	0.17	7.17	9.07	3.07	0.22	0.20	0.03	8.40	0.05	0.9	0.01	107	0.42	0.01	0.01	6.36	0.09	18.2	54.1
12_8_1	alkali basalt	G03_599	43.12	2.41	12.62	8.56	6.04	0.25	8.41	10.61	4.22	1.89	1.66	0.21	6.58	0.23	1.1	0.01	981	3.08	0.01	0.01	7.11	0.12	290.0	49.5
12_8_2	alkali basalt	G03_600	43.36	2.32	12.45	5.11	8.84	0.24	9.46	11.01	3.54	1.91	1.56	0.22	6.36	0.38	1.0	0.01	889	2.80	0.01	0.04	7.22	0.12	265.0	50.3
12_8_3	alkali basalt	G03_601	45.19	2.23	13.03	5.10	8.50	0.22	9.88	10.11	3.27	1.33	1.03	0.12	6.95	0.14	1.7	0.01	595	2.00	0.01	0.01	6.93	0.12	150.0	57.4
12_8_4	tholeiitic basalt	G03_602	51.94	1.56	14.88	2.20	8.57	0.16	7.83	9.10	3.02	0.50	0.20	0.04	8.17	0.06	0.3	0.01	178	0.58	0.01	0.07	6.46	0.09	29.6	53.6

Sample	rock	DMRNo	Cr	Cs	Cu	Dy	Er	Eu	F	Fe	Ga	Gd	Ge	Hf	Ho	In	K	La	Li	Lu	Mg	Mn	Mo	Na	Nb	Nd
13_3_12	tholeiitic basalt	G03_548	307	0.1	55	3.6	1.8	1.2	0.01	6.83	22.0	4.0	0.62	3	0.7	0.06	0.24	10.9	9.1	0.2	4.33	1030	0.67	2.18	11.0	12.0
15_4_1	alkali basalt	G03_549	268	1.2	46	5.8	2.5	3.1	0.01	7.90	22.0	9.2	0.74	8	1.0	0.07	1.16	71.1	6.0	0.2	5.40	1400	3.80	2.69	79.0	51.5
15_4_3	alkali basalt	G03_550	306	0.2	62	3.5	1.8	1.3	0.01	7.66	22.0	3.9	0.55	4	0.7	0.06	0.83	15.2	6.4	0.2	5.85	1180	1.50	2.02	28.0	14.7
15_4_5	alkali basalt	G03_552	221	0.4	57	4.4	2.2	1.8	0.01	6.97	22.0	5.4	0.41	5	0.8	0.07	1.43	19.9	6.1	0.2	4.02	1080	1.69	2.18	35.0	21.3
15_4_6	alkali basalt	G03_553	251	0.2	61	4.0	1.9	2.1	0.01	7.83	23.0	5.7	0.74	7	0.7	0.08	0.99	33.8	5.7	0.2	4.97	1220	3.85	2.66	64.0	29.0
15_4_7	alkali basalt	G03_554	73	0.1	39	4.7	2.1	2.4	0.01	8.70	23.0	6.8	0.50	10	0.8	0.09	2.03	44.6	7.8	0.2	4.34	1390	4.25	2.98	57.0	39.6
15_4_10	alkali basalt	G03_555	177	0.2	60	4.5	2.1	2.2	0.01	8.38	24.0	6.1	0.57	8	0.8	0.08	1.75	37.2	7.7	0.2	4.92	1340	4.51	2.68	61.0	30.4
15_4_13	alkali basalt	G03_556	79	0.4	41	4.8	2.3	2.4	0.01	7.73	24.0	7.0	0.64	10	0.8	0.08	1.56	50.0	10.8	0.2	3.76	1240	4.73	4.16	75.0	37.7
15_4_15	tholeiitic basalt	G03_557	177	0.3	61	3.0	1.8	0.9	0.01	7.63	21.0	3.1	0.45	6	0.6	0.05	0.36	6.2	9.3	0.2	4.55	1220	0.65	2.8	8.0	8.2
15_4_18	alkali basalt	G03_558	303	0.6	61	4.2	2.0	2.1	0.01	7.73	20.0	5.9	0.52	7	0.7	0.07	0.90	34.3	5.3	0.2	6.01	1250	2.89	2.24	55.0	28.9
15_4_19	tholeiitic basalt	G03_559	252	0.4	44	2.6	1.5	0.8	0.01	6.94	22.0	2.7	0.34	3	0.5	0.05	0.61	9.6	9.2	0.2	4.79	1090	0.98	3.14	8.0	9.4
15_4_20	alkali basalt	G03_560	239	0.6	38	8.1	3.2	4.9	0.01	8.62	22.0	14.5	0.64	13	1.3	0.09	1.63	151.0	13.7	0.2	5.27	1650	5.27	2.4	148.0	98.9
16_4_17	granite	G03_561	10	4.2	12	6.4	3.9	2.4	390.00	3.06	20.0	8.8	0.28	22	1.3	0.10	4.72	88.1	16.3	0.6	0.22	951	0.52	3.11	9.0	64.2
17_4_2	tholeiitic basalt	G03_562	176	0.2	54	3.4	1.9	1.1	0.01	7.42	20.0	3.5	0.31	3	0.7	0.06	0.46	10.2	6.0	0.2	4.55	1180	1.09	2.15	10.0	11.9
23_6_2a	Braemar volcaniclastic	G03_583	996	0.1	62	1.0	0.5	0.4	0.01	18.96	53.2	1.2	0.21	9	0.2	0.15	0.04	17.7	1.1	0.1	0.07	424	1.99	0.01	63.0	7.7
23_6_2b	Braemar volcaniclastic	G03_584	605	0.1	33	4.7	2.1	1.6	0.01	1.49	37.2	5.2	0.16	5	0.8	0.09	0.01	30.1	28.2	0.1	0.08	93	0.80	0.09	54.2	21.6
23_6_3	tholeiitic basalt	G03_585	260	0.5	53	3.3	1.6	1.1	0.01	7.81	25.3	3.7	0.16	2	0.6	0.05	0.64	13.9	5.7	0.2	3.61	978	1.36	3.26	15.0	12.0
24_6_2	aplite	G03_586	10	30.7	13	4.5	2.7	0.1	1160.00	1.40	22.9	2.6	0.09	3	0.9	0.11	4.22	5.9	112.0	0.4	0.06	370	1.18	2.08	7.5	6.7
24_6_10	granite	G03_587	12	23.6	19	6.2	3.8	0.7	700.00	1.74	21.4	5.2	0.13	5	1.2	0.08	3.76	22.4	56.5	0.5	0.22	451	1.39	2.30	7.5	19.9
25_6_5	alkali basalt	G03_588	193	0.3	71	5.1	2.4	2.1	0.01	7.96	26.1	6.1	0.21	6	0.9	0.07	1.34	28.0	6.6	0.3	3.89	1140	2.74	2.43	55.1	24.6
25_6_7	alkali basalt	G03_589	239	0.2	69	4.7	2.3	1.9	0.01	7.99	24.5	5.6	0.22	6	0.8	0.07	1.61	25.5	6.3	0.2	4.42	1150	2.53	2.24	50.8	22.6
25_6_8	alkali basalt	G03_590	291	0.3	67	4.5	2.2	1.8	0.01	8.10	24.9	5.3	0.19	5	0.8	0.07	1.37	22.4	6.4	0.2	5.06	1150	2.14	2.13	45.8	21.7
26_6_1	tholeiitic basalt	G03_591	302	0.1	62	4.3	2.0	1.3	0.01	7.75	23.6	4.5	0.20	3	0.7	0.06	0.28	10.0	7.3	0.2	4.54	905	1.08	2.23	11.0	12.1
26_6_2	tholeiitic basalt	G03_592	292	0.2	56	4.4	2.1	1.5	0.01	7.21	22.0	4.7	0.14	4	0.8	0.06	0.38	12.4	5.6	0.2	4.48	997	1.23	2.16	14.3	14.6
26_6_7	Bingara	G03_593	316	0.9	57	7.4	3.1	3.9	0.01	9.47	24.7	12.3	0.29	8	1.2	0.09	0.63	97.5	7.5	0.3	5.70	1450	5.23	3.10	110.0	70.1
26_6_8	Bingara	G03_594	313	0.6	51	7.3	2.8	3.7	0.01	9.40	25.3	11.6	0.31	8	1.1	0.08	0.98	94.8	7.3	0.3	5.62	1490	4.71	2.79	111.0	67.9
26_6_10	Bingara	G03_595	264	0.1	80	4.0	2.0	1.2	0.01	8.02	21.5	3.8	0.17	3	0.7	0.06	0.28	10.1	4.9	0.2	4.82	1130	0.88	2.11	12.0	11.4
26_6_13	Bingara	G03_596	324	1.5	60	7.2	3.0	3.7	0.01	9.95	26.7	11.9	0.30	8	1.1	0.08	1.49	95.3	11.6	0.2	6.15	1580	4.86	2.71	120.0	69.3
11_8_1	Bingara	G03_597	252	0.1	68	4.4	2.3	1.4	0.01	8.80	22.6	4.5	0.18	3	0.8	0.06	0.49	13.1	6.2	0.3	5.41	1270	1.20	2.33	16.3	14.6
11_8_2	Bingara	G03_598	257	0.1	83	3.9	2.0	1.2	0.01	8.09	21.0	3.8	0.18	2	0.7	0.06	0.17	8.5	5.9	0.2	4.66	1180	0.82	2.30	10.3	10.5
12_8_1	alkali basalt	G03_599	260	0.9	44	10.2	3.8	5.9	0.01	9.63	27.5	18.0	0.41	12	1.6	0.10	1.69	160.0	14.0	0.3	5.27	1690	6.82	3.08	179.0	112.0
12_8_2	alkali basalt	G03_600	329	0.8	45	9.6	3.5	5.4	0.01	9.14	26.7	16.5	0.39	11	1.4	0.08	1.64	149.0	13.6	0.2	5.78	1600	5.92	2.52	160.0	103.0
12_8_3	alkali basalt	G03_601	351	0.7	51	7.2	2.9	3.5	0.01	9.32	24.9	10.7	0.31	9	1.2	0.08	1.22	79.9	10.1	0.3	6.36	1510	5.13	2.44	108.0	61.3
12_8_4	tholeiitic basalt	G03_602	310	0.2	62	4.4	2.1	1.5	0.01	7.92	22.7	4.7	0.22	3	0.8	0.06	0.43	14.4	5.2	0.2	5.20	1120	1.37	2.32	16.2	15.8

Sample	rock	DMRNo	Ni	P	Pb	Pr	Rb	Re	S	Sb	Sc	Se	Sm	Sn	Sr	Ta	Tb	Te	Th	Ti	Tl	Tm	U	V	W	Y
13_3_12	tholeiitic basalt	G03_548	160	721	17.8	2.5	3.2	0.02	0.02	0.11	20.5	1	3.7	4	245	0.74	0.7	0.05	2.0	0.76	0.02	0.2	0.3	162	0.2	21.8
15_4_1	alkali basalt	G03_549	185	4170	4.3	14.0	37.4	0.00	0.01	0.14	17.6	2	9.9	6	1270	4.67	1.2	0.05	8.0	1.26	0.07	0.3	1.8	172	1.1	27.3
15_4_3	alkali basalt	G03_550	188	1580	1.3	3.4	11.2	0.00	0.01	0.06	21.5	1	3.8	4	511	1.76	0.6	0.05	2.0	1.24	0.04	0.2	0.6	193	0.3	19.9
15_4_5	alkali basalt	G03_552	89	1890	2.4	5.0	27.0	0.00	0.01	0.07	20.3	1	5.0	5	870	2.19	0.8	0.05	3.0	1.36	0.06	0.3	0.7	201	0.2	21.3
15_4_6	alkali basalt	G03_553	199	3220	2.3	7.2	13.3	0.00	0.02	15.00	16.0	1	6.0	6	1490	4.22	0.8	0.05	4.0	1.62	0.13	0.3	1.2	168	0.4	20.9
15_4_7	alkali basalt	G03_554	89	3930	2.7	9.9	23.6	0.00	0.02	5.00	13.8	2	7.8	6	1470	4.18	1.0	0.05	4.0	1.8	0.05	0.3	1.5	153	3.0	25.2
15_4_10	alkali basalt	G03_555	153	3220	2.3	7.6	21.8	0.00	0.01	7.00	18.4	1	6.4	5	919	3.92	0.9	0.05	4.0	1.59	0.03	0.3	1.3	169	0.3	24.3
15_4_13	alkali basalt	G03_556	89	3840	3.1	10.0	12.2	0.00	0.01	10.00	12.1	1	7.2	6	1120	5.01	1.0	0.05	5.0	1.57	0.05	0.3	1.6	141	0.3	23.7
15_4_15	tholeiitic basalt	G03_557	179	616	1.4	1.8	8.3	0.00	0.05	0.05	15.6	1	2.4	2	205	0.47	0.6	0.05	1.0	0.53	0.04	0.2	0.3	183	0.1	15.8
15_4_18	alkali basalt	G03_558	251	3400	1.9	7.3	10.2	0.00	0.01	0.07	19.2	2	6.3	5	969	3.61	0.8	0.05	3.0	1.66	0.03	0.2	1.1	187	0.4	23.2
15_4_19	tholeiitic basalt	G03_559	186	767	2.8	2.2	12.0	0.00	0.04	0.06	15.6	1	2.4	2	214	0.59	0.5	0.05	2.0	0.46	0.08	0.2	0.6	151	0.2	15.4
15_4_20	alkali basalt	G03_560	210	6580	7.3	27.4	52.9	0.00	0.02	0.22	11.8	2	16.8	4	2000	9.18	1.8	0.05	15.0	1.35	0.02	0.3	4.0	141	1.1	38.6
16_4_17	granite	G03_561	13	517	17.9	17.0	122.0	0.00	0.01	12.00	22.4	1	9.8	4	96	0.53	1.2	0.05	10.0	0.32	0.57	0.5	1.7	14	1.0	35.8
17_4_2	tholeiitic basalt	G03_562	136	757	1.6	2.7	10.5	0.00	0.05	12.00	21.8	1	3.2	2	235	0.65	0.6	0.05	1.0	0.8	0.05	0.2	0.3	167	0.2	20.0
23_6_2a	Braemar volcaniclastic	G03_583	35	1550	3.9	2.4	1.3	0.00	0.02	0.16	37.7	2	1.3	5	17	4.57	0.2	0.12	5.0	2.54	0.02	0.1	1.6	403	0.6	2.9
23_6_2b	Braemar volcaniclastic	G03_584	127	2310	3.2	5.7	0.5	0.00	0.01	0.09	17.6	2	4.4	3	835	11.00	0.8	0.07	3.0	1.83	0.02	0.2	1.7	215	0.5	30.3
23_6_3	tholeiitic basalt	G03_585	218	1090	2.4	2.9	7.9	0.00	0.04	0.08	14.7	1	3.1	3	283	1.12	0.6	0.05	2.0	0.52	0.09	0.2	0.6	153	0.3	16.1
24_6_2	aplite	G03_586	7	821	13.4	1.8	409.0	0.00	0.01	0.85	2.8	1	2.3	20	14	1.08	0.6	0.05	10.0	0.06	1.60	0.4	7.6	3	18.0	9.5
24_6_10	granite	G03_587	10	596	19.6	5.2	232.0	0.00	0.01	0.85	4.6	1	4.7	12	108	0.94	1.3	0.05	13.0	0.16	1.00	0.6	5.4	18	3.0	14.2
25_6_5	alkali basalt	G03_588	92	2290	2.2	5.9	19.3	0.00	0.01	0.09	20.0	2	5.6	4	956	3.38	0.9	0.05	3.0	1.51	0.05	0.3	1.0	208	0.5	23.8
25_6_7	alkali basalt	G03_589	102	2250	2.0	5.5	22.7	0.00	0.01	0.09	20.7	2	5.4	4	839	3.27	0.9	0.05	3.0	1.50	0.03	0.3	0.9	210	0.4	21.4
25_6_8	alkali basalt	G03_590	148	2050	2.0	5.0	24.6	0.00	0.01	0.08	20.8	2	5.0	4	798	2.88	0.8	0.05	3.0	1.41	0.04	0.3	0.9	203	0.3	21.8
26_6_1	tholeiitic basalt	G03_591	139	683	1.7	2.5	4.3	0.00	0.01	0.08	21.2	1	3.5	3	228	0.79	0.7	0.05	1.0	0.81	0.02	0.3	0.3	161	12.0	20.1
26_6_2	tholeiitic basalt	G03_592	171	896	1.6	3.1	12.3	0.00	0.02	0.08	20.3	1	4.1	2	312	0.94	0.8	0.05	2.0	0.89	0.04	0.3	0.4	158	0.3	19.7
26_6_7	Bingara	G03_593	218	4550	5.3	18.6	26.1	0.00	0.01	0.19	17.0	2	12.6	3	1340	6.25	1.5	0.05	10.0	1.32	0.06	0.3	2.5	188	2.0	29.3
26_6_8	Bingara	G03_594	214	4620	11.0	18.2	24.7	0.00	0.01	0.20	16.2	2	11.7	3	1670	6.32	1.4	0.05	10.0	1.32	0.05	0.3	2.6	189	1.0	29.1
26_6_10	Bingara	G03_595	168	748	1.0	2.5	7.0	0.00	0.01	0.07	21.5	1	3.1	3	257	0.87	0.6	0.05	1.0	0.77	0.02	0.3	0.3	188	0.4	17.8
26_6_13	Bingara	G03_596	226	4690	5.7	18.6	51.3	0.00	0.01	0.21	16.8	2	11.9	3	1110	6.64	1.4	0.05	10.0	1.35	0.06	0.4	2.6	193	1.0	31.2
11_8_1	Bingara	G03_597	166	1090	1.5	3.3	10.7	0.00	0.03	0.07	24.8	1	3.7	2	495	16.00	0.7	0.05	1.0	0.90	0.02	0.3	0.4	208	0.2	22.2
11_8_2	Bingara	G03_598	169	682	1.0	2.3	1.8	0.00	0.03	0.08	22.3	1	3.1	2	246	0.74	0.6	0.05	0.9	0.79	0.02	0.3	0.3	194	0.4	18.4
12_8_1	alkali basalt	G03_599	204	6840	9.0	30.9	46.8	0.00	0.01	0.28	11.8	2	18.8	4	1760	9.97	2.1	0.05	16.0	1.37	0.02	0.4	4.0	152	2.0	40.6
12_8_2	alkali basalt	G03_600	257	6320	7.1	28.2	56.7	0.00	0.01	0.26	11.5	2	17.6	4	1840	8.64	2.0	0.05	15.0	1.29	0.03	0.4	4.0	148	1.0	36.2
12_8_3	alkali basalt	G03_601	254	4450	6.0	16.3	34.8	0.00	0.01	0.21	17.9	2	11.1	8	1130	6.49	1.4	0.05	9.0	1.29	0.04	0.3	2.5	188	1.0	30.0
12_8_4	tholeiitic basalt	G03_602	202	1100	1.5	3.6	12.4	0.00	0.02	0.05	21.3	1	3.9	2	328	1.06	0.8	0.05	2.0	0.92	0.03	0.3	0.5	175	0.3	20.1

Sample	rock	DMRNo	Yb	Zn	Zr
13_3_12	tholeiitic basalt	G03_548	1.5	142	100
15_4_1	alkali basalt	G03_549	1.7	135	300
15_4_3	alkali basalt	G03_550	1.5	103	151
15_4_5	alkali basalt	G03_552	1.7	106	195
15_4_6	alkali basalt	G03_553	1.5	124	322
15_4_7	alkali basalt	G03_554	1.4	110	362
15_4_10	alkali basalt	G03_555	1.6	125	301
15_4_13	alkali basalt	G03_556	1.7	111	389
15_4_15	tholeiitic basalt	G03_557	1.5	104	67
15_4_18	alkali basalt	G03_558	1.5	112	266
15_4_19	tholeiitic basalt	G03_559	1.2	94	77
15_4_20	alkali basalt	G03_560	1.9	177	516
16_4_17	granite	G03_561	3.7	73	784
17_4_2	tholeiitic basalt	G03_562	1.6	95	93
23_6_2a	Braemar volcaniclastic	G03_583	0.6	77	307
23_6_2b	Braemar volcaniclastic	G03_584	1.0	42	234
23_6_3	tholeiitic basalt	G03_585	1.3	113	100
24_6_2	aplite	G03_586	3.2	38	58
24_6_10	granite	G03_587	3.7	42	109
25_6_5	alkali basalt	G03_588	1.9	109	243
25_6_7	alkali basalt	G03_589	1.9	110	229
25_6_8	alkali basalt	G03_590	1.7	104	205
26_6_1	tholeiitic basalt	G03_591	1.7	104	93
26_6_2	tholeiitic basalt	G03_592	1.8	120	129
26_6_7	Bingara	G03_593	2.0	154	358
26_6_8	Bingara	G03_594	2.0	154	372
26_6_10	Bingara	G03_595	1.6	110	84
26_6_13	Bingara	G03_596	2.0	161	349
11_8_1	Bingara	G03_597	2.1	119	109
11_8_2	Bingara	G03_598	1.7	115	79
12_8_1	alkali basalt	G03_599	2.2	192	530
12_8_2	alkali basalt	G03_600	2.1	178	503
12_8_3	alkali basalt	G03_601	2.1	147	370
12_8_4	tholeiitic basalt	G03_602	1.7	110	113

APPENDIX 4: TABLE OF MAPPED GEOLOGICAL UNITS

Letter Symbol	Geological System	Stratigraphic Names: Supergroup/Group_SuperSuite/ SubGroup/Formation_Pluton/ Member_unit	Era	Period	Lithological Description: Note additional information is available in the digital dataset
w	water body	///water body/	Cainozoic	Quaternary	water body / dam
Qacv1	Quaternary-Alluvium	///Quaternary alluvium - channel deposits/Current channel	Cainozoic	Quaternary	Unconsolidated silt and clay, minor sand. Commonly carbonaceous and flat to cross laminated.
Qabv1	Quaternary-Alluvium	///Quaternary alluvium - backplain deposits/Current backplain	Cainozoic	Quaternary	Unconsolidated clay, silt and quartz sand. Common desiccation cracks. Laminated and contains rootlets.
Qalm1	Quaternary-Alluvium	///Quaternary alluvium - abandoned channel deposits/	Cainozoic	Quaternary	Unconsolidated silt and clay, minor sand. Commonly carbonaceous and flat to cross laminated.
Qalv1	Quaternary-Alluvium	///Quaternary alluvium - abandoned channel deposits/	Cainozoic	Quaternary	Unconsolidated silt and clay, minor sand. Commonly carbonaceous and flat to cross laminated.
Qamv1	Quaternary-Alluvium	///Quaternary alluvium - meander plain deposits/Current meander plain	Cainozoic	Quaternary	Unconsolidated silt and clay with sandy lenses and organic matter. Poor to moderately sorted. Bioturbation and desiccation cracking are common. Some cross bedding.
Qamv2	Quaternary-Alluvium	///Quaternary alluvium - meander plain deposits/Palaeo-meander plain	Cainozoic	Quaternary	Unconsolidated to semi-consolidated silt, silty clay and fine sand. Sorting poor to very poor. Minor medium sand, ferromagnesian nodules, charcoal and salts. Strongly modified by pedogenesis.
Qaps1	Quaternary-Alluvium	///Quaternary alluvium - valley fill deposits/	Cainozoic	Quaternary	Unconsolidated gravel, sand, silt and clay
Qapv1	Quaternary-Alluvium	///Quaternary alluvium - valley fill deposits/	Cainozoic	Quaternary	Unconsolidated gravel, sand, silt and clay
Qats1	Quaternary-Terrace	///Quaternary alluvium - terrace deposits/Most recent terrace	Cainozoic	Quaternary	Unconsolidated gravel, sand, silt and clay
Qatv1	Quaternary-Terrace	///Quaternary alluvium - terrace deposits/Most recent terrace	Cainozoic	Quaternary	Unconsolidated gravel, sand, silt and clay
Qafe	Quaternary-Alluvium	///Quaternary alluvium - Heavy mineral deposits/	Cainozoic	Quaternary	Unconsolidated gravel, sand, silt and clay. Contains heavy mineral sands

Letter Symbol	Geological System	Stratigraphic Names: Supergroup/Group_SuperSuite/ SubGroup/Formation_Pluton/ Member_unit	Era	Period	Lithological Description: Note additional information is available in the digital dataset
Qahm	Quaternary-Alluvium	///Quaternary alluvium - Heavy mineral deposits/	Cainozoic	Quaternary	Unconsolidated gravel, sand, silt and clay. Contains iron-rich sands
Qffv1	Quaternary-Piedmont	///Quaternary piedmont - fan shaped/Palaeo-fan	Cainozoic	Quaternary	Unconsolidated gravel, sand, silt and clay
Qfov1	Quaternary-Piedmont	///Quaternary piedmont - flood out sheets/	Cainozoic	Quaternary	Unconsolidated gravel, sand, silt and clay
Tnm	Nandewar Volcanic Complex	/Nandewar Volcanic Complex///Monzonite intrusion	Cainozoic	Tertiary	Monzonite
Tnr1	Nandewar Volcanic Complex	/Nandewar Volcanic Complex///Felsic intrusives1	Cainozoic	Tertiary	Comendite plugs & alkali rhyolite plugs & domes
Tnr2	Nandewar Volcanic Complex	/Nandewar Volcanic Complex///Felsic intrusives2	Cainozoic	Tertiary	Alkali rhyolite and comendite plugs and domes.
Tnt1	Nandewar Volcanic Complex	/Nandewar Volcanic Complex///Basalt extrusives	Cainozoic	Tertiary	Hawaiite, trachyandesite, tristanite, trachyte, minor peralkaline trachyte, tuff
Tnt2	Nandewar Volcanic Complex	/Nandewar Volcanic Complex///Trachyte intrusives1	Cainozoic	Tertiary	Peralkaline trachyte plugs & ring dykes
Tny	Nandewar Volcanic Complex	/Nandewar Volcanic Complex///Trachyte intrusives2	Cainozoic	Tertiary	Trachyte dykes & plugs
Tno	Nandewar Volcanic Complex	/Nandewar Volcanic Complex///Mafic intrusives	Cainozoic	Tertiary	Undifferentiated basic sills, dykes & plugs
Tnf	Nandewar Volcanic Complex	/Nandewar Volcanic Complex///Diatomite members	Cainozoic	Tertiary	Diatomite

Letter Symbol	Geological System	Stratigraphic Names: Supergroup/Group_SuperSuite/ SubGroup/Formation_Pluton/ Member_unit	Era	Period	Lithological Description: Note additional information is available in the digital dataset
Tnx	Nandewar Volcanic Complex	/Nandewar Volcanic Complex///Unnamed sediments	Cainozoic	Tertiary	Undifferentiated poorly to well consolidated sediments. May include conglomerate, sandstone, claystone, diatomite, gravel, sand, silt & mud. In places, lateritic sediments, lateritic ironstone, laterite, lateritic basalt, and silcrete (Greybilly).
Tnj	Nandewar Volcanic Complex	/Nandewar Volcanic Complex///Teschenite intrusives	Cainozoic	Tertiary	Analcime dolerite & teschenite sills, dykes, & plugs
Tctb	Central Province- Tholeiitic Association	/Central Province (inf)///Mafic extrusives	Cainozoic	Tertiary	Tholeiitic basalt, fine-grained, massive, equigranular containing olivine- calcic plagioclase-clinopyroxene groundmass, characteristic black radiometric signature
Tctbb	Central Province- Tholeiitic Association	/Central Province (inf)///Mafic extrusives	Cainozoic	Tertiary	Tholeiitic basalt, fine-grained, massive, equigranular containing olivine- calcic plagioclase-clinopyroxene groundmass, characteristic bright blue radiometric signature
Tctbg	Central Province- Tholeiitic Association	/Central Province (inf)///Mafic extrusives	Cainozoic	Tertiary	Tholeiitic basalt, fine-grained, massive, equigranular, characteristic dark green radiometric signature due to weathering and/or Quaternary cover
Tctv	Central Province- Tholeiitic Association	/Central Province (inf)///Mafic extrusives	Cainozoic	Tertiary	Tholeiitic volcaniclastics of basaltic composition, characteristic dark green radiometric signature
Tutb	Central Province- Tholeiitic Association	/Central Province (inf)///Mafic extrusives	Cainozoic	Tertiary	Undifferentiated tholeiitic basalt, black radiometric signature
Tctx	Central Province- Tholeiitic Association	/Central Province (inf)///Unnamed sediments	Cainozoic	Tertiary	Undifferentiated volcanics and sediments
Tcab	Central Province- Alkaline Association	/Central Province (inf)///Mafic extrusives	Cainozoic	Tertiary	Alkaline basalt comprising alkali olivine basalts, basanites and more rarely nephelenites, characteristic red radiometric signature.
Tcabb	Central Province- Alkaline Association	/Central Province (inf)///Mafic extrusives	Cainozoic	Tertiary	Alkaline basalt comprising basanites and nephelenites, characteristic bright blue radiometric signature.

Letter Symbol	Geological System	Stratigraphic Names: Supergroup/Group_SuperSuite/ SubGroup/Formation_Pluton/ Member_unit	Era	Period	Lithological Description: Note additional information is available in the digital dataset
Tcabg	Central Province- Alkaline Association	/Central Province (inf)///Mafic extrusives	Cainozoic	Tertiary	Alkaline basalt comprising alkali olivine basalts, basanites and more rarely nephelenites, characteristic dark green radiometric signature due to weathering and/or Quaternary cover
Tcav	Central Province- Alkaline Association	/Central Province (inf)///Mafic extrusives	Cainozoic	Tertiary	Undifferentiated alkali basaltic volcaniclastics, characteristic dark green radiometric signature
Tl	Liverpool Range Volcanics	/Liverpool Range Volcanics///Undifferentiated	Cainozoic	Tertiary	Flows of alkaline intergranular olivine basalt , ankaramite and tholeiitic basalt, with occasional sediment interbeds, dolerite, teschenite, trachyte and microsyenite
Tbb	Barrington Volcanic Province	/Barrington Volcanic Province///Mafic extrusives	Cainozoic	Tertiary	Flows of alkaline olivine basalt, hawaiite and theralite with minor intrusions of theralite and teschenite. Minor tholeiitic basalt flows at the base of the sequence.
Tbi	Barrington Volcanic Province	/Barrington Volcanic Province///Unnamed intrusions	Cainozoic	Tertiary	Dolerite, syenite and trachyte
Tbx	Barrington Volcanic Province	/Barrington Volcanic Province///Unnamed sediments	Cainozoic	Tertiary	Deep lead gravel and sands, locally grading into ferruginised or silicified conglomerate and sandstone. Also locally diatomite and lignite
Tui	Undifferentiated Volcanics	///Undifferentiated Volcanics/Mafic intrusives	Cainozoic	Tertiary	Dolerite, syenite and trachyte
Tuabb	Undifferentiated Volcanics	///Undifferentiated Volcanics/Tholeiitic member	Cainozoic	Tertiary	Tholeiitic basalt, fine-grained, massive, equigranular containing olivine- calcic plagioclase-clinopyroxene groundmass.
Tc	Tertiary Sediments	///Tertiary Conglomerate/	Cainozoic	Tertiary	Gravel, conglomerate, minor sandstone. Includes high-level gravels
Tx	Tertiary Sediments	///Tertiary Sediments1/	Cainozoic	Tertiary	Undifferentiated poorly to well consolidated sediments. May include conglomerate, sandstone, claystone, diatomite, gravel, sand, silt & mud. In places, lateritic sediments, lateritic ironstone, laterite, lateritic basalt, and silcrete (Greybilly).
Ts	Tertiary Sediments	///Tertiary Sediments1/	Cainozoic	Tertiary	Sandstone, pebbly sandstone
Jsb	Surat Basin	Surat Basin///Undifferentiated/	Mesozoic	Triassic	Assorted Jurassic to Cretaceous sedimentary rocks

Letter Symbol	Geological System	Stratigraphic Names: Supergroup/Group_SuperSuite/ SubGroup/Formation_Pluton/ Member_unit	Era	Period	Lithological Description: Note additional information is available in the digital dataset
JKlk	Surat Basin	///Keelindi beds/	Mesozoic	Jurassic	Off-white, fine to coarse-grained, poorly to well sorted, quartzose sandstone, pebbly sandstone and conglomerate interbedded with minor shale, siltstone and coal. Cross-bedded, kaolinitic and iron stained. Rare silicified wood, ?worm burrows.
Jps	Surat Basin	///Pilliga Sandstone/	Mesozoic	Jurassic	Medium to coarse, cross bedded quartzose sandstone with basal pebble lenses common; minor interbeds of siltstone & mudstone
Jwx	Surat Basin	///Walloon Coal Measures/	Mesozoic	Jurassic	Lithic arenite, granule to pebble conglomerate, siltstone, mudstone & coal; the unit is carbonaceous throughout
Jhs	Surat Basin	///Hutton Sandstone/	Mesozoic	Jurassic	Coarse to medium, quartz labile sandstone with minor conglomerate, siltstone, mudstone & coal
Jpu	Surat Basin	///Purlewaugh Formation/	Mesozoic	Jurassic	Fine to medium-grained lithic to labile sandstone thinly interbedded with siltstone, mudstone and thin coal seams. Abundant carbonaceous fragments, thin beds of flint clay.
RJgv	Surat Basin	///Garrawilla Volcanics/	Mesozoic	Triassic	Vesicular & non-vesicular, alkali-olivine basalt, hawaiite, basanite, mugearite & associated sills & plugs
RJux	Surat Basin	///Unnamed Triassic to Jurassic sedimentary rocks/	Mesozoic	Triassic	Sandstone, siltstone & mudstone
Jro	Mesozoic Intrusives	///Ruby Hill neck (informal)/	Mesozoic	Jurassic	Basic breccia with eclogite & granulite inclusions, intruded by alkali olivine basalt dykes. Informally referred to as the Ruby Hill Neck
Ji	Mesozoic Intrusives	///Unnamed Jurassic Intrusions/	Mesozoic	Jurassic	Analcimite dykes & plugs
Md	Mesozoic Intrusives	///Mesozoic Igneous Rocks2/	Mesozoic	Triassic	Medium- to coarse-grained porphyritic alkali diorite, alkali gabbro, teschenite
Rgc	Warialda Trough	///Gragin Conglomerate/	Mesozoic	Triassic	Orthoconglomerate, sporadic paraconglomerate, minor lithic arenite & rare mudstone at the top of the unit
Rgx	Warialda Trough	///Gunee Formation/	Mesozoic	Triassic	Interbedded conglomerate & very coarse lithic arenite; very coarse feldspatholithic gravel at the base, grades upwards into labile sandstone, siltstone & carbonaceous mudstone & minor coal
Pli	Werrie Basin-North	///Willow Tree Formation/	Palaeozoic	Permian	Shale, lithic sandstone, conglomerate, coal

Letter Symbol	Geological System	Stratigraphic Names: Supergroup/Group_SuperSuite/ SubGroup/Formation_Pluton/ Member_unit	Era	Period	Lithological Description: Note additional information is available in the digital dataset
Pwb2	Werrie Basin-North	///Werrie Basalt/	Palaeozoic	Permian	Basaltic lavas with intervening palaeosols and local, thin coals
Pwc	Werrie Basin-North	///Warrigundi Igneous Complex/	Palaeozoic	Permian	Pyroxene andesite, dacite, rhyolite flows and dykes, diorite
Pwco	Werrie Basin-North	///Warrigundi Igneous Complex/Diorite member	Palaeozoic	Permian	Diorite
Plm1	Werrie Basin-North	///Temi Formation/	Palaeozoic	Permian	Tuffaceous lithic sandstone and conglomerate, shale, carbonaceous shale
Pm2	Werrie Basin-South	///Murula beds/	Palaeozoic	Permian	Coal seams, claystone, siltstone, sandstone, conglomerate.
Pb	Werrie Basin-South	///Bickham Formation/	Palaeozoic	Permian	Sandstones and conglomerates
Pk	Werrie Basin-South	///Koogah Formation/	Palaeozoic	Permian	Coals, carbonaceous shales and sandstones
Pwb3	Werrie Basin-South	///Werrie Basalt/	Palaeozoic	Permian	Basaltic lavas with intervening palaeosols and local, thin coals
Plm2	Werrie Basin-South	///Temi Formation/	Palaeozoic	Permian	Tuffaceous lithic sandstone and conglomerate, shale, carbonaceous shale
PRgb	Gunnedah Coalfield	Gunnedah Coalfield///Undifferentiated/	Palaeozoic	Permian	Undifferentiated Gunnedah Coalfield sedimentary and volcanic rocks
Rdh	Gunnedah Coalfield	///Deriah Formation/	Mesozoic	Triassic	Fine to medium-grained lithic sandstone rich in volcanic fragments with common mudstone clasts overlain by off-white lithic sandstone and dark grey mudstone
Rns	Gunnedah Coalfield	///Napperby Formation/	Mesozoic	Triassic	Finely laminated quartzose sandstone & siltstone interbedded with thick, massive or crossbedded quartzose sandstone. Minor conglomerate
Rdc	Gunnedah Coalfield	///Digby Formation/	Mesozoic	Triassic	Poorly sorted, pebble to boulder orthoconglomerate, rare sandstone
Pps	Gunnedah Coalfield	/Millie Group//Porcupine Formation/	Palaeozoic	Permian	Basal conglomerate passing upward into bioturbated silty sandstone and minor siltstone with dropped pebbles
Pmx	Gunnedah Coalfield	/Bellata Group//Maules Creek Formation/	Palaeozoic	Permian	Basal carbonaceous claystone, pelletoidal clay sandstone, minor coal, passing upwards into upward-fining cycles of sandstone, thinly bedded siltstone / sandstone and coal. Conglomerate dominant towards top

Letter Symbol	Geological System	Stratigraphic Names: Supergroup/Group_SuperSuite/ SubGroup/Formation_Pluton/ Member_unit	Era	Period	Lithological Description: Note additional information is available in the digital dataset
Pwb1	Gunnedah Coalfield	///Werrie Basalt/	Palaeozoic	Permian	Basaltic lavas with intervening palaeosols and local, thin coals
Rna1	Hunter Coalfield	/Narrabeen Group//Undifferentiated/	Mesozoic	Triassic	Pebbly lithic-quartz to quartz sandstone, red-brown to green mudstone, sporadic lenses of quartz paraconglomerate
Pm1	Hunter Coalfield	Singleton Supergroup///Murula beds/	Palaeozoic	Permian	Coal seams, claystone, siltstone, sandstone, conglomerate.
Rlsu	Moonbi Supersuite	Moonbi Supersuite/leucogranites//Stanthorpe Monzogranite/	Mesozoic	Triassic	Coarse-grained, even textured to weakly porphyritic, pale pink to buff, biotite-poor leucogranite with scattered fine-grained saccharoidal leucogranite. Eight varieties have been mapped in places mainly based on textural differences
PRlcu	Moonbi Supersuite	Moonbi Supersuite/leucogranites//Clive Monzogranite/	Palaeozoic	Permian	Coarse-gr. equigranular, pale buff to white biotite leucogranite.
PRmio	Moonbi Supersuite	Moonbi Supersuite///Inlet Monzonite/	Palaeozoic	Permian	Meduim to coarse-grained porphyritic hornblende - biotite monzonite
PRmlu	Moonbi Supersuite	Moonbi Supersuite///Limbri Leucomonzogranite/	Palaeozoic	Permian	Equigranular biotite - (muscovite) leucomonzogranite
PRmag1	Moonbi Supersuite	Moonbi Supersuite///Attunga Creek Monzogranite/	Palaeozoic	Permian	Massive, weakly to strongly porphyritic, biotite & hornblende monzogranite. High potassium uranium and thorium
PRmag2	Moonbi Supersuite	Moonbi Supersuite///Attunga Creek Monzogranite/	Palaeozoic	Permian	Massive, weakly to strongly porphyritic, biotite & hornblende monzogranite. Moderate potassium uranium and thorium
PRmbg	Moonbi Supersuite	Moonbi Supersuite/Moonbi Suite//Bendemeer Monzogranite/	Palaeozoic	Permian	Approximately equigranular coarse-grained, hornblende - biotite monzogranite and minor monzonite
PRmcg	Moonbi Supersuite	Moonbi Supersuite///Congi Creek Monzogranite/	Palaeozoic	Permian	Approximately equigranular fine to medium-grained biotite monzogranite
PRmdg	Moonbi Supersuite	Moonbi Supersuite///Unnamed monzogranite in the Echo Hills area/	Palaeozoic	Permian	Monzogranite in Echo Hills area
PRmkg	Moonbi Supersuite	Moonbi Supersuite///Back Creek Tonalite/	Palaeozoic	Permian	Tonalite
PRmlg	Moonbi Supersuite	Moonbi Supersuite///Looanga Monzogranite/	Palaeozoic	Permian	Medium to coarse-grained equigranular biotite - (hornblende) monzogranite

Letter Symbol	Geological System	Stratigraphic Names: Supergroup/Group_SuperSuite/ SubGroup/Formation_Pluton/ Member_unit	Era	Period	Lithological Description: Note additional information is available in the digital dataset
PRmmg	Moonbi Supersuite	Moonbi Supersuite/Moonbi Suite//Moonbi Monzogranite/	Palaeozoic	Permian	Coarsely porphyritic biotite - hornblende monzogranite and minor monzonite
PRmpg	Moonbi Supersuite	Moonbi Supersuite///Campbells Hill Monzogranite/	Palaeozoic	Permian	Approximately equigranular biotite leucomonzogranite and monzogranite
PRmsg	Moonbi Supersuite	Moonbi Supersuite///Standbye Monzogranite/	Palaeozoic	Permian	Coarsely porphyritic hornblende-biotite monzogranite with inequigranular groundmass
PRmwg	Moonbi Supersuite	Moonbi Supersuite///Walcha Road Monzogranite/	Palaeozoic	Permian	Monzogranite: High K sphene-magnetite bearing I-type granitoid
PRmzg	Moonbi Supersuite	Moonbi Supersuite///Unnamed porphyries & granitoids/	Palaeozoic	Permian	Unnamed porphyries and granitoids
Rlmu	Uralla Supersuite	Uralla Supersuite/leucogranites//Mole Granite/	Mesozoic	Triassic	Coarse to very coarse-grained seriate leucocratic granite & minor microleucogranite. Marginal porphyritic leucogranite & microgranite; greisen
Rluu	Uralla Supersuite	Uralla Supersuite/leucogranites//Dumboy-Gragin Granite/	Mesozoic	Triassic	Leucocratic, medium to coarse-grained syenogranite with K-feldspar megacrysts common & a micrographic to granophyric texture developed in places
Rlwu	Uralla Supersuite	Uralla Supersuite/leucogranites//Webbs Consols Leucogranite/	Mesozoic	Triassic	Medium to coarse-grained leucocratic & granophyric alkali feldspar granite with large quartz & K-feldspar megacrysts; a second phase consists of graphic & granophyric fine-grained granite
Rliu	Uralla Supersuite	Uralla Supersuite/leucogranites//Gilgai Granite/	Mesozoic	Triassic	Fine to coarse-grained porphyritic to equigranular biotite- (hornblende) granite and monzogranite
Rlium	Uralla Supersuite	Uralla Supersuite/leucogranites//Gilgai Granite/	Mesozoic	Triassic	Fine to coarse-grained porphyritic to equigranular biotite- (hornblende) granite and monzogranite, mottled radiometric signature
Rliup	Uralla Supersuite	Uralla Supersuite/leucogranites//Gilgai Granite/	Mesozoic	Triassic	Fine to coarse-grained porphyritic to equigranular biotite- (hornblende) granite and monzogranite, pink radiometric signature
Rliur	Uralla Supersuite	Uralla Supersuite/leucogranites//Gilgai Granite/	Mesozoic	Triassic	Fine to coarse-grained porphyritic to equigranular biotite- (hornblende) granite and monzogranite, red radiometric signature
Rliuy	Uralla Supersuite	Uralla Supersuite/leucogranites//Gilgai Granite/	Mesozoic	Triassic	Fine to coarse-grained porphyritic to equigranular biotite- (hornblende) granite and monzogranite, yellow radiometric signature

Letter Symbol	Geological System	Stratigraphic Names: Supergroup/Group_SuperSuite/ SubGroup/Formation_Pluton/ Member_unit	Era	Period	Lithological Description: Note additional information is available in the digital dataset
Rlfu	Uralla Supersuite	Uralla Supersuite/leucogranites//Elsmore Granite/	Mesozoic	Triassic	Medium-grained leucocratic monzogranite with a seriate to porphyritic texture; in part extensively altered with greisenisation & silicification being typical
Rutg	Uralla Supersuite	Uralla Supersuite///Tingha Monzogranite/	Palaeozoic	Permian	Porphyritic hornblende-biotite monzogranite
Pnz	Clarence River Supersuite	Clarence River Supersuite/Nundle Suite//Unnamed felsic intrusives/	Palaeozoic	Permian	Porphyries, granitoids, leucocratic sills & dykes
Pnz1	Clarence River Supersuite	Clarence River Supersuite/Nundle Suite//Unnamed felsic intrusives/	Palaeozoic	Permian	Porphyries and granitoids
Pne	Clarence River Supersuite	Clarence River Supersuite/Nundle Suite//Mt Ephraim Granodiorite/	Palaeozoic	Permian	Trondhjemite, granodiorite
Pnd	Clarence River Supersuite	Clarence River Supersuite/Nundle Suite//Duncans Creek Trondhjemite/	Palaeozoic	Permian	Trondhjemite
Pnx	Clarence River Supersuite	Clarence River Supersuite/Nundle Suite//Unnamed granitoids/	Palaeozoic	Permian	Porphyries and granitoids
Pnr	Clarence River Supersuite	Clarence River Supersuite/Nundle Suite//Rockisle Granodiorite/	Palaeozoic	Permian	Granodiorite and minor monzogranite bearing trace secondary sub-aluminous calcic amphibole; primary hornblende bearing granitoids of mafic complexes; some are amphibole bearing phases in Clarence River Supersuite members
Pabd	Clarence River Supersuite	Clarence River Supersuite///Boxwell Granodiorite/	Palaeozoic	Permian	Dark grey, medium to coarse-grained, equigranular, hornblende-bearing monzodiorite & quartz monzodiorite
Pbg	Bundarra Supersuite	Bundarra Supersuite///Undifferentiated/	Palaeozoic	Permian	Coarse to very coarse-grained, porphyritic & equigranular (biotite) - (muscovite) - (garnet) -(cordierite) granite & leucogranite. K-feldspar megacrysts abundant in places
Pbg1	Bundarra Supersuite	Bundarra Supersuite///Unnamed intrusive member 1/	Palaeozoic	Permian	Coarse to very coarse-grained, porphyritic & equigranular (biotite) - (muscovite) - (garnet) -(cordierite) granite & leucogranite. K-feldspar megacrysts abundant in places
Pbg2	Bundarra Supersuite	Bundarra Supersuite///Unnamed intrusive member 2/	Palaeozoic	Permian	Coarse to very coarse-grained, porphyritic & equigranular (biotite) - (muscovite) - (garnet) -(cordierite) granite & leucogranite. K-feldspar megacrysts abundant in places

Letter Symbol	Geological System	Stratigraphic Names: Supergroup/Group_SuperSuite/ SubGroup/Formation_Pluton/ Member_unit	Era	Period	Lithological Description: Note additional information is available in the digital dataset
Pbgg	Bundarra Supersuite	Bundarra Supersuite/Glenclair Suite//Glenclair Monzogranite/	Palaeozoic	Permian	Porphyritic biotite granite
Pbbg	Bundarra Supersuite	Bundarra Supersuite/Banalasta Suite//Banalasta Monzogranite/	Palaeozoic	Permian	Porphyritic biotite - muscovite - cordierite granite
Pbgp	Bundarra Supersuite	Bundarra Supersuite/Banalasta Suite//Pringles Monzogranite/	Palaeozoic	Permian	Approximately equigranular biotite-muscovite- cordierite granite
Rwd	Undifferentiated intrusives	///"Willowie Diorite"/	Mesozoic	Triassic	Diorite
Pfd	Undifferentiated intrusives	///"Foxtor Diorite"/	Palaeozoic	Permian	Diorite
PRxg	Undifferentiated intrusives	///Unnamed felsic dykes/	Palaeozoic	Permian	Felsic dykes & stocks.
Po	Undifferentiated intrusives	///Unnamed gabbroic intrusions/	Palaeozoic	Permian	Gabbroic intrusions
Poo	Undifferentiated intrusives	///Unnamed mafic intrusive bodies/	Palaeozoic	Permian	Undifferentiated small mafic dykes & masses; hornblende diorite, hornblende gabbro; mafic intrusives possibly associated with granitoids
Pu	Undifferentiated intrusives	///Unnamed aplite dyke/	Palaeozoic	Permian	Unnamed aplite dyke
Pxd	Undifferentiated intrusives	///Unnamed granodiorite & tonalite bodies/	Palaeozoic	Permian	Undifferentiated granodiorites, tonalites, & unnamed mass of Moggs swamp composed of med.-gr., equigranular, plagioclase- quartz- biotite- hornblende- pyroxene tonalite; med. to coarse-gr. granodiorite
Pxg	Undifferentiated intrusives	///Unnamed granitoids/	Palaeozoic	Permian	Granite, biotite granite, microgranite, aplite, leucogranite
Pxg1	Undifferentiated intrusives	///Unnamed granite/	Palaeozoic	Permian	Quartz-feldspar-biotite granitoid
Pkx	Early Permian strata next to Peel Fault	/Unnamed Early Permian Group//Kensington Formation/	Palaeozoic	Permian	Conglomerate, siltstone, sandstone, rare basalt & limestone

Letter Symbol	Geological System	Stratigraphic Names: Supergroup/Group_SuperSuite/ SubGroup/Formation_Pluton/ Member_unit	Era	Period	Lithological Description: Note additional information is available in the digital dataset
Pts	Early Permian strata next to Peel Fault	/Unnamed Early Permian Group//Tarakan Formation/	Palaeozoic	Permian	Quartzose & lithic sandstone, orthoconglomerate, minor mudstone & siltstone
Pis	Early Permian strata next to Peel Fault	/Unnamed Early Permian Group//Ironbark Creek Arenite/	Palaeozoic	Permian	Massive fossiliferous quartzose & lithic sandstone
Cuw	Unnamed overlap assemblage	/Unnamed overlap assemblage//Willuri Formation/Undifferentiated	Palaeozoic	Carboniferous	Ignimbrites (rhyolitic, dacitic and andesitic), rhyolite flows, dacite dome, rhyolitic agglomerate & conglomerate, & interbedded thinly bedded ash-rich siltstone, medium to thick bedded medium to coarse-grained volcanolithic sandstone & thick bedded conglomerate
Cuwb	Unnamed overlap assemblage	/Unnamed overlap assemblage//Willuri Formation/Bunaleer Dacite	Palaeozoic	Carboniferous	Grey, strongly flow foliated, dacite; dome-like structure 4x1.5 km, interbedded glass, pyroclastics and conglomerate at flanks; 316.3±2.7 Ma 1 sigma, AS3, loc 432-7, 0238859 6610351; related flow remnants south of dome
Cuwg	Unnamed overlap assemblage	/Unnamed overlap assemblage//Willuri Formation/Gunnan Ignimbrite	Palaeozoic	Carboniferous	Brown-grey, coarse, crystal-rich, slightly welded to unwelded, rhyolitic ignimbrite
Cuwo	Unnamed overlap assemblage	/Unnamed overlap assemblage//Willuri Formation/Ourinperee Ignimbrite	Palaeozoic	Carboniferous	Beige, purple to red, unwelded to slightly welded rhyolitic ignimbrite; underlain by pyroxene andesite at 'Ourimperee'
Cuwp	Unnamed overlap assemblage	/Unnamed overlap assemblage//Willuri Formation/Penryn Rhyolite - Undifferentiated	Palaeozoic	Carboniferous	Beige-orange rhyolite lava, glass and welded, rhyolitic ignimbrite
Cuwp1	Unnamed overlap assemblage	/Unnamed overlap assemblage//Willuri Formation/Penryn Rhyolite - Unnamed Volcanic Member 1	Palaeozoic	Carboniferous	Purpe, red or beige, felsic volcanic breccia and grey to green andesitic ignimbrite (hornblende + biotite)
Cuwp2	Unnamed overlap assemblage	/Unnamed overlap assemblage//Willuri Formation/Penryn Rhyolite - Unnamed Volcanic Member 2	Palaeozoic	Carboniferous	Crystal-rich, grey, beige or red, unwelded, rhyolitic ignimbrite
Cuwp3	Unnamed overlap assemblage	/Unnamed overlap assemblage//Willuri Formation/Penryn Rhyolite - Unnamed Volcanic Member 3	Palaeozoic	Carboniferous	Moderately welded, purple rhyolitic ignimbrite
Cuwpr	Unnamed overlap assemblage	/Unnamed overlap assemblage//Willuri Formation/Plagyan Ignimbrite	Palaeozoic	Carboniferous	Interbedded coarse grey, or purple rhyolitic ignimbrite and interbedded grey hornblende-rich dacitic to andesitic ignimbrite

Letter Symbol	Geological System	Stratigraphic Names: Supergroup/Group_SuperSuite/ SubGroup/Formation_Pluton/ Member_unit	Era	Period	Lithological Description: Note additional information is available in the digital dataset
Cuwr	Unnamed overlap assemblage	/Unnamed overlap assemblage//Willuri Formation/Birken Head Rhyolite - Undifferentiated	Palaeozoic	Carboniferous	Red-green, glassy to partly pumiceous, unwelded ignimbrite ; 324.0±3.0 1 sigma, Pb loss, loc 429-1, 0244559 6603207
Cuwr1	Unnamed overlap assemblage	/Unnamed overlap assemblage//Willuri Formation/Birken Head Rhyolite - Unnamed Volcanic Member 1	Palaeozoic	Carboniferous	Purple, slightly welded, rhyolitic ignimbrite; 320.8±1.8 1 sigma, loc 512-1A, 0244001 6603630
Cuwr2	Unnamed overlap assemblage	/Unnamed overlap assemblage//Willuri Formation/Birken Head Rhyolite - Unnamed Volcanic Member 2	Palaeozoic	Carboniferous	Purple, welded, rhyolitic ignimbrite
Cuwr3	Unnamed overlap assemblage	/Unnamed overlap assemblage//Willuri Formation/Birken Head Rhyolite - Unnamed Volcanic Member 3	Palaeozoic	Carboniferous	Purple, pumiceous, unwelded, rhyolitic ignimbrite
Cuwr4	Unnamed overlap assemblage	/Unnamed overlap assemblage//Willuri Formation/Birken Head Rhyolite - Unnamed Volcanic Member 4	Palaeozoic	Carboniferous	Beige, welded, rhyolitic ignimbrite; flow foliated, glassy
Cuwr5	Unnamed overlap assemblage	/Unnamed overlap assemblage//Willuri Formation/Birken Head Rhyolite - Unnamed Volcanic Member 5	Palaeozoic	Carboniferous	Beige, welded, pumiceous, rhyolitic ignimbrite, glassy at base; 310.6±2.1 1 sigma AS3 standard , loc 429-2 0242010 6604876
Cuwr6	Unnamed overlap assemblage	/Unnamed overlap assemblage//Willuri Formation/Birken Head Rhyolite - Unnamed Volcanic Member 6	Palaeozoic	Carboniferous	Beige, pumiceous, unwelded, rhyolitic ignimbrite
Cuwr7	Unnamed overlap assemblage	/Unnamed overlap assemblage//Willuri Formation/Birken Head Rhyolite - Unnamed Volcanic Member 7	Palaeozoic	Carboniferous	Grey, beige to red, coarse, crystal-rich pyroclastic/ignimbrite; vitric in places; 311.0±2.0 1 sigma AS3 standard, loc 429-6 0239787 6604990
Cuwr9	Unnamed overlap assemblage	/Unnamed overlap assemblage//Willuri Formation/Birken Head Rhyolite - Unnamed Volcanic Member 9	Palaeozoic	Carboniferous	Grey, fine-grained, rhyolite lava
Cuwr10	Unnamed overlap assemblage	/Unnamed overlap assemblage//Willuri Formation/Birken Head Rhyolite - Unnamed Volcanic Member 10	Palaeozoic	Carboniferous	Crystal-rich, beige, pumiceous ignimbrite/resedimented pyroclastic with overlying red rhyolitic ignimbrite in north

Letter Symbol	Geological System	Stratigraphic Names: Supergroup/Group_SuperSuite/ SubGroup/Formation_Pluton/ Member_unit	Era	Period	Lithological Description: Note additional information is available in the digital dataset
Cuwr11	Unnamed overlap assemblage	/Unnamed overlap assemblage//Willuri Formation/Birken Head Rhyolite - Unnamed Volcanic Member 11	Palaeozoic	Carboniferous	Grey to beige, welded, rhyolitic ignimbrite; pumiceous, flow foliated, glassy to spherulitic
Cuwt	Unnamed overlap assemblage	/Unnamed overlap assemblage//Willuri Formation/Tranquille Dacite	Palaeozoic	Carboniferous	Purple-red, welded to unwelded, rhyolitic ignimbrite
Cuwv	Unnamed overlap assemblage	/Unnamed overlap assemblage//Willuri Formation/Unnamed volcanic member	Palaeozoic	Carboniferous	Tuff
Cuwy	Unnamed overlap assemblage	/Unnamed overlap assemblage//Willuri Formation/Yarralumba Rhyolite	Palaeozoic	Carboniferous	Beige, pink or grey, rhyolitic ignimbrite, agglomerate, conglomerate, coarse resedimented rhyolitic sandstone and minor rhyolite flows
Cbc	Unnamed overlap assemblage	/Unnamed overlap assemblage//Currabubula Formation/Undifferentiated	Palaeozoic	Carboniferous	Paraconglomerate, orthoconglomerate, crossbedded feldspathic & lithic sandstone, siltstone, mudstone & minor limestone. Felsic ashflow & airfall tuff, rhyolitic-andesitic crystal & vitric tuff. Includes tallus at base of Mooki Thrust escarpment
Cba	Unnamed overlap assemblage	/Unnamed overlap assemblage//Currabubula Formation/Cana Creek Ignimbrite Member	Palaeozoic	Carboniferous	Rhyolitic, green, crystal-rich tuff, consisting of volcaniclastic and pyroclastic facies, dominantly reworked
Cbb	Unnamed overlap assemblage	/Unnamed overlap assemblage//Currabubula Formation/Brogans Ignimbrite	Palaeozoic	Carboniferous	Beige, unwelded, rhyolitic ignimbrite, pumiceous in part
Cbcs	Unnamed overlap assemblage	/Unnamed overlap assemblage//Currabubula Formation/Unnamed sandstone member	Palaeozoic	Carboniferous	Sandstone
Cbcc	Unnamed overlap assemblage	/Unnamed overlap assemblage//Currabubula Formation/Unnamed conglomerate member	Palaeozoic	Carboniferous	Conglomerate
Cbd	Unnamed overlap assemblage	/Unnamed overlap assemblage//Currabubula Formation/Tremaine Tuff Member (Inf)	Palaeozoic	Carboniferous	Lightly welded crystal-vitric tuff. Heulandite-rich
Cbf	Unnamed overlap	/Unnamed overlap assemblage//Currabubula	Palaeozoic	Carboniferous	Tuff

Letter Symbol	Geological System	Stratigraphic Names: Supergroup/Group_SuperSuite/ SubGroup/Formation_Pluton/ Member_unit	Era	Period	Lithological Description: Note additional information is available in the digital dataset
	assemblage	Formation/White Rocks Tuff Member (Inf)			
Cbg	Unnamed overlap assemblage	/Unnamed overlap assemblage//Currabubula Formation/Gun Barrel Tuff Member (Inf)	Palaeozoic	Carboniferous	Tuff
Cbh	Unnamed overlap assemblage	/Unnamed overlap assemblage//Currabubula Formation/Bald Hill Tuff Member (Inf)	Palaeozoic	Carboniferous	Buff brown coloured, andesitic, highly welded vitric tuff, containing celadonite
Cbi	Unnamed overlap assemblage	/Unnamed overlap assemblage//Currabubula Formation/Iventure Ignimbrite Member	Palaeozoic	Carboniferous	Ignimbrite
Cbk	Unnamed overlap assemblage	/Unnamed overlap assemblage//Currabubula Formation/Back Creek Tuff Member (Inf)	Palaeozoic	Carboniferous	Tuff
Cbl	Unnamed overlap assemblage	/Unnamed overlap assemblage//Currabubula Formation/Allawa Tuff Member (Inf)	Palaeozoic	Carboniferous	Tuff
Cbm	Unnamed overlap assemblage	/Unnamed overlap assemblage//Currabubula Formation/Castle Mountain Tuff Member (Inf)	Palaeozoic	Carboniferous	Tuff
Cbn	Unnamed overlap assemblage	/Unnamed overlap assemblage//Currabubula Formation/Inglewood Member	Palaeozoic	Carboniferous	Laminated to massive, multicoloured, silty mudstone, fine to medium-grained, beige, lithic sandstone (some with rip-up clasts), diamictite and conglomerate
Cbo	Unnamed overlap assemblage	/Unnamed overlap assemblage//Currabubula Formation/Chilcotts Creek Tuff Member (Inf)	Palaeozoic	Carboniferous	Tuff
Cbp	Unnamed overlap assemblage	/Unnamed overlap assemblage//Currabubula Formation/Piallaway Trig Ignimbrite Member	Palaeozoic	Carboniferous	Ignimbrite

Letter Symbol	Geological System	Stratigraphic Names: Supergroup/Group_SuperSuite/ SubGroup/Formation_Pluton/ Member_unit	Era	Period	Lithological Description: Note additional information is available in the digital dataset
Cbr	Unnamed overlap assemblage	/Unnamed overlap assemblage//Currabubula Formation/Tara Formation (Inf)	Palaeozoic	Carboniferous	Fine-grained laminated deposits composed predominantly of volcanic ash, subordinate mudstone
Cbt	Unnamed overlap assemblage	/Unnamed overlap assemblage//Currabubula Formation/Taggarts Mountain Ignimbrite Member	Palaeozoic	Carboniferous	Ignimbrite
Cbu	Unnamed overlap assemblage	/Unnamed overlap assemblage//Currabubula Formation/Highlands Creek Tuff Member (Inf)	Palaeozoic	Carboniferous	Tuff
Cbv	Unnamed overlap assemblage	/Unnamed overlap assemblage//Currabubula Formation/Unnamed tuff members	Palaeozoic	Carboniferous	Tuff
Cbwr	Unnamed overlap assemblage	/Unnamed overlap assemblage//Currabubula Formation/Willawarra Dacite	Palaeozoic	Carboniferous	Rhyodacite
Cbx	Unnamed overlap assemblage	/Unnamed overlap assemblage//Currabubula Formation/Two pyroxene andesite	Palaeozoic	Carboniferous	Dark grey andesite with plagioclase, ?augite, hypersthene and biotite in a glassy to devitrified groundmass. Kelk (1986) is unsure if it is a flow or intrusion.
Cms	Unnamed overlap assemblage	/Unnamed overlap assemblage//Merlewood Formation/Undifferentiated	Palaeozoic	Carboniferous	Coarse crossbedded feldspathic and lithic sandstone, minor conglomerate, mudstone and limestone
Cmsk	Unnamed overlap assemblage	/Unnamed overlap assemblage//Merlewood Formation/Kyndalyn Mudstone Member	Palaeozoic	Carboniferous	Ignimbrite
Cmskl	Unnamed overlap assemblage	/Unnamed overlap assemblage//Merlewood Formation/Kyndalyn Mudstone Member/unnamed limestone	Palaeozoic	Carboniferous	Limestone lenses
Cmsl	Unnamed overlap assemblage	/Unnamed overlap assemblage//Merlewood	Palaeozoic	Carboniferous	Limestone lenses

Letter Symbol	Geological System	Stratigraphic Names: Supergroup/Group_SuperSuite/ SubGroup/Formation_Pluton/ Member_unit	Era	Period	Lithological Description: Note additional information is available in the digital dataset
		Formation/Unnamed limestone			
Cmsa	Unnamed overlap assemblage	/Unnamed overlap assemblage//Merlewood Formation/Unnamed ignimbrite member 1	Palaeozoic	Carboniferous	Red-pink, unwelded ignimbrite, moderately to strongly pumiceous south of Liverpool Range; pumices absent north of range
Cmsb	Unnamed overlap assemblage	/Unnamed overlap assemblage//Merlewood Formation/Unnamed ignimbrite member 2	Palaeozoic	Carboniferous	Red, unwelded, shard-rich ignimbrite, usually pumiceous; resedimented in places; SHRIMP ages range from 346.1±2.5, 345.5±2.5 to 348.1±1.8 (1 sigma) from between Liverpool Range in the north and Waverly Fault in South
Cmsc	Unnamed overlap assemblage	/Unnamed overlap assemblage//Merlewood Formation/Unnamed ignimbrite member 3	Palaeozoic	Carboniferous	Fine, unwelded, grey-beige-purple, welded to non-welded ignimbrite with small feldspars and minor quartz; SHRIMP AS3 age of 327.9±3.6 (1 sigma) from loc 469-43 0309515 6484148;
Cmsd	Unnamed overlap assemblage	/Unnamed overlap assemblage//Merlewood Formation/Unnamed ignimbrite member 4	Palaeozoic	Carboniferous	Unwelded pink-beige-purple pumiceous rhyolitic ignimbrite, glassy at base; SHRIMP AS3 age of 326.8±1.9 (1 sigma) from loc 488-16C 0312899 6472910
Cmb	Unnamed overlap assemblage	/Unnamed overlap assemblage//Merlewood Formation/Kingsmill's Peek Andesite	Palaeozoic	Carboniferous	Pyroxene andesite
Cls	Unnamed overlap assemblage	/Unnamed overlap assemblage//Lark Hill Formation/Undifferentiated	Palaeozoic	Carboniferous	Coarse lithic & feldspathic arenite, subordinate orthoconglomerate & paraconglomerate, siltstone & rhyodacitic and dacitic ashflow tuff
Clr	Unnamed overlap assemblage	/Unnamed overlap assemblage//Lark Hill Formation/Unnamed tuff	Palaeozoic	Carboniferous	Tuff
Clhr	Unnamed overlap assemblage	/Unnamed overlap assemblage//Lark Hill Formation/Hell Hole Pyroclastic Member	Palaeozoic	Carboniferous	Vitric tuff
Clshm	Unnamed overlap assemblage	/Unnamed overlap assemblage//Lark Hill Formation/Unnamed magnetic member	Palaeozoic	Carboniferous	Coarse lithic & feldspathic arenite, subordinate orthoconglomerate & paraconglomerate, siltstone & rhyodacitic and dacitic ashflow tuff. High magnetic response, high magnetic signature

Letter Symbol	Geological System	Stratigraphic Names: Supergroup/Group_SuperSuite/ SubGroup/Formation_Pluton/ Member_unit	Era	Period	Lithological Description: Note additional information is available in the digital dataset
Crc	Unnamed overlap assemblage	/Unnamed overlap assemblage//Rocky Creek Conglomerate/Undifferentiated	Palaeozoic	Carboniferous	Coarse bolder, cobble & pebble fluvial orthoconglomerate & paraconglomerate, minor feldsarenite & litharenite and intermediate ash flow, & glaciolacustrine tillite
Crclm	Unnamed overlap assemblage	/Unnamed overlap assemblage//Rocky Creek Conglomerate/Unnamed magnetic member 1	Palaeozoic	Carboniferous	Coarse bolder, cobble & pebble fluvial orthoconglomerate & paraconglomerate, minor feldsarenite & litharenite and intermediate ash flow, & glaciolacustrine tillite, low magnetic signature
Crchm	Unnamed overlap assemblage	/Unnamed overlap assemblage//Rocky Creek Conglomerate/Unnamed magnetic member 2	Palaeozoic	Carboniferous	Coarse bolder, cobble & pebble fluvial orthoconglomerate & paraconglomerate, minor feldsarenite & litharenite and intermediate ash flow, & glaciolacustrine tillite, high magnetic signature
Cra	Unnamed overlap assemblage	/Unnamed overlap assemblage//Rocky Creek Conglomerate/Unnamed tuff 1	Palaeozoic	Carboniferous	Tuff
Crb	Unnamed overlap assemblage	/Unnamed overlap assemblage//Rocky Creek Conglomerate/Unnamed tuff 2	Palaeozoic	Carboniferous	Tuff
Cre	Unnamed overlap assemblage	/Unnamed overlap assemblage//Rocky Creek Conglomerate/Unnamed tuff 3	Palaeozoic	Carboniferous	Tuff
Crf	Unnamed overlap assemblage	/Unnamed overlap assemblage//Rocky Creek Conglomerate/Unnamed tuff 4	Palaeozoic	Carboniferous	Tuff
Crr	Unnamed overlap assemblage	/Unnamed overlap assemblage//Rocky Creek Conglomerate/Unnamed tuff 5	Palaeozoic	Carboniferous	Tuff
Crpd	Unnamed overlap assemblage	/Unnamed overlap assemblage//Rocky Creek Conglomerate/Penryn Rhyolite	Palaeozoic	Carboniferous	Rhyolite
Crpr	Unnamed overlap assemblage	/Unnamed overlap assemblage//Rocky Creek Conglomerate/Plagyan Rhyodacitic Tuff Member	Palaeozoic	Carboniferous	Multiple beds of rhyolitic to andesitic crystal and vitric tuff
Crv1	Unnamed overlap assemblage	/Unnamed overlap assemblage//Rocky Creek Conglomerate/Unnamed ignimbrite member 1	Palaeozoic	Carboniferous	Red-beige, unwelded rhyolitic ignimbrite
Crv2	Unnamed overlap assemblage	/Unnamed overlap assemblage//Rocky Creek Conglomerate/Unnamed ignimbrite member 2	Palaeozoic	Carboniferous	Red-green, unwelded, pumiceous ignimbrite; interbedded with siltstone in south; at northern extremity grades into resedimented volcanolithic sandstone

Letter Symbol	Geological System	Stratigraphic Names: Supergroup/Group_SuperSuite/ SubGroup/Formation_Pluton/ Member_unit	Era	Period	Lithological Description: Note additional information is available in the digital dataset
Crv3	Unnamed overlap assemblage	/Unnamed overlap assemblage//Rocky Creek Conglomerate/Unnamed ignimbrite member 3	Palaeozoic	Carboniferous	Purple, volcanic agglomerate and interbedded, purple, ash-rich ignimbrite
Crv4	Unnamed overlap assemblage	/Unnamed overlap assemblage//Rocky Creek Conglomerate/Unnamed ignimbrite member 4	Palaeozoic	Carboniferous	Purple to beige, welded, rhyolitic ignimbrite
Crv5	Unnamed overlap assemblage	/Unnamed overlap assemblage//Rocky Creek Conglomerate/Unnamed ignimbrite member 5	Palaeozoic	Carboniferous	Red, welded, rhyolitic ignimbrite
Ccs	Unnamed overlap assemblage	/Unnamed overlap assemblage//Clifden Formation/Undifferentiated	Palaeozoic	Carboniferous	Cross bedded coarse-grained fluvial feldspathic & lithic sandstone, subordinate orthoconglomerate, mudstone, carbonaceous shale & felsic to intermediate tuff
Ccv	Unnamed overlap assemblage	/Unnamed overlap assemblage//Clifden Formation/Unnamed tuff	Palaeozoic	Carboniferous	Beige, unwelded, rhyolitic ignimbrite; single outcrop at southern closure of Rocky Creek Syncline
Ccv1	Unnamed overlap assemblage	/Unnamed overlap assemblage//Clifden Formation/Unnamed ignimbrite member 1	Palaeozoic	Carboniferous	Fine-grained, red, resedimented, shard and crystal-rich, unwelded ignimbrite; preserved in pods beneath the Peri Rhyolite
Ccv2	Unnamed overlap assemblage	/Unnamed overlap assemblage//Clifden Formation/Unnamed ignimbrite member 2	Palaeozoic	Carboniferous	Red-beige, unwelded, rhyolitic ignimbrite
Ccv3	Unnamed overlap assemblage	/Unnamed overlap assemblage//Clifden Formation/Unnamed ignimbrite member 3	Palaeozoic	Carboniferous	Pink-beige, unwelded, rhyolitic ignimbrite
Ccpr	Unnamed overlap assemblage	/Unnamed overlap assemblage//Clifden Formation/Peri Rhyodacite Tuff	Palaeozoic	Carboniferous	Rhyodacitic ash flow vitric tuff
Ccad	Unnamed overlap assemblage	/Unnamed overlap assemblage//Clifden Formation/Appleogue Dacite	Palaeozoic	Carboniferous	Grey to black, ignimbritic, horblende dacite to resedimented, volcanolithic sandstone
Ccwa	Unnamed overlap assemblage	/Unnamed overlap assemblage//Clifden Formation/Wanganui Andesite	Palaeozoic	Carboniferous	Unwelded, dark grey, ignimbritic, pyroxene andesite
Ccb	Unnamed overlap	/Unnamed overlap assemblage//Clifden	Palaeozoic	Carboniferous	Tuff

Letter Symbol	Geological System	Stratigraphic Names: Supergroup/Group_SuperSuite/ SubGroup/Formation_Pluton/ Member_unit	Era	Period	Lithological Description: Note additional information is available in the digital dataset
	assemblage	Formation/Unnamed tuff			
Ccf	Unnamed overlap assemblage	/Unnamed overlap assemblage//Clifden Formation/Unnamed tuff	Palaeozoic	Carboniferous	Tuff
Ccshm	Unnamed overlap assemblage	/Unnamed overlap assemblage//Clifden Formation/	Palaeozoic	Carboniferous	Cross bedded coarse fluvial arenite, minor conglomerate lenses, siltstone, mudstone and thin dacitic to rhyolitic tuffs, high magnetic signature
Ccr	Unnamed overlap assemblage	/Unnamed overlap assemblage//Clifden Formation/Unnamed tuff	Palaeozoic	Carboniferous	Tuff
Cea	Unnamed overlap assemblage	/Unnamed overlap assemblage//Ermelo Dacite Tuff/	Palaeozoic	Carboniferous	Coarse-grained dacitic, crystal vitric tuff, crystal rich sandstone & boulder conglomerate; many lithologies are extensively zeolitised
Csc	Unnamed overlap assemblage	/Unnamed overlap assemblage//Spion Kop Conglomerate/	Palaeozoic	Carboniferous	Cobble sized fluvial orthoconglomerate, subordinate wacke & siltstone
Cas	Unnamed overlap assemblage	/Unnamed overlap assemblage//Caroda Formation/Undifferentiated	Palaeozoic	Carboniferous	Cross bedded lithic arenite & conglomerate, subordinate laminated shale, siltstone, lenticular oolitic limestone, magnetite horizons. Suceeded by coarse fluvial litharenite, minor pebbly sandstone, shale, thin coal, conglomerate & andesitic tuff
Casl	Unnamed overlap assemblage	/Unnamed overlap assemblage//Caroda Formation/Unnamed limestone members	Palaeozoic	Carboniferous	Limestone
Cas1	Unnamed overlap assemblage	/Unnamed overlap assemblage//Caroda Formation/Unnamed volcanic members	Palaeozoic	Carboniferous	Tuff
Car	Unnamed overlap assemblage	/Unnamed overlap assemblage//Caroda Formation/Unnamed rhyolite	Palaeozoic	Carboniferous	Tuff
Cal	Unnamed overlap assemblage	/Unnamed overlap assemblage//Caroda Formation/Unnamed limestone members	Palaeozoic	Carboniferous	Fossiliferous limestone
Cae	Unnamed overlap assemblage	/Unnamed overlap assemblage//Caroda Formation/Unnamed tuff	Palaeozoic	Carboniferous	Tuff
Cab	Unnamed overlap assemblage	/Unnamed overlap assemblage//Caroda Formation/Unnamed rhyolite	Palaeozoic	Carboniferous	Tuff

Letter Symbol	Geological System	Stratigraphic Names: Supergroup/Group_SuperSuite/ SubGroup/Formation_Pluton/ Member_unit	Era	Period	Lithological Description: Note additional information is available in the digital dataset
Cabb	Unnamed overlap assemblage	/Unnamed overlap assemblage//Caroda Formation/Barneys Springs Andesite Member	Palaeozoic	Carboniferous	Porphyritic andesite
Cags	Unnamed overlap assemblage	/Unnamed overlap assemblage//Caroda Formation/Garrambeel Sandstone Member	Palaeozoic	Carboniferous	Sandstone, conglomerate
Caslm	Unnamed overlap assemblage	/Unnamed overlap assemblage//Caroda Formation/	Palaeozoic	Carboniferous	Cross bedded lithic arenite & conglomerate, subordinate laminated shale, siltstone, lenticular oolitic limestone, magnetite horizons. Suceeded by coarse fluvial litharenite, minor pebbly sandstone, shale, thin coal, conglomerate & andesitic tuff, low magnetic signature
Cawt	Unnamed overlap assemblage	/Unnamed overlap assemblage//Caroda Formation/West Lynne Andesite Tuff	Palaeozoic	Carboniferous	Andesitic tuff
Cayt	Unnamed overlap assemblage	/Unnamed overlap assemblage//Caroda Formation/Yunedoo Andesite Tuff	Palaeozoic	Carboniferous	Andesitic ash-flow tuff
Cpnf	Parry Group	/Parry Group//Namoi Formation/Undifferentiated	Palaeozoic	Carboniferous	Mudstone, minor, calcareous, feldspathic sandstone and limestone
Cpns	Parry Group	/Parry Group//Namoi Formation/Unnamed sandstone members	Palaeozoic	Carboniferous	Sandstone
Cpnl	Parry Group	/Parry Group//Namoi Formation/Unnamed limestone members	Palaeozoic	Carboniferous	Limestone
Cpnc	Parry Group	/Parry Group//Namoi Formation/Unnamed conglomerate members	Palaeozoic	Carboniferous	Conglomerate
Cpnpc	Parry Group	/Parry Group//Namoi Formation/Pallal Conglomerate Member	Palaeozoic	Carboniferous	Cross bedded coarse-grained wacke, lenticular orthoconglomerate & siltstone
Cpnv	Parry Group	/Parry Group//Namoi Formation/Unnamed volcanic members	Palaeozoic	Carboniferous	Tuff
Cpntl	Parry Group	/Parry Group//Namoi	Palaeozoic	Carboniferous	Limestone

Letter Symbol	Geological System	Stratigraphic Names: Supergroup/Group_SuperSuite/ SubGroup/Formation_Pluton/ Member_unit	Era	Period	Lithological Description: Note additional information is available in the digital dataset
		Formation/Tiilungra Limestone Member			
Cpts	Parry Group	/Parry Group//Tulcumba Sandstone/Undifferentiated	Palaeozoic	Carboniferous	Coarse, crossbedded feldsarenite, siltstone, conglomerate, calcareous mudstone, oolitic & bioclastic limestone
Cptc	Parry Group	/Parry Group//Tulcumba Sandstone/Unnamed conglomerate members	Palaeozoic	Carboniferous	Conglomerate
Cptl	Parry Group	/Parry Group//Tulcumba Sandstone/Unnamed limestone members	Palaeozoic	Carboniferous	Oolitic limestone
Cptrl	Parry Group	/Parry Group//Tulcumba Sandstone/Rangrai Limestone	Palaeozoic	Carboniferous	Fine-grained oolitic crinoidal limestone & minor bioclastic limestone
Cpgx	Parry Group	/Parry Group//Tangaratta Formation/Undifferentiated	Palaeozoic	Carboniferous	Thinly bedded, fine-grained feldsarenite, siltstone, mudstone & rare limestone
Cpga	Parry Group	/Parry Group//Tangaratta Formation/Garoo Conglomerate	Palaeozoic	Carboniferous	Polymictic conglomerate in argillaceous matrix and some lithic arenites
Cpgo	Parry Group	/Parry Group//Tangaratta Formation/Gowrie Sandstone	Palaeozoic	Carboniferous	Green labile sandstones minor conglomerate with discontinuous bedding. Shale breccias are abundant and crinoids stems are locally present
Cpgs	Parry Group	/Parry Group//Tangaratta Formation/Unnamed sandstone members	Palaeozoic	Carboniferous	Sandstone
Cpgsc	Parry Group	/Parry Group//Tangaratta Formation/Scrub Mountain Conglomerate	Palaeozoic	Carboniferous	Polymictic conglomerate with argillaceous matrix and some lithic arenite
Cpgd	Parry Group	/Parry Group//Tangaratta Formation/Dancing Dicks Conglomerate	Palaeozoic	Carboniferous	Polymictic para- and ortho- conglomerate
Cpgg	Parry Group	/Parry Group//Tangaratta Formation/Glenlawn Mudstone	Palaeozoic	Carboniferous	Mudstone, siltstone, sandstone, lithic sandstone
Cpgu	Parry Group	/Parry Group//Tangaratta Formation/Sutcliff Conglomerate	Palaeozoic	Carboniferous	Polymictic orthoconglomerate, siltstone and lithic sandstone

Letter Symbol	Geological System	Stratigraphic Names: Supergroup/Group_SuperSuite/ SubGroup/Formation_Pluton/ Member_unit	Era	Period	Lithological Description: Note additional information is available in the digital dataset
Cpgp	Parry Group	/Parry Group//Tangaratta Formation/Pyramid Hill Arenite	Palaeozoic	Carboniferous	Lenses of labile sandstones and lithic wackes with minor conglomerate interbedded with Tangaratta Formation
Cpgw	Parry Group	/Parry Group//Tangaratta Formation/Wombrumurra Formation	Palaeozoic	Carboniferous	Zone of lenses of polymictic conglomerate and lithic wackes interbedded with Tangaratta Formation
Cpgt	Parry Group	/Parry Group//Tangaratta Formation/Martindale Mudstone	Palaeozoic	Carboniferous	Siltstone, lithic sandstone, mudstone, minor conglomerate horizons and rare crinoidal and oolitic limestone interbeds
Cpgf	Parry Group	/Parry Group//Tangaratta Formation/Duxford Member	Palaeozoic	Carboniferous	Lithic sandstone, polymictic conglomerate, siltstone
Cpls	Parry Group	/Parry Group//Luton Formation/Undifferentiated	Palaeozoic	Carboniferous	Calcareous & arkosic arenite, siltstone & claystone with orthoconglomerate towards the base; rare limestone lenses & tuff; laminite extensively developed in the north
Cplsd	Parry Group	/Parry Group//Luton Formation/Unnamed magnetic member 1	Palaeozoic	Carboniferous	Calcareous & arkosic arenite, siltstone & claystone with orthoconglomerate towards the base; rare limestone lenses & tuff; laminite extensively developed in the north, dark radiometric signature
Cplsp	Parry Group	/Parry Group//Luton Formation/Unnamed magnetic member 2	Palaeozoic	Carboniferous	Calcareous & arkosic arenite, siltstone & claystone with orthoconglomerate towards the base; rare limestone lenses & tuff; laminite extensively developed in the north, pale radiometric signature
Dpmf	Parry Group	/Parry Group//Mandowa Mudstone/Undifferentiated	Palaeozoic	Devonian	Grey, thinly bedded, laminated & massive mudstone with subordinate, thin siltstone and fine sandstone
Dpmkl	Parry Group	/Parry Group//Mandowa Mudstone/Kiah Limestone	Palaeozoic	Devonian	Fine-grained, grey, thinly bedded & laminated micritic limestone
Dpms	Parry Group	/Parry Group//Mandowa Mudstone/Unnamed sandstone members	Palaeozoic	Devonian	Sandstone
Dpmh	Parry Group	/Parry Group//Mandowa Mudstone/Hyde Greywacke Member	Palaeozoic	Devonian	Labile lithic wacke
Dpmv	Parry Group	/Parry Group//Mandowa Mudstone/Unnamed volcanic members	Palaeozoic	Devonian	Andesite
Dpkc	Parry Group	/Parry Group//Keepit Conglomerate/Undifferentiated	Palaeozoic	Devonian	Boulder to pebble conglomerate, mudstone and thinly bedded sandstone

Letter Symbol	Geological System	Stratigraphic Names: Supergroup/Group_SuperSuite/ SubGroup/Formation_Pluton/ Member_unit	Era	Period	Lithological Description: Note additional information is available in the digital dataset
Dpkv	Parry Group	/Parry Group//Keepit Conglomerate/Unnamed volcanic members	Palaeozoic	Devonian	Andesite
Dpkcc	Parry Group	/Parry Group//Keepit Conglomerate/Unnamed conglomerate members	Palaeozoic	Devonian	Conglomerate
Dpkcs	Parry Group	/Parry Group//Keepit Conglomerate/Unnamed sandstone members	Palaeozoic	Devonian	Sandstone
Dpmx	Parry Group	/Parry Group//Mostyn Vale Formation/Undifferentiated	Palaeozoic	Devonian	Pebbly lithic wacke, diamictite, lithic wacke, orthoconglomerate, olistostromal volcanic breccia, rhyodacitic to basaltic lavas, tuffs, agglomerates, rare limestone
Dpmx1	Parry Group	/Parry Group//Mostyn Vale Formation/Lower member	Palaeozoic	Devonian	Pebbly lithic wacke, diamictite, lithic wacke, orthoconglomerate, olistostromal volcanic breccia, rhyodacitic to basaltic lavas, tuffs, agglomerates, rare limestone
Dpmx1v	Parry Group	/Parry Group//Mostyn Vale Formation/Lower member volcanics	Palaeozoic	Devonian	Andesite, basalt
Dpmx2	Parry Group	/Parry Group//Mostyn Vale Formation/Upper member	Palaeozoic	Devonian	Pebbly lithic wacke, diamictite, lithic wacke, orthoconglomerate, olistostromal volcanic breccia, rhyodacitic to basaltic lavas, tuffs, agglomerates, rare limestone
Dpmx2v	Parry Group	/Parry Group//Mostyn Vale Formation/Upper member volcanics	Palaeozoic	Devonian	Andesite, basalt
Dpef	Parry Group	/Parry Group//Eungai Mudstone/Undifferentiated	Palaeozoic	Devonian	Massive & laminated grey mudstone with rare wacke horizons & tuffaceous laminae & beds
Dplf	Parry Group	/Parry Group//Lowanna Formation/Undifferentiated	Palaeozoic	Devonian	Green-black,thinly bedded siltstone & mudstone with thin white tuffaceous beds
Dplflm	Parry Group	/Parry Group//Lowanna Formation/Unnamed magnetic member 1	Palaeozoic	Devonian	Green-black,thinly bedded siltstone & mudstone with thin white tuffaceous beds, low magnetic signature
Dpns	Parry Group	/Parry Group//Noumea	Palaeozoic	Devonian	Interbedded massive & andesitic lithic wacke, pebbly wacke, laminated

Letter Symbol	Geological System	Stratigraphic Names: Supergroup/Group_SuperSuite/ SubGroup/Formation_Pluton/ Member_unit	Era	Period	Lithological Description: Note additional information is available in the digital dataset
		beds/Undifferentiated			siltstone & mudstone
Dpnsd	Parry Group	/Parry Group//Noumea beds/Unnamed radiometric member 1	Palaeozoic	Devonian	Interbedded massive & andesitic lithic wacke, pebbly wacke, laminated siltstone & mudstone, dark radiometric signature
Dpnsp	Parry Group	/Parry Group//Noumea beds/Unnamed radiometric member 2	Palaeozoic	Devonian	Interbedded massive & andesitic lithic wacke, pebbly wacke, laminated siltstone & mudstone, pale radiometric signature
Cw	Parry Group	/Parry Group//Waverly Formation/Undifferentiated	Palaeozoic	Carboniferous	Lithic sandstone and conglomerate
Dety	Tamworth Group	/Tamworth Group//Yarrime Formation/Undifferentiated	Palaeozoic	Devonian	Green-grey to black, siliceous, radiolarian siltstone & mudstone with local radiolarian & biohermal limestone lenses & sparse lithic wacke beds
Detyl	Tamworth Group	/Tamworth Group//Yarrime Formation/Unnamed limestone members	Palaeozoic	Devonian	Olistostromal limestone lenses in Yarrimie Formation. Includes the Moore Creek and Sulcor Limestone Members
Detycl	Tamworth Group	/Tamworth Group//Yarrime Formation/Crawney Limestone Member	Palaeozoic	Devonian	Fossiliferous and recrystallised limestone and calcareous mudstone
Detytl	Tamworth Group	/Tamworth Group//Yarrime Formation/Timor Limestone Member	Palaeozoic	Devonian	Grey fossiliferous bioclastic limestone with local basal conglomerate, three cherty intervals and jasperoid nodules.
Detf	Tamworth Group	/Tamworth Group//Folly Spillite/	Palaeozoic	Devonian	Massive basalts with subordinate intercalated basaltic pillow lavas, albite dolerite, siliceous argillite, sandstone and rare basaltic breccias
Dets	Tamworth Group	/Tamworth Group//Silver Gully Formation/Undifferentiated	Palaeozoic	Devonian	Coarse andesitic sandstone, diamictite & pebble orthoconglomerate; subordinate andesitic tuff & andesitic to dacitic lava, ashflow tuff & agglomerate; minor limestone & calc-silicate hornfels
Detsl	Tamworth Group	/Tamworth Group//Silver Gully Formation/Unnamed limestone members	Palaeozoic	Devonian	Dolomitic limestone & calc-silicate hornfels lenses in Silver Gully Formation
Detw	Tamworth Group	/Tamworth Group//Wogarda Argillite/Undifferentiated	Palaeozoic	Devonian	Cherty argillites, fine lithic arenites, interbedded sandstone and mudstone, fine-grained tuffaceous siltstones, rare massive sandstone, conglomerates and limestone
Detwl	Tamworth Group	/Tamworth Group//Wogarda Argillite/Unnamed limestone members	Palaeozoic	Devonian	Limestone

Letter Symbol	Geological System	Stratigraphic Names: Supergroup/Group_SuperSuite/ SubGroup/Formation_Pluton/ Member_unit	Era	Period	Lithological Description: Note additional information is available in the digital dataset
Detn	Tamworth Group	/Tamworth Group//Northcotte Formation/Undifferentiated	Palaeozoic	Devonian	Sandstone, tuff, minor argillite and rare limestone
Detnb	Tamworth Group	/Tamworth Group//Northcotte Formation/Bog Hole Formation	Palaeozoic	Devonian	Keratophyre, minor argillite and tuff
Detnk	Tamworth Group	/Tamworth Group//Northcotte Formation/Unnamed limestone members	Palaeozoic	Devonian	Keratophyre and crystalline limestone and limestone breccia impregnated with haematite, quartz rich wacke and minor limestone conglomerate of Northcotte Limestone Member
Detd	Tamworth Group	/Tamworth Group//Drik Drik Formation/	Palaeozoic	Devonian	Arenites, argillites, haematite breccias, minor siltstones & calcareous siltstone, keratophyre, conglomerate and crystalline limestone lenses & limestone breccia impregnated with haematite of Nemingha Limestone .
Deto	Tamworth Group	/Tamworth Group//Copes Creek Andesite/	Palaeozoic	Devonian	Massive, green to grey keratophyre and quartz-keratophyre, minor brecciated or vesicular keratophyre
SDd	Tamworth Group	/Tamworth Group//Unnamed Silurian-Devonian intrusive/	Palaeozoic	Silurian	Dolerite
Oh	Early Palaeozoic succession	/early Palaeozoic succession//Haedon Formation/	Palaeozoic	Ordovician	Wackes and conglomerate, limestone blocks, rare siltstone and argillite
Ep	Early Palaeozoic succession	/early Palaeozoic succession//Pipeclay Creek Formation/	Palaeozoic	Cambrian	Thinly banded black and white argillite and chert, volcanolithic wackes
Em	Early Palaeozoic succession	/early Palaeozoic succession//Murrawong Creek Formation/	Palaeozoic	Cambrian	Fine to coarse bedded sandstone, limestone conglomerate, argillite and chert
Pwv	Late Permian Volcanics	/Wandsworth Volcanic Group//Undifferentiated/	Palaeozoic	Permian	Undifferentiated felsic volcanics, minor sediments & granites. Dominantly ignimbritic rhyolites & rhyodacites (dark crystal-lithic tuffs); rhyodacitic lavas, minor dacite, andesite. trachyte; interbedded fine-grained tuff and volcanoclastics
Pwx	Late Permian Volcanics	/Wandsworth Volcanic Group//Undifferentiated sedimentary rocks/	Palaeozoic	Permian	Siltstone, claystone, sandstone, lithic wacke, polymictic conglomerate & breccia, with interbedded felsic volcanics; typically contact metamorphosed. Includes conglomerate with tuffaceous & argillite beds underlying felsic volcanics
Pwar	Late Permian	/Wandsworth Volcanic	Palaeozoic	Permian	Ignimbritic rhyolite & rhyodacite & lesser rhyolitic lavas. Includes bedded

Letter Symbol	Geological System	Stratigraphic Names: Supergroup/Group_SuperSuite/ SubGroup/Formation_Pluton/ Member_unit	Era	Period	Lithological Description: Note additional information is available in the digital dataset
	Volcanics	Group//Wallangarra Volcanics/			epiclastic tuffs
Pwev	Late Permian Volcanics	/Wandsworth Volcanic Group//Emmaville Volcanics/	Palaeozoic	Permian	Undifferentiated felsic volcanics: ignimbritic rhyolites & rhyodacites (crystal & crystal- lithic tuffs); rhyodacitic lavas, minor dacite, andesite; minor interbedded sediments; basal conglomerate, sandstone, lutite
Pwgr	Late Permian Volcanics	/Wandsworth Volcanic Group//Gibraltar Ignimbrite/	Palaeozoic	Permian	Ignimbritic rhyolite
Pwp	Late Permian Volcanics	/Wandsworth Volcanic Group//Unnamed porphyry/	Palaeozoic	Permian	Quartz porphyry & porphyritic microgranite
Pwevb	Late Permian Volcanics	/Wandsworth Volcanic Group//Emmaville Volcanics/Unnamed radiometric member 1	Palaeozoic	Permian	Undifferentiated felsic volcanics: ignimbritic rhyolites & rhyodacites (crystal & crystal- lithic tuffs); rhyodacitic lavas, minor dacite, andesite; minor interbedded sediments; basal conglomerate, sandstone, lutite in places; widespread contact meta, blue radiometric signature
Pwevg	Late Permian Volcanics	/Wandsworth Volcanic Group//Emmaville Volcanics/Unnamed radiometric member 2	Palaeozoic	Permian	Undifferentiated felsic volcanics: ignimbritic rhyolites & rhyodacites (crystal & crystal- lithic tuffs); rhyodacitic lavas, minor dacite, andesite; minor interbedded sediments; basal conglomerate, sandstone, lutite in places; widespread contact meta, grgreen radiometric signature
Pwevp	Late Permian Volcanics	/Wandsworth Volcanic Group//Emmaville Volcanics/Unnamed radiometric member 3	Palaeozoic	Permian	Undifferentiated felsic volcanics: ignimbritic rhyolites & rhyodacites (crystal & crystal- lithic tuffs); rhyodacitic lavas, minor dacite, andesite; minor interbedded sediments; basal conglomerate, sandstone, lutite in places; widespread contact meta, pink radiometric signature
Pwevr	Late Permian Volcanics	/Wandsworth Volcanic Group//Emmaville Volcanics/Unnamed radiometric member 4	Palaeozoic	Permian	Undifferentiated felsic volcanics: ignimbritic rhyolites & rhyodacites (crystal & crystal- lithic tuffs); rhyodacitic lavas, minor dacite, andesite; minor interbedded sediments; basal conglomerate, sandstone, lutite in places; widespread contact meta, red radiometric signature
Pwevbb	Late Permian Volcanics	/Wandsworth Volcanic Group//Emmaville Volcanics/Unnamed radiometric member 5	Palaeozoic	Permian	Undifferentiated felsic volcanics: ignimbritic rhyolites & rhyodacites (crystal & crystal- lithic tuffs); rhyodacitic lavas, minor dacite, andesite; minor interbedded sediments; basal conglomerate, sandstone, lutite in places; widespread contact meta, dark blue radiometric signature
Pwevd	Late Permian Volcanics	/Wandsworth Volcanic Group//Emmaville Volcanics/Unnamed radiometric member 6	Palaeozoic	Permian	Undifferentiated felsic volcanics: ignimbritic rhyolites & rhyodacites (crystal & crystal- lithic tuffs); rhyodacitic lavas, minor dacite, andesite; minor interbedded sediments; basal conglomerate, sandstone, lutite in places;

Letter Symbol	Geological System	Stratigraphic Names: Supergroup/Group_SuperSuite/ SubGroup/Formation_Pluton/ Member_unit	Era	Period	Lithological Description: Note additional information is available in the digital dataset
					widespread contact meta, dark radiometric signature
Pwevhm	Late Permian Volcanics	/Wandsworth Volcanic Group//Emmaville Volcanics/Unnamed radiometric member 7	Palaeozoic	Permian	Undifferentiated felsic volcanics: ignimbritic rhyolites & rhyodacites (crystal & crystal- lithic tuffs); rhyodacitic lavas, minor dacite, andesite; minor interbedded sediments; basal conglomerate, sandstone, lutite in places; widespread contact meta, high magnetic response
Pwevlg	Late Permian Volcanics	/Wandsworth Volcanic Group//Emmaville Volcanics/Unnamed radiometric member 8	Palaeozoic	Permian	Undifferentiated felsic volcanics: ignimbritic rhyolites & rhyodacites (crystal & crystal- lithic tuffs); rhyodacitic lavas, minor dacite, andesite; minor interbedded sediments; basal conglomerate, sandstone, lutite in places; widespread contact meta, light green radiometric response
Pwevlm	Late Permian Volcanics	/Wandsworth Volcanic Group//Emmaville Volcanics/Unnamed radiometric member 9	Palaeozoic	Permian	Undifferentiated felsic volcanics: ignimbritic rhyolites & rhyodacites (crystal & crystal- lithic tuffs); rhyodacitic lavas, minor dacite, andesite; minor interbedded sediments; basal conglomerate, sandstone, lutite in places; widespread contact meta, low magnetic response
Pwevw	Late Permian Volcanics	/Wandsworth Volcanic Group//Emmaville Volcanics/Unnamed radiometric member 10	Palaeozoic	Permian	Undifferentiated felsic volcanics: ignimbritic rhyolites & rhyodacites (crystal & crystal- lithic tuffs); rhyodacitic lavas, minor dacite, andesite; minor interbedded sediments; basal conglomerate, sandstone, lutite in places; widespread contact meta, white radiometric response
Pwevy	Late Permian Volcanics	/Wandsworth Volcanic Group//Emmaville Volcanics/Unnamed radiometric member 11	Palaeozoic	Permian	Undifferentiated felsic volcanics: ignimbritic rhyolites & rhyodacites (crystal & crystal- lithic tuffs); rhyodacitic lavas, minor dacite, andesite; minor interbedded sediments; basal conglomerate, sandstone, lutite in places; widespread contact meta, yellow radiometric response
Pzu	Late Permian Volcanics	/Wandsworth Volcanic Group//Unnamed felsic porphyry dykes/	Palaeozoic	Permian	Flow-banded quartz-feldspar porphyry dykes, some spotted & ?epidote-rich; quartz-aplite dykes; granitic quartz-orthoclase porphyry, & various granitic quartz-feldspar porphyries
Pmv	Late Permian Volcanics	/Wandsworth Volcanic Group?//Unnamed volcanics in Echo Hills area/	Palaeozoic	Permian	Rhyolitic volcanics and associated intrusives
Pax	Early Permian coal sequence	///Ashford Coal Measures/	Palaeozoic	Permian	Fluvial arenite, argillite, cobble conglomerate & interbedded coal horizons
Pgx	Early Permian coal	///Glenmore Formation/	Palaeozoic	Permian	Bolder conglomerate, coarse arenite, epiclastics, coal+R455 & fossiliferous

Letter Symbol	Geological System	Stratigraphic Names: Supergroup/Group_SuperSuite/ SubGroup/Formation_Pluton/ Member_unit	Era	Period	Lithological Description: Note additional information is available in the digital dataset
	sequence				limestone
Pem	Early Permian marine sequences	/Manning Group//Undifferentiated/	Palaeozoic	Permian	Diamictite, conglomerate, sandstone, mudstone, felsic and intermediate volcanics and limestone
Pema	Early Permian marine sequences	/Manning Group//Andersons Flat beds/	Palaeozoic	Permian	Lithofeldspathic sandstone, conglomerate and mudstone
Pemm	Early Permian marine sequences	/Manning Group//Echo Hills Formation/Undifferentiated	Palaeozoic	Permian	Siltstone and sandstone
Pemmc	Early Permian marine sequences	/Manning Group//Echo Hills Formation/Unnamed conglomerate	Palaeozoic	Permian	Conglomerate dominated sediments
Pox	Early Permian marine sequences	///Bondonga beds/Undifferentiated	Palaeozoic	Permian	Undifferentiated: ortho & para- conglomerate, lithic sandstone & minor siltstone. Commonly weakly metamorphosed
Poc	Early Permian marine sequences	///Bondonga beds/Unnamed conglomerate	Palaeozoic	Permian	Conglomerate units
Px	Early Permian marine sequences	///Undifferentiated sedimentary rocks/	Palaeozoic	Permian	Mixed lithologies, undifferentiated, dominantly fine-grained sediment. All weakly regionally metamorphosed, some contact metamorphosed
Pc	Early Permian marine sequences	///Unnamed Permian conglomerate/	Palaeozoic	Permian	Lithic sandstone, ortho- & para- conglomerate.
Cax	Wisemans Arm Formation	///Wisemans Arm Formation/Undifferentiated	Palaeozoic	Devonian	Sandstone, granule to boulder conglomerate and siltstone with olistoliths of chert, limestone basalt, andesite and siltstone
Caxq	Wisemans Arm Formation	///Wisemans Arm Formation/Unnamed chert members	Palaeozoic	Devonian	Chert
Caxc	Wisemans Arm Formation	///Wisemans Arm Formation/Unnamed Conglomerate Members	Palaeozoic	Devonian	Conglomerate

Letter Symbol	Geological System	Stratigraphic Names: Supergroup/Group_SuperSuite/ SubGroup/Formation_Pluton/ Member_unit	Era	Period	Lithological Description: Note additional information is available in the digital dataset
Csx	Texas-Sandon association	///Sandon beds/	Palaeozoic	Devonian	Low grade regionally metamorphosed, multiply deformed lithic wacke, paraconglomerate, siltstone, mudstone, chert, jasper & minor basalt
Ctx	Texas-Sandon association	///Texas beds/Undifferentiated	Palaeozoic	Carboniferous	Low grade regionally metamorphosed, variably deformed lithic wacke, conglomerate, siltstone, mudstone, chert, basalt & rare tuff
Ctal	Texas-Sandon association	///Texas beds/Ashford Limestone	Palaeozoic	Carboniferous	Fossiliferous limestone, marble & magnetite-rich rock
Ctb	Texas-Sandon association	///Texas beds/Unnamed Volcanic Members	Palaeozoic	Carboniferous	Basic & andesitic volcanics
Cws	Whitlow Formation	///Whitlow Formation/Undifferentiated	Palaeozoic	Carboniferous	Low grade regionally metamorphosed, multiply deformed thickly bedded, feldspathic & volcanic lithic wacke, interbedded siltstone, fine wacke & minor conglomerate & rare olistostromal limestone; some siltstone & wacke
Cwsp	Whitlow Formation	///Whitlow Formation/	Palaeozoic	Carboniferous	Low grade regionally metamorphosed, multiply deformed thickly bedded, feldspathic & volcanic lithic wacke, interbedded siltstone, fine wacke & minor conglomerate & rare olistostromal limestone; some siltstone & wacke, pale radiometric signature
Cwf	Whitlow Formation	///Whitlow Formation/Unnamed mudstone member	Palaeozoic	Carboniferous	Low grade regionally metamorphosed, multiply deformed, mudstone and fine sandstone
Cwq	Whitlow Formation	///Whitlow Formation/Unnamed chert members	Palaeozoic	Carboniferous	Chert
Cwb	Whitlow Formation	///Whitlow Formation/Unnamed Basalt Members	Palaeozoic	Carboniferous	Basalt
DCcf	Cara Formation	///Cara Formation/Undifferentiated	Palaeozoic	Devonian	Low grade regionally metamorphosed, multiply deformed siliceous & tuffaceous thinly bedded argillite, chert, volcaniclastic wacke, pebble conglomerate & rare basalt
DCcfd	Cara Formation	///Cara Formation/Unnamed radiometric member 1	Palaeozoic	Devonian	Low grade regionally metamorphosed, multiply deformed siliceous & tuffaceous thinly bedded argillite, chert, volcaniclastic wacke, pebble conglomerate & rare basalt, dark radiometric signature
DCcfp	Cara Formation	///Cara Formation/Unnamed radiometric member 2	Palaeozoic	Devonian	Low grade regionally metamorphosed, multiply deformed siliceous & tuffaceous thinly bedded argillite, chert, volcaniclastic wacke, pebble conglomerate & rare basalt, pale radiometric signature

Letter Symbol	Geological System	Stratigraphic Names: Supergroup/Group_SuperSuite/ SubGroup/Formation_Pluton/ Member_unit	Era	Period	Lithological Description: Note additional information is available in the digital dataset
DCcfpu	Cara Formation	///Cara Formation/Unnamed radiometric member 3	Palaeozoic	Devonian	Low grade regionally metamorphosed, multiply deformed siliceous & tuffaceous thinly bedded argillite, chert, volcaniclastic wacke, pebble conglomerate & rare basalt, purple radiometric signature
DCcfb	Cara Formation	///Cara Formation/Unnamed radiometric member 4	Palaeozoic	Devonian	Low grade regionally metamorphosed, multiply deformed siliceous & tuffaceous thinly bedded argillite, chert, volcaniclastic wacke, pebble conglomerate & rare basalt, blue radiometric signature
DCcl	Cara Formation	///Cara Formation/Unnamed limestone members	Palaeozoic	Devonian	Limestone
DCcq	Cara Formation	///Cara Formation/Unnamed chert members	Palaeozoic	Devonian	Chert
DCcs	Cara Formation	///Cara Formation/Unnamed sandstone members	Palaeozoic	Devonian	Sandstone
Ddx	Dinoga Formation	///Dinoga Formation/	Palaeozoic	Devonian	Well bedded siltstone, quartz & lithic wacke, minor mudstone & conglomerate, blocks of fossiliferous limestone
SDwx	Woolomin Group	/Woolomin Group//Undifferentiated/Undifferentiated	Palaeozoic	Silurian	Low grade regionally metamorphosed, multiply deformed chert, wacke, basic volcanic & mudstone; lateral equivalent of Bobs Creek and Nangahrah Formations
SDwbf	Woolomin Group	/Woolomin Group//Bobs Creek Formation/Undifferentiated	Palaeozoic	Silurian	Low grade regionally metamorphosed, multiply deformed thinly bedded chert, mudstone, wacke, basic volcanic & rare limestone
SDwbfd	Woolomin Group	/Woolomin Group//Bobs Creek Formation/Unnamed radiometric member 1	Palaeozoic	Silurian	Low grade regionally metamorphosed, multiply deformed thinly bedded chert, mudstone, wacke, basic volcanic & rare limestone, dark radiometric signature
SDwbfp	Woolomin Group	/Woolomin Group//Bobs Creek Formation/Unnamed radiometric member 2	Palaeozoic	Silurian	Low grade regionally metamorphosed, multiply deformed thinly bedded chert, mudstone, wacke, basic volcanic & rare limestone, pale radiometric signature
SDwbl	Woolomin Group	/Woolomin Group//Bobs Creek Formation/Unnamed limestone members	Palaeozoic	Silurian	Limestone
SDwbq	Woolomin Group	/Woolomin Group//Bobs Creek Formation/Unnamed chert members	Palaeozoic	Silurian	Chert

Letter Symbol	Geological System	Stratigraphic Names: Supergroup/Group_SuperSuite/ SubGroup/Formation_Pluton/ Member_unit	Era	Period	Lithological Description: Note additional information is available in the digital dataset
SDwnx	Woolomin Group	/Woolomin Group//Nangahrah Formation/Undifferentiated	Palaeozoic	Silurian	Low grade regionally metamorphosed, multiply deformed chert, lithic & volcaniclastic wacke, breccia, basic volcanics, siltstone, mudstone & rare limestone
SDwnxd	Woolomin Group	/Woolomin Group//Nangahrah Formation/Unnamed radiometric member 1	Palaeozoic	Silurian	Low grade regionally metamorphosed, multiply deformed chert, lithic & volcaniclastic wacke, breccia, basic volcanics, siltstone, mudstone & rare limestone, dark radiometric signature
SDwnxp	Woolomin Group	/Woolomin Group//Nangahrah Formation/Unnamed radiometric member 2	Palaeozoic	Silurian	Low grade regionally metamorphosed, multiply deformed chert, lithic & volcaniclastic wacke, breccia, basic volcanics, siltstone, mudstone & rare limestone, pale radiometric signature
SDwnl	Woolomin Group	/Woolomin Group//Nangahrah Formation/Unnamed limestone members	Palaeozoic	Silurian	Limestone
SDwnc	Woolomin Group	/Woolomin Group//Nangahrah Formation/Undifferentiated Conglomerate Members	Palaeozoic	Silurian	Conglomerate
SDwnj	Woolomin Group	/Woolomin Group//Nangahrah Formation/Undifferentiated Jasper members	Palaeozoic	Silurian	Jasper
EPm	Great Serpentinite Belt	/Great Serpentinite Belt//Undifferentiated serpentinite/Unnamed serpentinite	Palaeozoic	Cambrian	Schistose, sheared serpentinite with minor inclusions of gabbro, dolerite, harzburgite, pyroxenite, plagiogranite, basalt & sedimentary rocks & metamorphic equivalents
EPwi	Great Serpentinite Belt	/Great Serpentinite Belt//Woodsreef Melange/Unnamed harzburgite	Palaeozoic	Cambrian	Altered harzburgite with minor to rare pyroxenite, plagiogranite, basalt & sedimentary rock, in a matrix of schistose serpentinite
EPwm	Great Serpentinite Belt	/Great Serpentinite Belt//Woodsreef Melange/Unnamed serpentinite	Palaeozoic	Cambrian	Schistose, sheared serpentinite that locally hosts plagiogranite, harzburgite, basalt, gabbro, dolerite & sedimentary rock
EPwo	Great Serpentinite Belt	/Great Serpentinite Belt//Woodsreef Melange/Unnamed gabbro & dolerite	Palaeozoic	Cambrian	Gabbro & dolerite that is variously metamorphosed & altered; minor to rare plagiogranite, pyroxenite, basalt & sedimentary rock
EPwf	Great Serpentinite Belt	/Great Serpentinite Belt//Woodsreef Melange/Unnamed mudstone member	Palaeozoic	Cambrian	Mudstone
EPwl	Great Serpentinite Belt	/Great Serpentinite Belt//Woodsreef	Palaeozoic	Cambrian	Limestone

Letter Symbol	Geological System	Stratigraphic Names: Supergroup/Group_SuperSuite/ SubGroup/Formation_Pluton/ Member_unit	Era	Period	Lithological Description: Note additional information is available in the digital dataset
		Melange/Unnamed limestone members			
EPws	Great Serpentinite Belt	/Great Serpentinite Belt//Woodsreef Melange/Unnamed sandstone members	Palaeozoic	Cambrian	Sandstone
EPh	Great Serpentinite Belt	/Great Serpentinite Belt//Woodsreef Melange/Unnamed silica-carbonate alteration	Palaeozoic	Cambrian	Silica-carbonate rich hypogene replacement of variably serpentinised rock. Minerals include ferroan magnesite and quartz, with minor ferroan dolomite, calcite, fuchsite, chlorite and spinel.

APPENDIX 5: METADATA STATEMENTS FOR THE GEOLOGICAL DATASETS PREPARED FOR THIS PROJECT

METADATA CATEGORY	CORE METADATA ELEMENT	DESCRIPTION
DATASET	Title	Fossickers Way and subset Nandewar geological coverage of the Nandewar Western regional Assessment study area including the Nandewar Bioregion in NSW at 1:100 000 scale equivalent comprising the area covered by parts of the SH/56-1,GOONDIWINDI; SH/56-2,WARWICK; SH/56-6, GRAFTON; SH/56-5, INVERELL; SH/56-9, MANILLA; SH/55-12 NARRABRI; SH/56-13, TAMWORTH 1:250 000 sheets.
	Custodian	NSW Department of Mineral Resources, Geological Survey of New South Wales
	Jurisdiction	New South Wales, Australia
	WRA Project Name	Nandewar Geology Integration and Upgrade
	WRA Project Number	NAND04
CONTACT ADDRESS	Contact organisation	NSW Department of Mineral Resources Geological Survey of New South Wales Minerals Assessment Program Strategic Assessments sub-program
	Contact position	Robert G Barnes, Senior Geologist Ken McDonald, Land Information Officer
	Mail Address 1	PO Box 65
	Mail Address 2	
	Suburb/Place/Locality	Armidale
	State/Locality 2	NSW
	Country	Australia
	Postcode	2350
	Telephone	02 6776 0318
	Facsimile	02 6776 0399
	Electronic mail address	ken.mcdonald@minerals.nsw.gov.au rob.barnes@minerals.nsw.gov.au

METADATA CATEGORY	CORE METADATA ELEMENT	DESCRIPTION
DESCRIPTION	Abstract	A geological coverage has been created for the Nandewar Western Regional Assessment study area including the Nandewar Bioregion. A continuous topologically structured geological coverage was created in Arc/Info for the Nandewar WRA study area comprising parts of the covered by parts of the SH/56-1 GOONDIWINDI; SH/56-2, WARWICK; SH/56-6, GRAFTON; SH/56-5, INVERELL; SH/56-9, MANILLA; SH/55-12, NARRABRI; SH/56-13, TAMWORTH 1:250 000 sheet areas. The data contained in this coverage has been sourced from data compiled by the Geological Survey of New South Wales, NSW Department of Mineral Resources (DMR). This coverage has been compiled using a process of on-screen digitisation during interpretation of remotely sensed data and landform images, in combination with digital vector datasets captured from published and unpublished hard copy maps. The geology is presented as attributed polygons and arcs of geological units, boundaries and faults at 1:100 000 to 1:250 000 scale equivalent.
	Search Word	Geoscience, geology, faults, lithology, stratigraphy
	Geographic Extent Name(s)	Nandewar Western Regional Assessment study area as defined from a file supplied by RACD for RACAC.
	Geographic Extent Polygon(s)	NOTE: The dataset is in MGA 56 coordinates on GDA 94 including those parts of the dataset in Zone 55. The data will be projected to AMG56 coordinates on AGD 66 for release for use by other agencies for the Nandewar Western Regional Assessment.
	Type of feature	Polygons and arcs of mapped geology unit boundaries and vectors of faults derived from the dataset.
	Attribute/Field List	See next field.
	Attribute/Field Description LTR_SYM	AREA ArcInfo information PERIMETER ArcInfo information Xxx#ArcInfo information Xxx –ID ArcInfo information LTR_SYM –Geological letter symbol This is the key field used to link polygons in the coverage to attribute tables and can be used as labels for the mapped units. There are three additional fields for mapped unit symbols, derived from the LTR-SYM field when this

METADATA CATEGORY	CORE METADATA ELEMENT	DESCRIPTION
		symbol includes more that one rock type (for example, a Quaternary unit overlying another unit). The link to a separate table of the geological units can be made using surficial or bedrock1 fields. It is recommended that the link be made using surficial for modelling using rock exposures and bedrock for a continuous geological coverage with surface cover ignored. The link to unit attributes provides information on:
	SURFACE	SURFACE QUAL_A – Qualifier such as "?" being where the units identification is uncertain. REL_A – Relationship- For example "/" where one unit overlies another unit or "+" (plus) where a mapped unit is made of two units BEDROCK – used as a link for continuous geological coverage QUAL_B Qualifier B REL_B Relationship B BEDROCK_B
	LGD_ORD	LGD_ORD – Legend Order (equivalent to the order which would be used on the legend of a geological map). This field allows the mapped units in the attribute table to be ordered as if they were in a legend on a geological map. Usually the units are ordered by age but units may be grouped for some other geological reason
	SYS SYM_SYS	SYS – Short code for groups of units, which is concatenated with LTR_SYM to form SYM_SYS. This ensures no duplication of symbols across large areas
	STATUS	STATUS – The currency this dataset.
	GEOLPROV	GEOLPROV – A broad classification of units into general geological provinces
	GEOLSYS1	GEOLSYS1 – Geological System 1. This is a generalised classification of units to allow simplified geological maps to be generated. This and GEOSYS2 have no specific standing and are open for re-interpretation by others
	GeSysOrd1	GESYSORD1 – The legend order for the Geological System 1 field
	GEOLSYS2	GEOLSYS2 – A more detailed breakup of units into geological systems
	GeSysOrd2	GESYSORD2 – The legend order for the Geological System 2 field
	EQUIVALENCE	EQUIVALENCE – This field is used to classify units into broadly equivalent levels and is similar to Geological Systems. This assists in regional syntheses of mapped units
	ALLSTRAT	ALLSTRAT – Stratigraphic Names field: This field

METADATA CATEGORY	CORE METADATA ELEMENT	DESCRIPTION
	SUPERGRP, GRPSUITE, SUBGRP, FRMPLUTON, MEMBER	Includes information on the name of the unit using the structure of Supergroup/Group or Suite/Subgroup/Formation or Pluton/Member or unit. These fields have been concatenated to allow for general enquires to be made when the stratigraphic heirachy of a unit in question is not known. The stratigraphic order can be determined by the position of the name in the field
	LITHDESC	LITHDESC – Lithological description. This is equivalent to the descriptive information on the face of a geological map. It describes the separate lithologies (rock types) and may include information, which allows the particular unit to be identified.
	DOMLITH	DOMLITH – This is a single generalised rock type for each unit.
	LITH_COGENT	LITH_COGENT - not yet completed
	THICKNESS	THICKNESS – not yet completed
	DEP_ENV	DEP_ENV – Depositional environment
	OLDAGEMR, YNGAGEMR, ERA_OLD, PERIOD_OLD, EPOCH_OLD, AGEAB_OLD, ERA_YNG, PERIOD_YNG, EPOCH_YNG, AGEAB_YNG	OLDAGEMR YNGAGEMR ERA_OLD PERIOD_OLD EPOCH_OLD AGEAB_OLD ERA_YNG PERIOD_YNG EPOCH_YNG AGEAB_YNG AGECONTROL These are all age parameters (Era, Period, and Epoch) and are used because many geological units span an age range. The _old fields refer to the Era, Period and Epoch and age ABSOLUTE age of the units oldest age. Similarly the _yng age fields refer to the youngest age of the unit.
	AGECONTROL	AGECONTROL - Not yet completed.
	BATHNOGRANSUIT FRACTN	BATHNOGRANSUIT FRACTN These fields are reserved for granite units and are not complete in this dataset
	RAD_RESPONSE	RAD_RESPONSE – This is used for Quaternary units to describe the range of responses seen in ternary radiometric images which show potassium, thorium and uranium responses.
	MAJOR_REFS	MAJOR_REFS– References to descriptions of units (this field is incomplete for many units)
	COMMENTS	COMMENTS – This field has been used for a small number of units where some further clarification is needed The coverage contains lines, which are coded for geological attributes such as approximate geological boundary, faults etc. Types of boundaries are listed in the arc table and are included as arc attributes.
	Scale/Resolution	1:100 000
DATASET CURRENCY	Beginning date	2002.
	Ending date	December 2003.

METADATA CATEGORY	CORE METADATA ELEMENT	DESCRIPTION
DATASET STATUS	Progress	Completed WRA NAND04 project Nandewar Geology Integration and Upgrade
	Maintenance and update frequency	This coverage will form a starting point for future geology data upgrades in the area.
DATASET ENVIRONMENT	Software	ArcInfo, ArcView
	Computer Operating System	Windows 98SE, Windows NT, Windows 2000, Windows XP, UNIX
	Dataset Size	28Mb ArcInfo Coverage, 36Mb ArcInfo Export file
ACCESS	Stored Data Format	ArcView shape files and/or ArcInfo coverage
	Available format types	ArcView shape files. ArcInfo Export file
	Access constraints	Available upon licensing with DMR. Please do not distribute this dataset – refer requests for copies to the Department of Mineral Resources. This will ensure that the best available information is distributed
DATA QUALITY	Lineage	A continuous topologically structured geological coverage was created in Arc/Info for Nandewar WRA study area. The data contained in this coverage has been sourced from data compiled by the Geological Survey, NSW Department of Mineral Resources (DMR) The mapping derives from a very large heritage of existing geological maps and reports, both published and unpublished. The major source documents are recorded in a separate spatial index coverage This coverage has been compiled using a process of digitisation on screen during interpretation of remotely sensed data and landform images, in combination with digital vector datasets captured from published and unpublished hard copy maps
	Positional accuracy	Appropriate scale, spatial accuracy, level of interpretation The geological coverage was created at 1:100 000 scale equivalent but includes area derived from 1:250 000 scale mapping The data are appropriate for use at medium to small scale, (scales of approximately 1:100,000 to 1:500 000). The data should not be used for interpretations at scales greater than 1:100 000. Geological boundaries and features shown in the coverage are appropriate to 1:100 000 scale interpretation. Most boundaries can be considered to have a spatial accuracy of between 50 and 500m with the majority of boundaries being located with accuracy in the 50m to 250m range. For many geological contacts, it is impossible to effectively map contacts with more accuracy. This is because many geological boundaries are themselves gradational, and many are poorly exposed or not

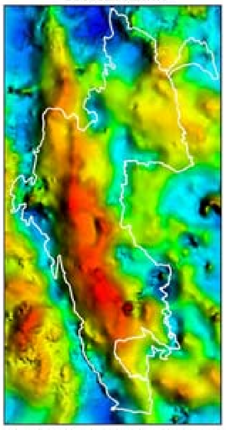
METADATA CATEGORY	CORE METADATA ELEMENT	DESCRIPTION
		exposed. Most geological maps are created by interpolations between a limited number of actual ground observations. Interpolation may be assisted by reference to airphotos, topographic maps, geophysical data, digital terrain models, satellite imagery, soil types etc. Some of these are a function of poor base maps in older sources and some are from varying geological interpretations. Users are advised to compare information to more precisely referenced datasets such as DTM and Landsat imagery in these instances. The spatial accuracy of boundaries is a different parameter to geological reliability. Geological reliability is a term which generally reflects the confidence which could be assigned to the mapped versus actual geology at a given point. Parts of the map coverage include extremely rugged and remote areas, where there has been little detailed geological mapping. As a result, most of the coverage could be considered to have a moderate to good geological reliability. It would be a reasonable estimate that for 90% or more of the area of the coverage, the actual unit present will correspond to that shown on the geological map. The representation of spatial accuracy on geological maps is generally indicated by the line style used to show a geological boundary. For example, accurate geological boundaries are shown as a solid line, and approximate geological boundaries are shown as dashed lines (see arc attributes where the boundary type is fully described).
	Attribute accuracy	Descriptive geological data One of the major tasks in producing the geological coverage was to provide a textual database containing a description and classification of each of the mapped geological units. On a standard geological map, information about geological units is portrayed on the geological legend. In addition to explicit descriptive information about each unit, information about the grouping and age relationships between units is generally portrayed graphically. Each unit on a geological map is given a letter symbol. The letter symbol itself provides some information about the age, name and lithology of the units. Each geological unit polygon was tagged with a letter symbol code to be used as a link to the rock unit description. The rock unit description data were compiled in a PC database and transferred to an INFO table linked by letter symbol code to the geological coverage polygons. Much of this coverage depended upon the interpretation of units from remote-sensed data. As a result, further fieldwork will, almost certainly, identify areas or inaccuracy in the mapping in detail.

METADATA CATEGORY	CORE METADATA ELEMENT	DESCRIPTION
	Logical consistency	The geological dataset has been subject to checking during the compilation and there should be few logical consistency errors. However, the compilation has not been subject to rigorous error checking. Some minor errors such as mis-labelled units may exist in the data.
	Completeness	The level of completeness is described in other fields above. However, the entire dataset was prepared using similar criteria and should be "complete" within the parameters used to undertake the interpretation of units.
NOTES		This project was managed by R.G. Barnes, Senior Geologist, Strategic Assessments sub program 1.05c and was partly funded by RACAC for the Nandewar Western Regional Assessment. Most of the ArcView interpretation of remote sense and landform image data was undertaken by Geologists Mark Dawson and Nancy Vickery with smaller areas interpreted by Bob Brown, Harvey Henley, Rob Barnes, Jeff Brownlow and Frances Spiller. The ArcInfo work was undertaken by Cartographer Ken McDonald who drew the many ArcView datasets together in ArcInfo to create polygon topology and resolve any inconsistencies. Rob Barnes, Mark Dawson and Nancy Vickery built the mapped unit attribute table from data on published maps and other sources and provided the interpretation in the geological systems fields. Jeff Brownlow provided interpretative assistance, as did many others in the DMR. Work was undertaken between late 2002 and December 2003.
METADATA DATE		December 2003
METADATA COMPLETED BY		Robert G Barnes, Ken McDonald
FURTHER INFORMATION		For further information contact the Armidale regional office, Department of Mineral Resources.
DATASET ENVIRONMENT	Name of System:	DMR GEOSCIENCE
	Contact organisation	NSW Department of Mineral Resources
	Contact position	Rob Barnes, Senior Geologist, Strategic Assessments, or Ken McDonald, Land Information Officer, Geological Survey of NSW; Manager Geospatial Information, Geological Survey of NSW
	Mail address	PO Box 65
	Suburb/place/locality	Armidale
	State	NSW.
	Country	Australia
	Postcode	2350
	Telephone	02 6776 0318

METADATA CATEGORY	CORE METADATA ELEMENT	DESCRIPTION
	Facsimile	02 6776 0399
	Electronic mail address	rob.barnes@minerals.nsw.gov.au
	Description	ArcView / ArcInfo GIS
	Availability	Contact NSW Department of Mineral Resources for geoscience information.
	Minimum Hardware Requirements	PC Pentium
	Minimum Software Requirements	ArcView 3.2
	Input Format/Type	ArcView shape file, ArcInfo coverage
	Output Format/Type	Various exchange formats available through ESRI ArcView/ArcInfo
BIBLIOGRAPHIC REFERENCE		This datasets should be referred to as: Dawson, M., Vickery, N., Barnes, R.G., and McDonald, K., 2003. Compiled and interpreted geological dataset of the Nandewar Western regional Assessment area, northern NSW. Digital dataset, Geological Survey of New South Wales, NSW Department of Mineral Resources.

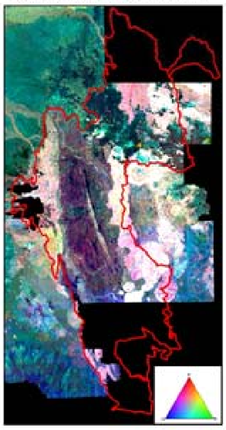
PLAN 1 SIMPLIFIED GEOLOGY OF THE NANDEWAR STUDY AREA

BOUGUER GRAVITY



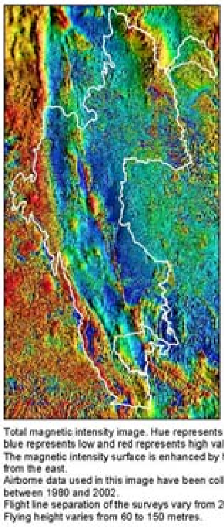
Bouguer Gravity image corrected for variations in crustal thickness (isostacy). The hue represents the strength of the Bouguer gravity anomaly, blue represents low and red represents high values. The Bouguer gravity surface is enhanced by hill shading with illumination from the east. The data have been generated from the Australian National Gravity Database published by Geoscience Australia.

GAMMA RAY SPECTROMETRIC DATA

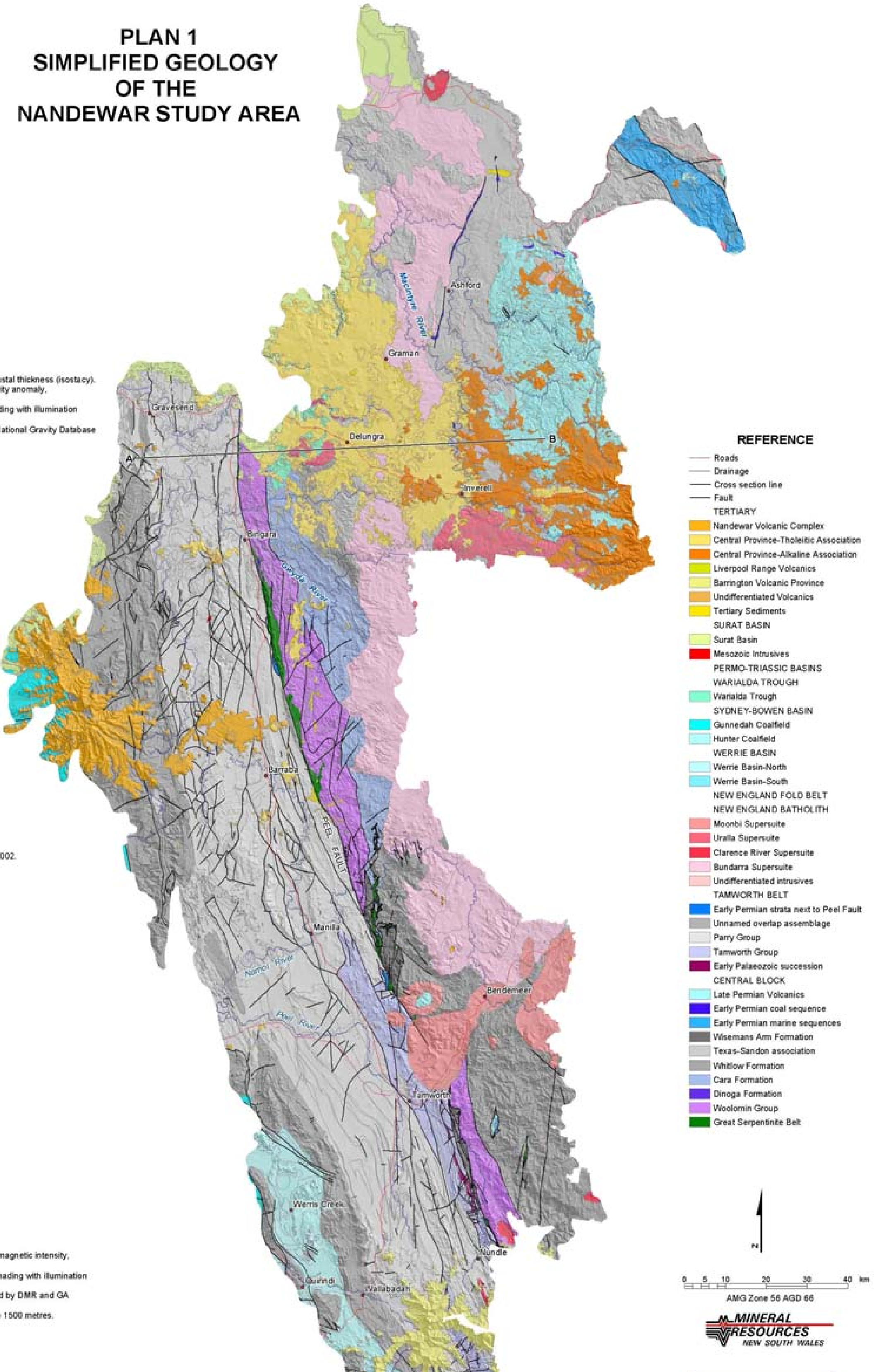


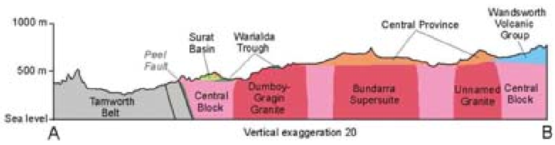
RGB image of gamma ray spectrometric data (red: potassium, green: thorium, blue: uranium). Data obtained by GA and DMR between 1990 and 2002. East West flight lines spaced at 200 to 400 metres. Flying height varies from 60 to 80 metres.

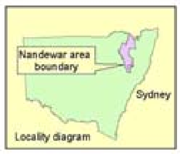
TOTAL MAGNETIC INTENSITY

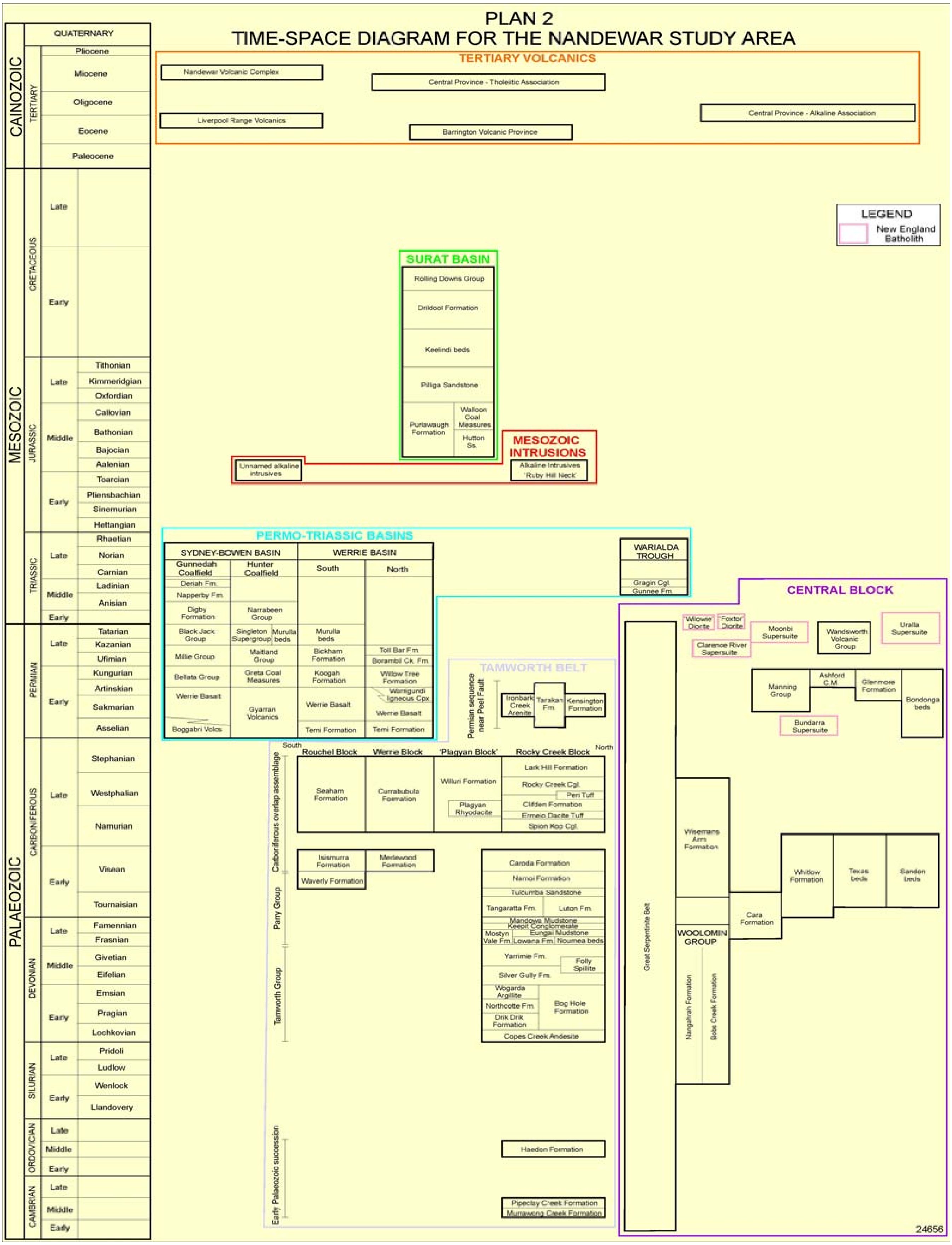


Total magnetic intensity image. Hue represents the magnetic intensity, blue represents low and red represents high values. The magnetic intensity surface is enhanced by hill shading with illumination from the east. Airborne data used in this image have been collected by DMR and GA between 1980 and 2002. Flight line separation of the surveys vary from 200 to 1500 metres. Flying height varies from 60 to 150 metres.








PLAN 2
TIME-SPACE DIAGRAM FOR THE NANDEWAR STUDY AREA
CAINOZOIC
MESOZOIC
PALAEOZOIC
QUATERNARY
TERTIARY
Pliocene
Miocene
Oligocene
Eocene
Paleocene
CRETACEOUS
Late
Early
JURASSIC
Middle
Tithonian
Kimmeridgian
Oxfordian
Callovian
Bathonian
Bajocian
Aalenian
Toarcian
Pliensbachian
Sinemurian
Hettangian
TRIASSIC
Rhaetian
Norian
Carnian
Ladinian
Anisian
PERMIAN
Tatarian
Kazanian
Ufimian
Kungurian
Artinskian
Sakmarian
Asselian
CARBONIFEROUS
Stephanian
Westphalian
Namurian
Visean
Tournaisian
DEVONIAN
Famennian
Frasnian
Givetian
Eifelian
Emsian
Pragian
Lochkovian
SILURIAN
Pridoli
Ludlow
Wenlock
Llandovery
ORDOVICIAN
CAMBRIAN
TERTIARY VOLCANICS
Nandewar Volcanic Complex
Central Province - Tholeiitic Association
Central Province - Alkaline Association
Liverpool Range Volcanics
Barrington Volcanic Province
LEGEND
New England Batholith
SURAT BASIN
Rolling Downs Group
Drildool Formation
Keelindi beds
Pilliga Sandstone
Purlawaugh Formation
Walloon Coal Measures
Hutton Ss.
MESOZOIC INTRUSIONS
Unnamed alkaline intrusives
Alkaline Intrusives 'Ruby Hill Neck'
PERMO-TRIASSIC BASINS
SYDNEY-BOWEN BASIN
WERRIE BASIN
Gunnedah Coalfield
Hunter Coalfield
South
North
Deriah Fm.
Napperby Fm.
Digby Formation
Narrabeen Group
Black Jack Group
Singleton Supergroup
Murulla beds
Millie Group
Maitland Group
Bickham Formation
Toll Bar Fm.
Borambil Ck. Fm.
Bellata Group
Greta Coal Measures
Koogah Formation
Willow Tree Formation
Warrigundi Igneous Cpx
Werrie Basalt
Gyarran Volcanics
Boggabri Volcs
Temi Formation
WARIALDA TROUGH
Gragin Cgl.
Gunnee Fm.
TAMWORTH BELT
Permian sequence near Peel Fault
Ironbark Creek Arenite
Tarakan Fm.
Kensington Formation
Rouchel Block
Werrie Block
'Plagyan Block'
Rocky Creek Block
Seaham Formation
Currabubula Formation
Willuri Formation
Plagyan Rhyodacite
Lark Hill Formation
Rocky Creek Cgl.
Peri Tuff
Clifden Formation
Ermelo Dacite Tuff
Spion Kop Cgl.
Carboniferous overlap assemblage
Isismurra Formation
Merlewood Formation
Waverly Formation
Caroda Formation
Namoi Formation
Tulcumba Sandstone
Tangaratta Fm.
Luton Fm.
Mandowa Mudstone
Keepit Conglomerate
Mostyn Vale Fm.
Lowana Fm.
Eungai Mudstone
Noumea beds
Parry Group
Yarrimie Fm.
Folly Spilite
Silver Gully Fm.
Wogarda Argillite
Northcotte Fm.
Bog Hole Formation
Drik Drik Formation
Copes Creek Andesite
Tamworth Group
Early Palaeozoic succession
Haedon Formation
Pipeclay Creek Formation
Murrawong Creek Formation
CENTRAL BLOCK
Wilowie Diorite
Foxtor Diorite
Moonbi Supersuite
Wandsworth Volcanic Group
Uralla Supersuite
Clarence River Supersuite
Manning Group
Ashford C.M.
Glenmore Formation
Bondonga beds
Bundarra Supersuite
Great Serpentinite Belt
Wisemans Arm Formation
Whitlow Formation
Texas beds
Sandon beds
Cara Formation
WOOLOMIN GROUP
Nangahrah Formation
Bobs Creek Formation
24656