A GEOSCIENCE ATLAS FOR NATURAL RESOURCE MANAGEMENT IN THE UPPER BURDEKIN AND FITZROY CATCHMENTS, QUEENSLAND, AUSTRALIA

M.E. Lech, M.C. Gray, C. F. Pain and Y. Miezitis

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PREFACE

This report is a companion to the Burdekin-Fitzroy web-based Geographic Information System (GIS). These were developed by Geoscience Australia, the Cooperative Research Centre for Landscape, Environment and Mineral Exploration (CRC LEME) and the Queensland Department of Natural Resources and Mines (NR&M) to bring together and describe a wide range of data layers that are of potential relevance to natural resource management decisions. Together, they provide an integrated body of knowledge that can be used as a tool by interested parties to rapidly access information and guide NRM decisions. They are unusual in the focus they provide on geoscience layers, which provide information on the distribution of surficial materials and the insights into subsurface geological features that influence soil types, groundwater and salinity.

The GIS, which is hosted by Geoscience Australia, is not a "live" system drawing on the latest versions of the various databases. However, it contains comprehensive metadata that facilitates access by interested parties of updated material from specific sources.

Feedback is sought on the usefulness of this GIS and report before consideration is given to development of similar systems for other regions. This should be sent to Colin Pain (colin.pain@ga.gov.au), Ian Lambert (ian.lambert@ga.gov.au) or Mike Grundy (Mike.Grundy@nrm.qld.gov.au).

Ian Lambert, Colin Pain (Geoscience Australia)
Mike Grundy (Queensland Department of Natural Resources and Mines)

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1. INTRODUCTION

1.1 Background and objectives

Over the past 10-15 years it has become clear that geophysical data and related interpretations can provide additional information for Natural Resource Management (NRM). This in turn has led to the recognition that geoscience data and information have further potential to improve planning for NRM, and perhaps the best way to do this is through collaborative and multidisciplinary projects. In the case of the Burdekin-Fitzroy catchments, geoscience datasets have been predominantly acquired for mineral exploration, geological mapping and regolith studies, among other things. This plethora of geoscience information, available from the commonwealth and state geological surveys, has not been previously reviewed from an NRM perspective because there has not been any "driver", but has potential to improve existing interpretations over the catchments.

This project addresses this situation in a limited manner through a collaborative demonstration project in the upper Burdekin and Fitzroy catchments. The project was set up to work under the National Geoscience Agreement with the Queensland Department of Natural Resources and Mines (NR&M), CRC LEME and Geoscience Australia. The primary aim was to compile geoscience datasets from the region that may have relevance to NRM (e.g. depth of weathering, palaeochannel information, major structures, landform evolution and regolith features). A second aim was to identify key knowledge gaps that should be filled, and provide a basis for rational and rapid decisions on which effective land management decisions could be based.

1.2 Structure of the report and geographic information system (GIS)

There are three main outputs from the study, this report, an interactive GIS application and a bibliographic index of information.

This report is designed to provide the reader with brief summaries of useful data located within the Burdekin-Fitzroy catchments that are of interest for NRM. These data have been compiled from a range of sources including the NR&M, Geoscience Australia (GA), CSIRO and private sources. These datasets include both digital and non-digital formats and some of the information remains confidential and can be obtained only from the appropriate custodians, which are identified. This report is designed to be used with an interactive GIS application, an output of this study, accessible through the Geoscience Australia webpage (http://www.ga.gov.au/map/burdekin-fitzroy/). The data (where possible) are spatially located on a map of the study region like the one shown in Figure 1.

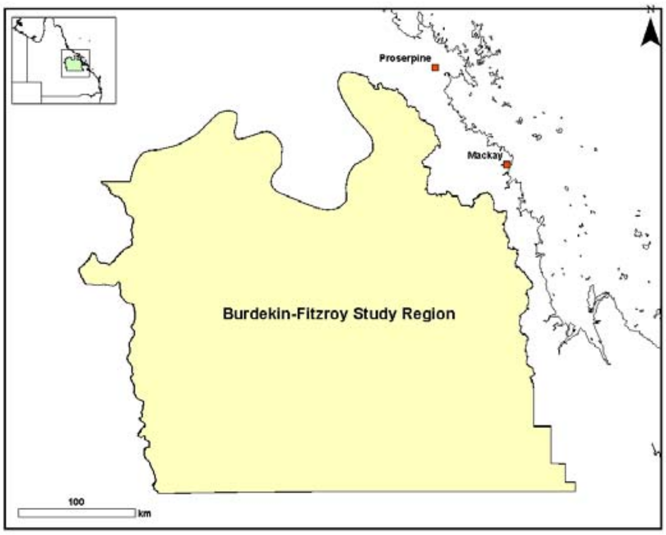


Figure 1. Upper Burdekin-Fitzroy study region. Data collected for the report and interactive GIS are contained within this region.

This report is a guide to what data are available within the interactive GIS application, and provides summary information for all of the identified datasets. Further information may be obtained by following the internet links provided. The GIS allows the user to view and query the datasets attributes interactively. The user cannot directly download data, but is instead directed to the appropriate resource via internet links. In some cases, these links allow the user to directly download data, but most of the time the user will need to make a request for the data they require.

The final output from this project is a comprehensive bibliographic index of information relevant to the Burdekin-Fitzroy pilot study. This resource provides the user with reference material relating to their searches within the confines of the study region. This information is available through the GA website only as a PDF file.

2. GEOLOGICAL DATA

2.1 Introduction

The geology within the study area has been studied and mapped at a range of scales. Here we provide a brief overview (Table 1); for more detailed information the reader is referred to the relevant references.

Table 1. Overview of the Geology of the Burdekin-Fitzroy Study area

Geological Province	Age Range	Units and Rock types
Surficial sediment and soils	Cainozoic - Recent	
Basalt	Cainozoic	
Duaringa Basin	Early Cainozoic	
Eromanga Basin	Early Jurassic to mid-Cretaceous	
Bowen Basin	Early Permian – Middle Triassic	
Galilee Basin	Late Carboniferous – Middle Triassic	
Connors Arc		
Drummond Basin	Late Devonian – Early Carboniferous	
Anakie Inlier	Devonian	Retreat Batholith; granite
		Scattered remnants sedimentary rocks
		Small areas of volcanic rocks
	Late Ordovician	Fork Lagoon beds: phacoidal quartzose sandstone, cleaved mudstone, limestone, basalt and volcaniclastics
	Neoproterozoic - Cambrian	Anakie Metamorphic Group: pelitic schist, psammitic schist, mafic schist, graphitic schist and quartzite; minor marble, calc-silicate rock and serpentinite

2.2 Data Sources

Data related to geological mapping over the region were obtained from the following sources. Most of this information is available in digital format.

- **NR&M–** Geological maps and explanatory notes, digital geology, drilling information, logs and reports.
- **GA –** Geological maps and explanatory notes, digital geology and reports.
- **CSIRO –** Solid geology (digital).

2.3 Available data

There is a large amount of geological mapping available at various scales for the Burdekin-Fitzroy region. The most recent covering the entire study region is an attributed, seamless digital coverage at 1:1 million scale compiled from existing 1:250,000 and 1:100,000 geological maps. Many of the 1:250,000 scale maps are now being revised and remapped at 1:100,000 scale. The 1:100,000 coverage is incomplete and is an ongoing project of NR&M. Solid geology coverage is also incomplete, and is in the processes of being updated.

Geological Mapping

Geology 1:2,500,000

The 1:2,500,000 scale geological map of Queensland was first produced in 1975 (Day *et al.*, 1983). An accompanying report was re-published in 1983. This coverage has now been superseded by higher resolution mapping.

Geology 1:1,000,000

The 1:1 million South Queensland Surface Geology covers the entire study area and was produced by Geoscience Australia in 2004 in collaboration with NR&M (Figure 2). This coverage integrates the most of the previous mapping down to 1:100,000 scale. Polygons less than 1 km square have been omitted making the layer useful for interpretation at scales no less than 1:500,000. The digital dataset represents the surface geological units for South Queensland as attributed polygons and lines (Whitaker *et al.*, 2003). The dataset was compiled from a variety of regional datasets, listed under 'lineage', for an area approximately coincident with 18.5 to 29.0 S and 138.0 to 153.5 E. The data are intended for use at 1:1M scale and has a spatial accuracy of approximately 750 m (Whitaker *et al.*, 2003). The coverage also contains attributed structural information.

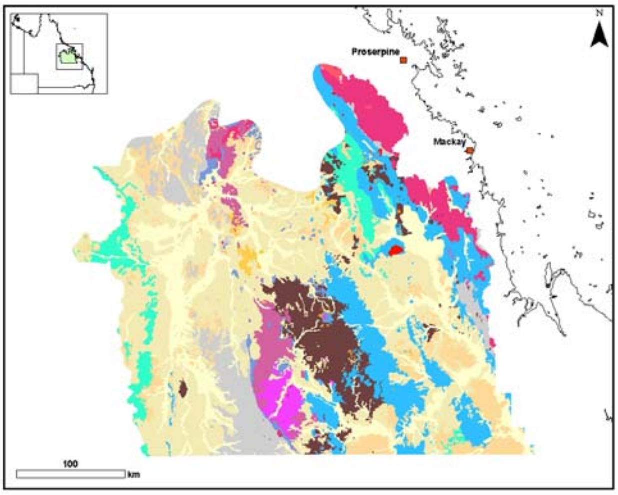


Figure 2. The 1:1,000,000 South Queensland Surface Geology for the study area.

Source: www.ga.gov.au or contact Alan.Whitaker@ga.gov.au

Geology 1:500,000

Digitised geological mapping at 1:500,000 scales include:

- Bowen Basin surface geology (1:500,000)
- Burdekin River regional geology (1:500,000)
- North Eromanga Basin regional geology (1:1,000,000)

All of the 1:500,000 scale mapping has been incorporated into the 1:1 million South Queensland Surface Geology (Whitaker, 2003).

Geology 1:250,000

The study area is covered by nine maps from the Australia 1:250,000 Geological Map Series (Figure 3). These are Charters Towers, Bowen (Paine and Cameron, 1972) Proserpine (Paine 1972), Buchanan (Olgers, 1969a), Mt Coolon (Malone, 1969), Mackay (Jensen, 1965), Galilee (Vine and Doutch, 1972), Clermont (Olgers, 1969b), St Lawrence (Malone, 1970), Jericho (Senior, 1973), Emerald (Olgers, 1984) and Duaringa (Kirkegaard, 1970). This series has only been partially captured digitally with the initial work performed by NR&M in 2001-02 for the National Action Plan (salinity and water quality) projects. Elementary attributes have been applied, however the digitised map sheets need to be edge matched and a standardised colour legend applied. The digital capture is an ongoing project with NR&M with an expected completion date by 2007 (Blight, pers comm). The coverages are expected to include significant revisions with re-mapping being performed at 1:100,000 scale. The sheets at this time are available as geo-referenced raster images (*.tiff) from NR&M or Geoscience Australia.

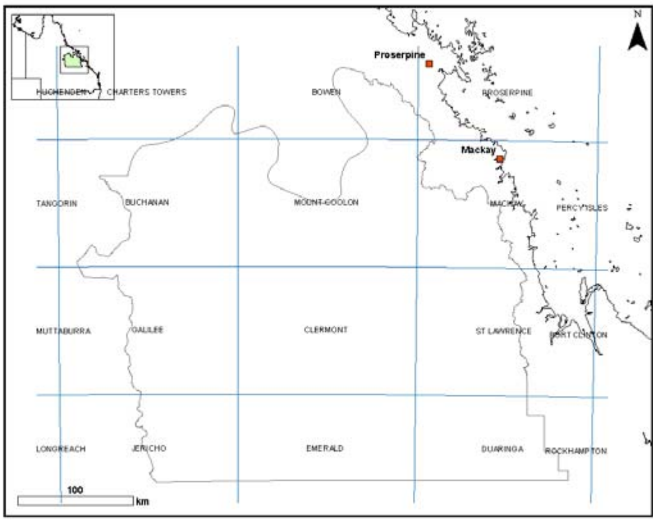


Figure 3. Australian 1:250 000 Geological map sheet series for the Burdekin-Fitzroy study region.

Source: NR&M : www.nrm.qld.gov.au Geoscience Australia: www.ga.gov.au

Geology 1:100,000

Forty-five 1:100,000 map sheets cover the study area (Figure 4). Not all of these sheets have been mapped and digitised. This is an ongoing activity within the Burdekin-Fitzroy region by NR&M. Sheets that have been mapped and digitised are commercially available forming part of the GEOLDATA 1:100,000 series available from NR&M. These sheets are Byerwen, Clermont, Connors Range, Duaringa, Frankfield, Gunjulla, Harrybrandt, Hillalong, Kilcummin, Monteagle, Mt Bluffkin, Mt Coolon, Rookwood, Rubyvale, Wyena, and Zigzag. These map sheets are available as attributed digital maps with accompanying structural information in various ESRI formats. Weathering profile data are also available. There are no standardised colour lookup tables for the 1:100,000 map sheets, and the attributed map symbology is non standard.

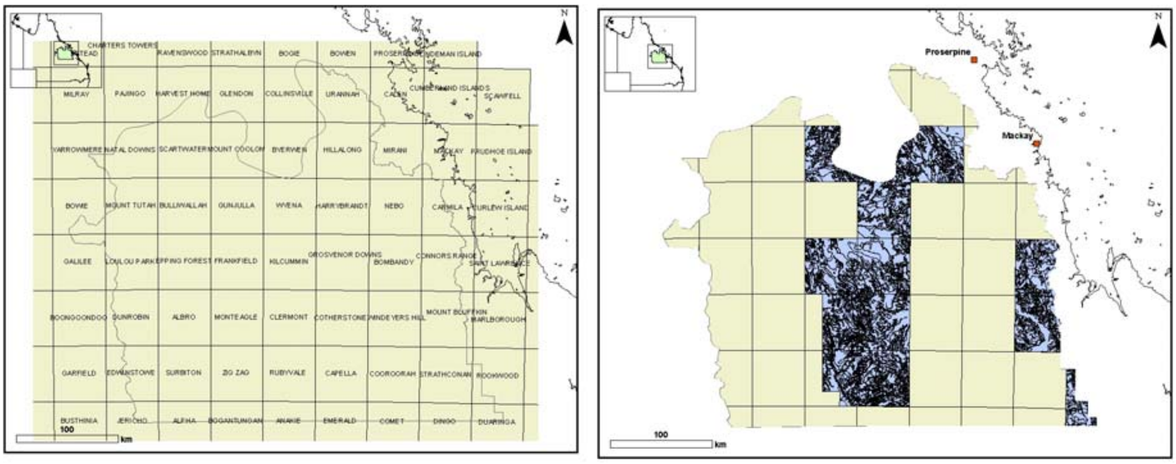


Figure 4. (a) Geological 1:100,000 sheets covering the Burdekin-Fitzroy study region (b) Areas where mapping has been completed and digitised.

One geological map combining a number of 1:100,000 map sheets has also been compiled by NR&M, titled the Anakie Special Sheet (Withnall *et al.*, 1995) (Figure 5). This map covers the southern part of the Anakie Inlier and is available as vector data with accompanying structural information and detailed report. This special sheet overlaps on some of the other 1:100,000 map sheets mentioned, but was produced as a stand alone product. The Anakie Special Sheet is commercially available through NR&M.

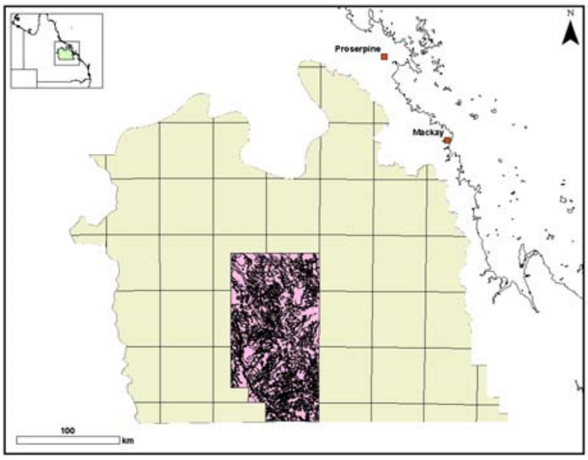


Figure 5. 1:100,000 Anakie Special Sheet shown within the Burdekin-Fitzroy study region.

Source: NR&M contact: Peter.Goldsworthy@nrm.qld.gov.au

Solid Geology Maps

A number of regional solid geology maps are available for the Burdekin-Fitzroy study region, and are included in the interactive GIS. The coverages include the Northern Bowen Basin Solid Geology compiled by CSIRO and NR&M (Sliwa and Draper, 2003), and the Bowen Basin Solid Geology interpretation of NR&M (1988). There is also a regional un-digitised Drummond Basin solid geology interpretation performed by Olgers (1972) which is currently being re-interpreted as an ongoing project within NR&M.

Northern Bowen Basin Solid Geology

This interpretation (Figure 6) is an output of the 'Glass Earth' Project, a collaborative research initiative between CSIRO Exploration and Mining and NR&M (Sliwa and Draper, 2003), and updates the northern part of the existing 1:500,000 Bowen Basin Solid Geology (1988). The coverage is available as ESRI shapefiles that may be downloaded from the CSIRO website. Data layers include an attributed basement interpretation, structural information, surface geological units along with a range of additional vector datasets. Much of the coverage is based on interpretation of high resolution geophysical data and detailed mapping.

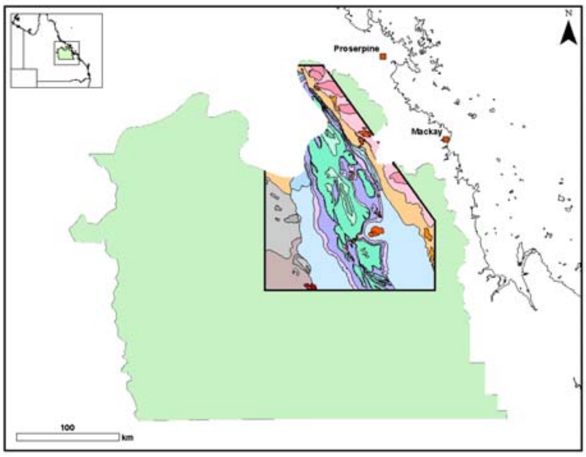


Figure 6. North Bowen Basin Solid Geology interpretation for the study area. Data are from the Glass Earth collaborative project between CSIRO and NR&M.

Source : http://www.glassearth.com or contact : Renate.Sliwa@csiro.gov.au

Bowen Basin Solid Geology

The Bowen Basin Solid Geology (1988) is an older interpretation than the Northern Bowen Basin Interpretation, but covers a significantly larger area (Figure 7). The attributed digital coverage includes a basement interpretation, structural data, surficial geological units, weathering profile mapping plus some additional vector datasets.

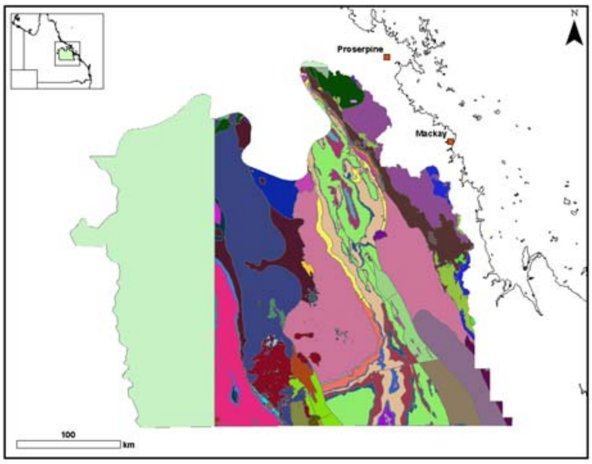


Figure 7. Bowen Basin solid geology interpretation for the Burdekin-Fitzroy study region (NR&M).

This coverage is available as an ESRI shape file from NR&M (www.nrm.qld.gov.au)

Drummond Basin Solid Geology

The only regional scale solid geology interpretation identified for the Drummond Basin is the work of Olgers (1972). This area is currently being updated by NR&M.

Other Coverages

A number of other geoscience related datasets were identified that have some relevance to NRM. They are mainly interpretive and regional in scope. Many of these coverages have been sourced from the digital QLD Petroleum GIS held by NR&M.

Sedimentary Basins

The main sedimentary basins (Drummond, Galilee and Bowen Basins) outlines have been delineated from stratigraphic, structural and geophysical information by NR&M (Figure 8).

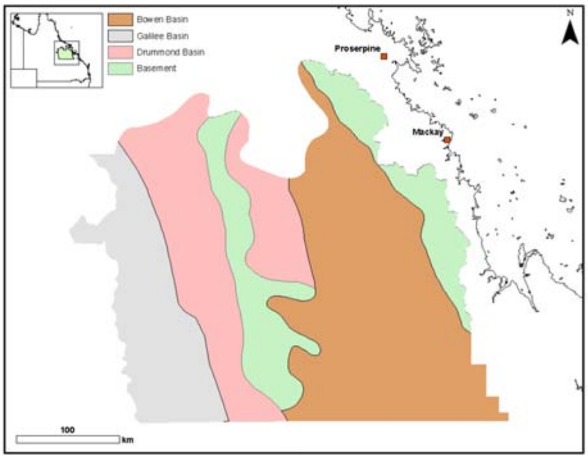


Figure 8. Late Devonian to Late Triassic sedimentary basins within the study area (QLD Petroleum GIS).

This coverage is available as an ESRI shapefile from NR&M (www.nrm.qld.gov.au).

Tectonic regions

The Burdekin-Fitzroy study region has been subdivided according to structural or tectonic domains. The different structural domains are the Galilee Basin, Drummond Basin, Anakie Metamorphic Inlier, Bowen Basin and the Connors Arch Igneous Complex (Figure 9). This information was compiled by NR&M.

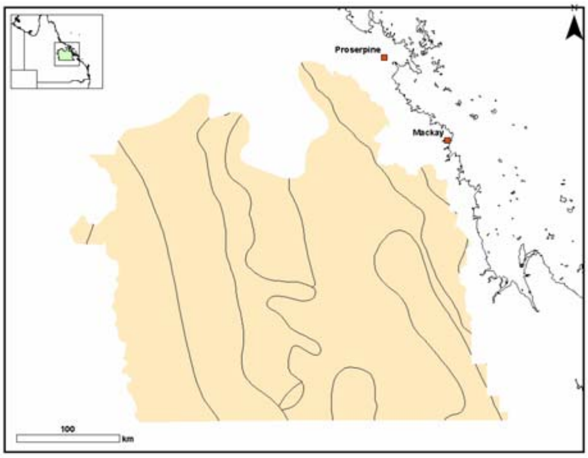


Figure 9. Tectonic framework of the Burdekin-Fitzroy study region.

This coverage is available as an ESRI shapefile from NR&M (www.nrm.qld.gov.au).

Drill Hole Data

NR&M has a number of databases containing information on drilled holes in the region (Figure 10). The two databases of importance to this study are the Queensland Petroleum Exploration Database (QPED) and the Queensland Groundwater Borehole Database (QGBD).

QPED

QPED contains all subsurface geological information for Queensland's sedimentary basins. One hundred and sixty of these holes are located within the study area, and consist of stratigraphic bores, petroleum wells and coal seam gas drill holes. A range of attributed information is available for these drill holes. Most of the information in the QPED database relating to these holes has little application to NRM, however some of the lithological data may be of use for bedrock interpretation. Information on regolith properties is virtually non-existent. The data are on open file and may be purchased from NR&M.

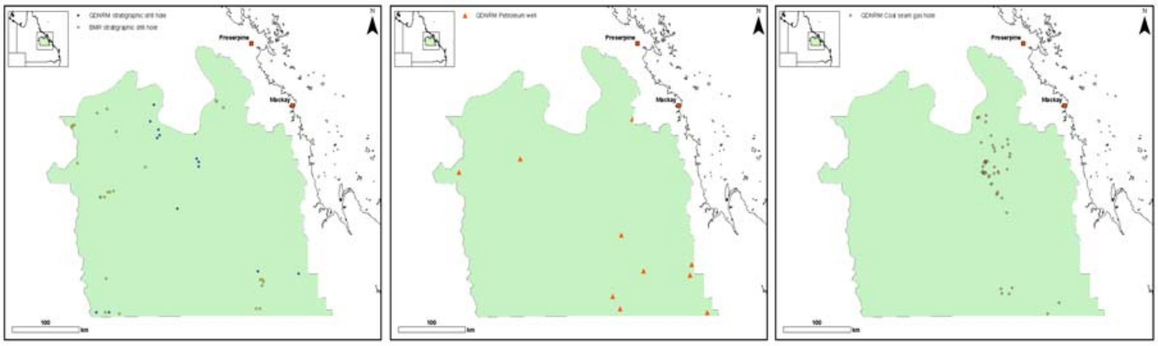


Figure 10. Drill hole locations within the Burdekin-Fitzroy area. (a) Stratigraphic drill holes. (b) Petroleum wells. (c) Coal seam gas holes.

Source www.nrm.qld.gov.au or contact: kinta.hoffmann@nrm.qld.gov.au

Water bores (QGBD)

The groundwater database is maintained by NR&M and contains a significant amount of information relevant to NRM. Borehole attributes often include stratigraphic, lithological, and hydrogeological information for logged regolith and bedrock interfaces. There is also some and hydrological information. A majority of these holes are shallow (<100m) and often are discontinued after bedrock is intersected. The information quality and the spatial accuracy of the drill hole locations can be of variable reliability. No standard regolith classification scheme (i.e. RTMAP) has been used to describe any of the units.

Bores are numerous (Figure 11), and further information may be obtained by request from NR&M. Some of the attributed information is presented on the interactive GIS through the GA website.

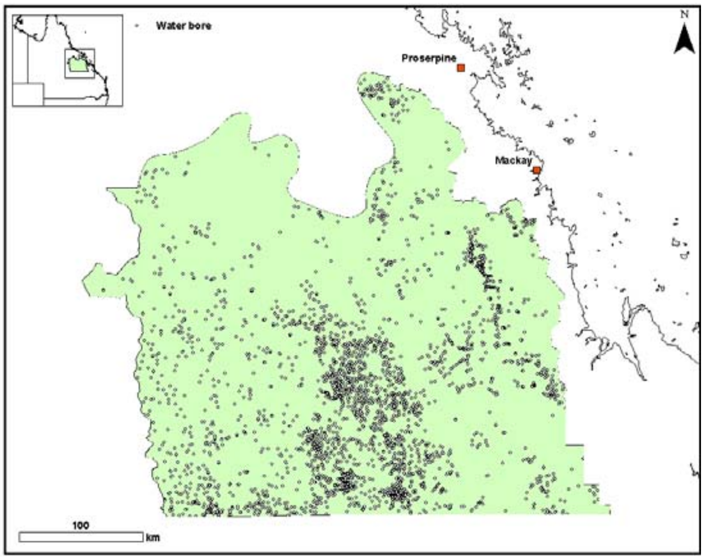


Figure 11. Water bore locations within the Burdekin-Fitzroy Study Area.

Source : www.nrme.qld.gov.au or contact Gary.Dawson@nrme.qld.gov.au

2.4 Summary

The datasets presented in the previous sections were evaluated for their use in NRM in the Burdekin-Fitzroy study region. The most detailed mapping available is the 1:100,000 scale data, however there are large gaps in the coverage which are awaiting mapping and digitising. It is recommended that the 1:1,000,000 scale maps are to be for interpretation where 1:100,000 mapping has not been completed. Regolith landform maps are generally non-existent over the region. Drilling information is abundance, but of variable quality. Of these existing holes, most have little to no useful information on regolith properties. There is also a large amount of prospect scale company exploration drilling that is still to be evaluated, and is not contained in any digital resource. The most useful drilling information available for NRM within the Burdekin-Fitzroy study region is in the groundwater database. Although there is an abundance of such drill holes, the attributed data associated with them is often unverified, and may at times be unreliable. Depth to fresh bedrock information was sometimes available, but only after careful analysis and some reliance on verified stratigraphic information. Differentiation and correlation of facies within the Cainozoic material between boreholes was almost impossible in most areas. Use of this information for further NRM related work is suggested, but the data must be carefully assessed.

Solid geology maps only cover part of the Burdekin-Fitzroy study region . The most recent from the Northern Bowen Basin (Sliwa & Draper, 2003) is a high quality interpretation. A similar re-interpretation should be performed for the Central Bowen Basin region using newly acquired geophysical data. The solid geology of the Drummond Basin is currently being completed and will provide a useful integrated digital product covering this area. There is considered to be sufficient information to perform this work.

2.5 Recommendations

As a result of this review, the recommendations for future work are:

- There should be further examination of company exploration reports to evaluate the quality of existing geological mapping performed at scales less than 1:100,000. This information may be useful for future NRM investigations and could also be compared to existing mapping.

- Regolith – landform mapping should be considered for future NRM work.

- Map symbology and colour lookup tables for the 1:100,000 scale digital geology products should be standardised.

- Edge matching and rectification of 1:250,000 digital geology series should be undertaken.

- The solid geology of the Drummond and Central Bowen Basins should be re-interpreted.

- Extraction of private exploration company drilling this information from company reports may provide additional information for the purposes of NRM in the region, and should be considered.

3. NATURAL RESOURCE MANAGEMENT DATA

3.1 Digital Elevation Models (DEM's)

GEODATA DEM (9 second V2)

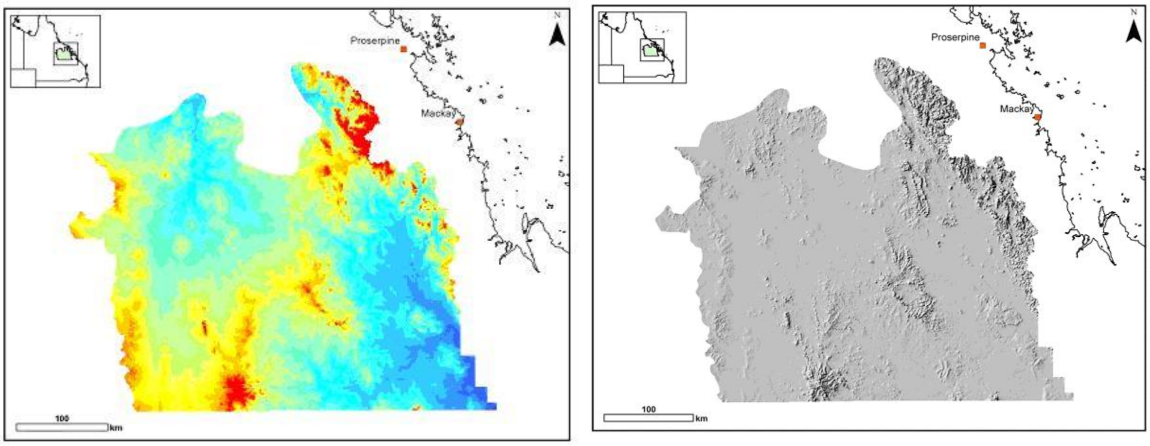


Figure 12. Digital elevation models. (a) Version 2 of the Continental Australia 9 second DEM for the study area (b) Hill shade derivative from Version 2 of the Continental Australia 9 second DEM for the study area.

The GEODATA 9 Second DEM Version 2 (Figure 12a) is a grided digital elevation model computed from topographic information including point elevation data, elevation contours, stream lines and cliff lines. The grid spacing is 9 seconds in longitude and latitude (approximately 250 metres). The 9 second DEM is a cooperative effort between Geoscience Australia and the Centre for Resource and Environmental Studies (CRES) at the Australian National University. A hill-shade derivative was created from version 2 of the 9 Second DEM. The grid spacing is 9 seconds in longitude and latitude (approximately 250 metres) (Figure 12b).

The National DEM is free to download form the Geoscience Australia website at:

http://www.ga.gov.au/download/nmd_download/#dem

Source : www.ga.gov.au or contact sales@ga.gov.au

Metadata: http://www.ga.gov.au/meta/ANZCW0703005624.html

Since this project was completed a Shuttle Radar Terrain Model (SRTM) has become available from NASA. This product should become available from Geoscience Australia in the near future.

25 metre DEM

A 25m DEM (Figure 13) for Queensland was derived from an existing ASTER (Advanced Spaceborne Thermal Emission and Reflectance, Radiometer) data were created at NR&M. ASTER acquires a simultaneous stereo pair of imagery at 15m resolution. This is usually transformed into a DEM of between 25-50 metres to reduce noise. This datasets is more suited to detailed small-scale studies than the 9 second DEM.

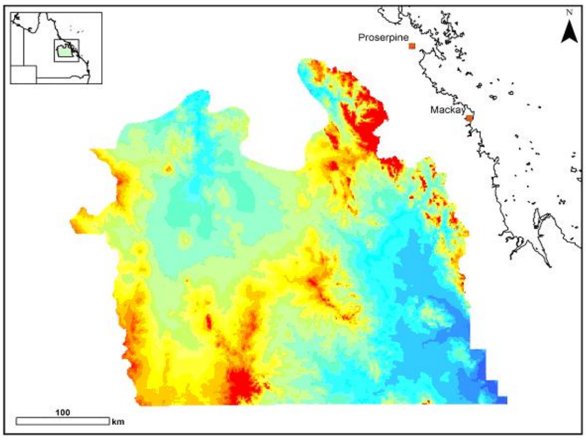


Figure 13. Twenty five m digital elevation model for the study area (NR&M)

At present the dataset is undergoing quality control and is not available for public use.

Contact: www.nrm.qld.gov.au

3.2 Groundwater Flow Systems

The following coverage is the Australian Groundwater Flow Systems from the National Land and Water Resources Audit (NLWRA), January 2000 (Figure 14).

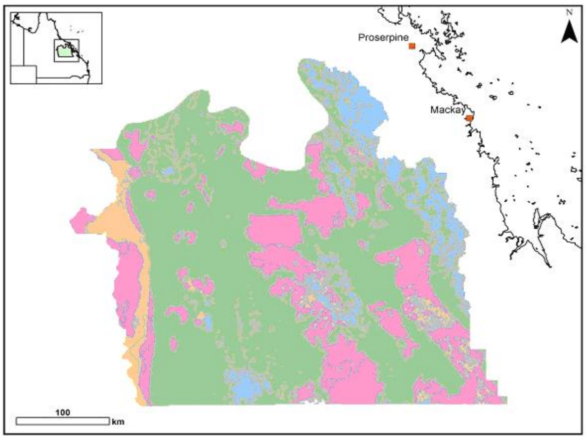


Figure 14. The continental groundwater flow systems coverage for the study area.

The continental groundwater flow systems coverage was derived using 3 databases:

1. Bedrock Geology (1: 2,500,000 scale from Geoscience Australia)

2. Regolith Terrain Map of Australia (1:5,000,000 scale from Geoscience Australia)

3. 9 second Digital Elevation model of Australia, (resampled to 1000 m from Geoscience Australia)

This is a two-dimensional interpretation which does not take into account complex three-dimensional geology. It also has artefacts from errors in the original datasets.

Source : www.brs.gov.au or contact dataman@brs.gov.au

Two National Action Plan for Dryland Salinity and Water Quality (NAP) groundwater flow system maps have been produced for the study area, one for the Burdekin, and another for the Fitzroy catchment areas (Figure 15).

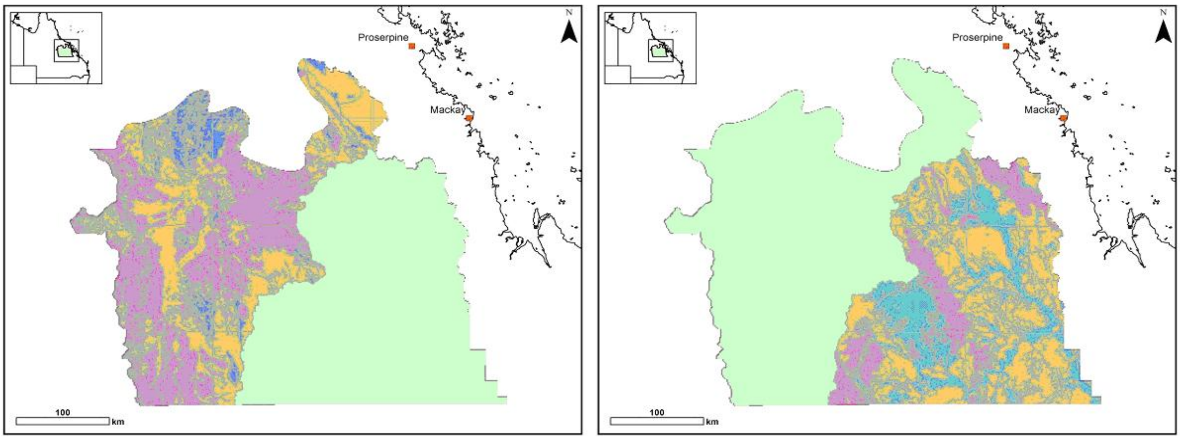


Figure 15. Groundwater flow systems. (Left) Burdekin NAP Region. (Right) Fitzroy NAP Region.

The Burdekin and Fitzroy NAP Region Groundwater Flow System maps were developed for the Queensland portion of the National Action Plan for Salinity and Water Quality, to assist in planning and management decisions. They define attributes for hydrogeological provinces that form a groundwater flow system and are based on the mapped geological units of the 1:250,000 geology coverage.

This is a 2 dimensional interpretation which does not take into account complex 3 dimensional geology. It also has artefacts from errors in the original datasets. Groundwater flow systems are not comparable between NAP Regions.

Source: Department Natural Resources and Mines, or contact james.moss@nrm.qld.gov.au

3.3 Satellite Imagery

Landsat 7

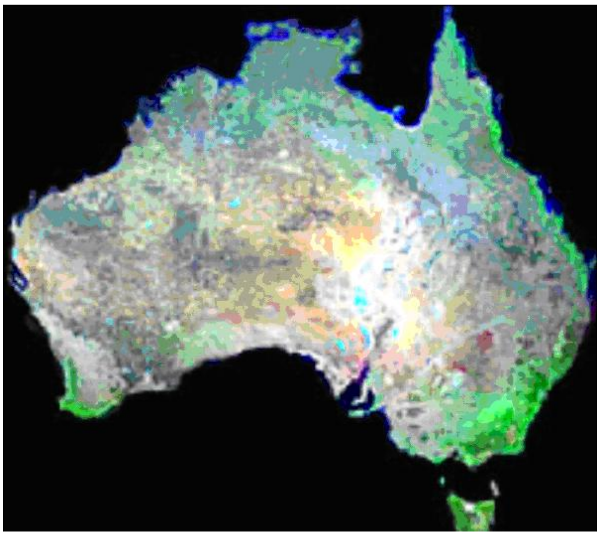


Figure 16. Landsat 7 Picture Mosaic of Australia

The Landsat 7 Picture Mosaic of Australia (Figure 16) was produced by the Australian Greenhouse Office (AGO) as part of their National Carbon Accounting System. The mosaic consists of 369 individual Landsat satellite scenes acquired between July 1999 and September 2000.

The picture mosaic file may be downloaded at no cost from the Geoscience Australia web site in ECW (compressed) form.

Source: http://www.ga.gov.au/acres/prod_ser/ls7_picmosaic.htm

Individual scenes can be searched for and ordered through the Acres remote sensing archive: http://www.ga.gov.au/acres/

Landsat 7TM Pan band mosaic

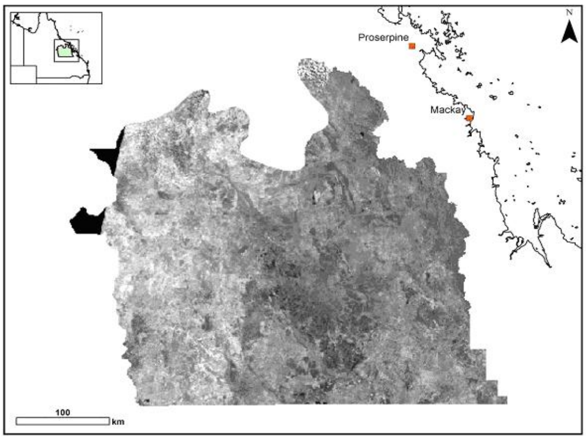


Figure 17. Landsat 7TM Pan band mosaic of the study area.

The 12.5m resolution pan band mosaic (Figure 17) was created using satellite imagery obtained from ACRES. The image has been colour balanced and a mosaic compiled for the study area. A seasonal mosaic has been compiled for autumn 2001 and summer 2001-02.

Individual satellite scenes can be searched for an ordered through the Acres remote sensing archive: http://www.ga.gov.au/acres/

Landsat 7TM 147 and 321 RGB colour

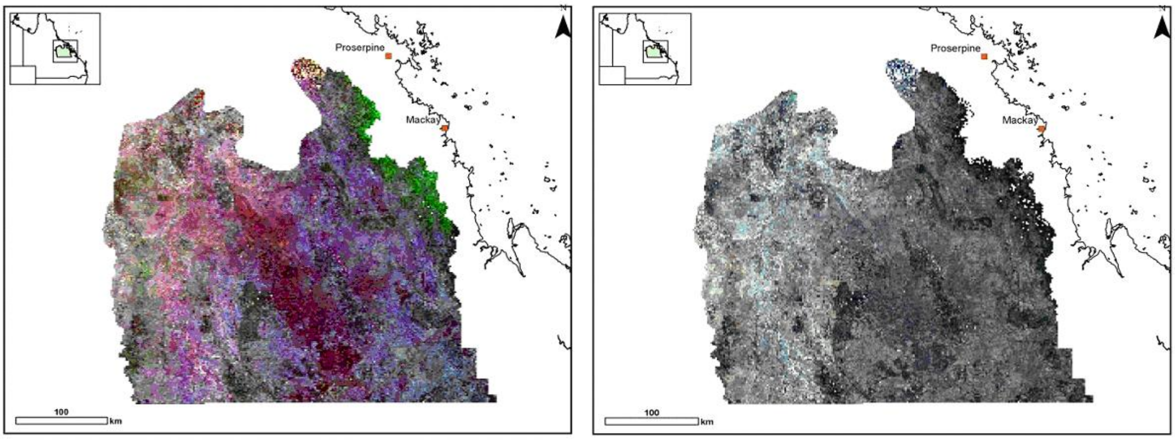


Figure 18. Landsat 7 TM. (Left) 147 RGB colour image. (Right) 321 RGB colour image.

The 25m resolution 147 and 321 RGB colour mosaics (Figure 18) were created using satellite imagery obtained from ACRES. The image has been colour balanced and a mosaic compiled for the study area. A seasonal mosaic has been compiled for autumn 2001 and summer 2001-2002.

Individual satellite scenes can be searched for an ordered through the Acres remote sensing archive: http://www.ga.gov.au/acres/

3.4 Physiographic Regions

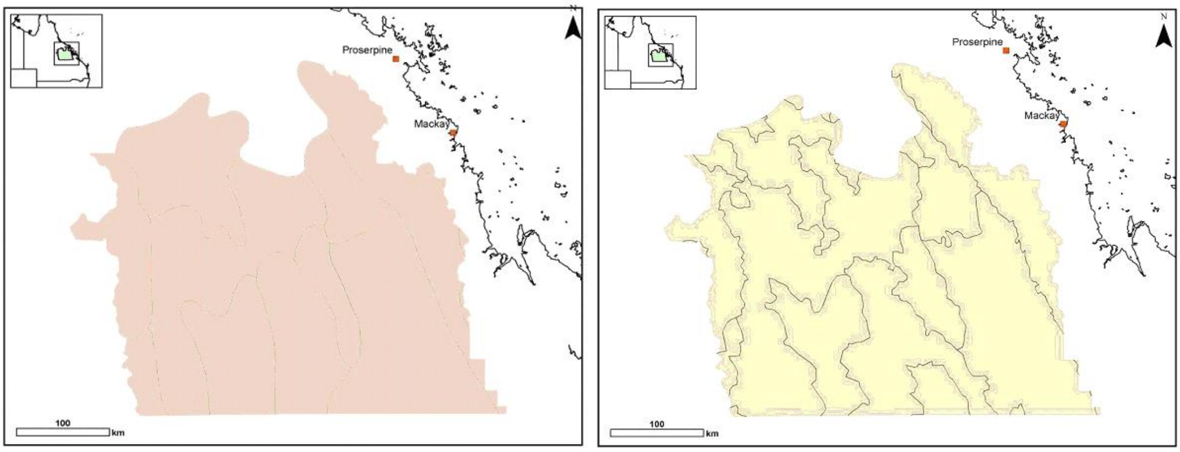


Figure 19. Physiographic regions. (Left) Extract from the national physiographic regions coverage of Jennings and Mabbutt (1986). (Right) Physiographic regions redefined for the study area.

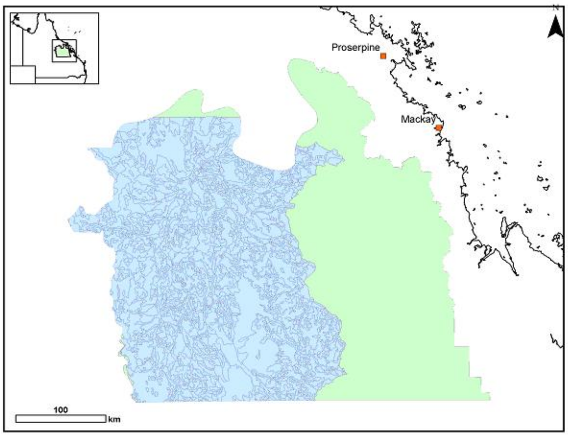
This coverage (Figure 19 left) was digitized by Geoscience Australia from a hardcopy report on the Physiographic Regions of Australia by Jennings and Mabbutt (1986). These regions are very broad outlines that subdivide Australia into distinct physiographic regions.

Jennings and Mabbutt's physiographic regions were refined using a hill shade derivative of Australia's 9 sec DEM as the primary data source. Australia was partitioned into regions that were solely determined by the landscape. Using Jennings and Mabbutt's coverage as a guide, the boundaries were redefined at a 1:700,000 scale (Figure 19 right). This recompiled map of physiographic regions is now being incorporated into a national coverage that will be part of the Australian Soil Resource Information System (ASRIS) (http://www.asris.csiro.au/index_ie.html).

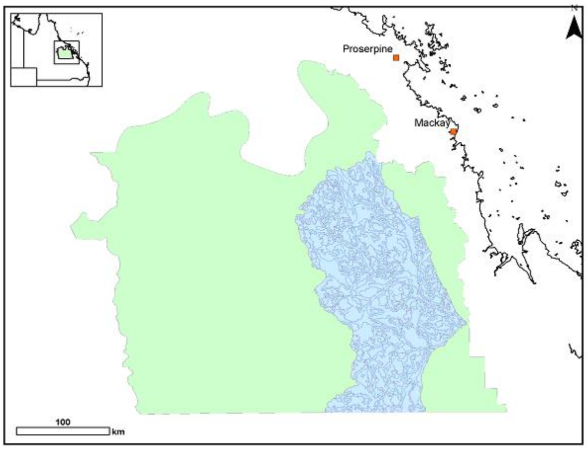
Contact: colin.pain@ga.gov.au

3.5 Land Systems

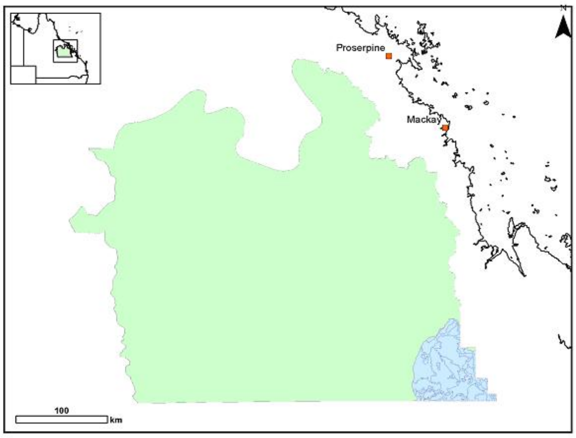
The Department of Natural Resources, with authorization from CSIRO, digitised and rectified the land system maps of the Nogoa-Belyando, Isaac-Comet and Dawson-Fitzroy areas (Figure 20 a, b, and c). It was been mapped at 1:500 000. Accompanying reports are part of the Land Research Series publications by CSIRO.



a



b



c

Figure 20. Land systems. (a) Nogoa-Belyando region. (b) Isaac-Comet Region. (c) Dawson-Fitzroy Region.

Source: NR&M Contact: Stuart.Brothers@nrm.qld.gov.au

Metadata (Nogoa-Belyando) http://www.nrme.qld.gov.au/asdd/qsii2/ANZQL0035000392.html

Metadata (Isaac-Comet) http://www.nrme.qld.gov.au/asdd/qsii2/ANZQL0035000395.html

Metadata (Dawson-Fitzroy) :http://www.nrme.qld.gov.au/asdd/qsii2/ANZQL0035000405.html

3.6 Salinity Hazard Maps

Two salinity hazard maps cover the study area, one for the Burdekin catchment and other for the Fitzroy catchment (Figure 21). These salinity hazard maps were derived from groundwater flow systems, and recharge and discharge maps. They portray areas with a high potential to develop salinity and reduce water quality.

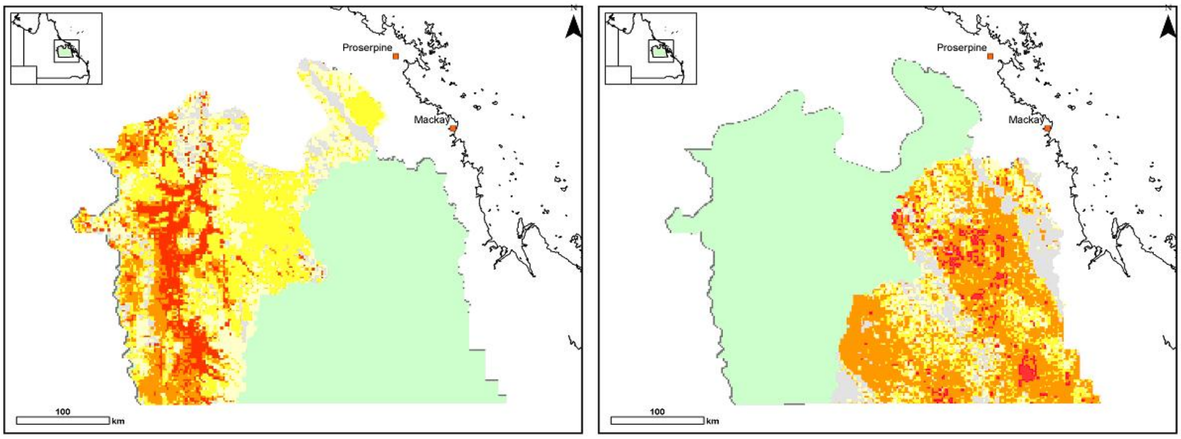


Figure 21. Salinity hazard. (Left) Burdekin catchment. (Right) Fitzroy catchment.

Source Burdekin Map: http://www.nrme.qld.gov.au/salinity/pdf/burdekin_salinity.pdf

Source: http://www.nrme.qld.gov.au/salinity/pdf/fitzroy_map.pdf

Contact: Stuart.Brothers@nrm.qld.gov.au

3.7 Other data

Australia's River Basins 1997

Australia's River Basins 1997 is the result of a joint State, Territory and Commonwealth Government project to create a national spatial database of major hydrological basins (Figure 22). It shows the boundaries of Australia's basins as defined by the Australian Water Resources Management Committee (WRMC).

Australia is divided into drainage divisions that are sub-divided into water regions which are in turn sub-divided into river basins. The map includes the name and number of each of the 245 drainage basins, 77 regions, and 12 divisions.

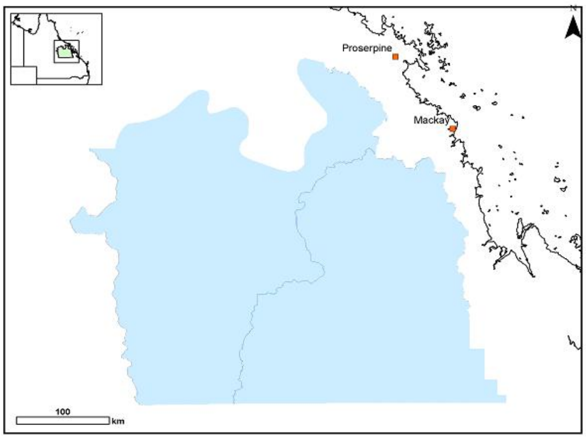


Figure 22. River basins over the Burdekin-Fitzroy study area.

The Australia's River Basins 1997 coverage is free to download form the Geoscience Australia website at: http://www.ga.gov.au/download/nmd_download/#dem

Source: www.ga.gov.au or contact sales@ga.gov.au

Metadata: http://www.ga.gov.au/meta/ANZCW0703005427.html

Sub-Basin Areas - Queensland - QLD_BASINSUBAREA_100K

This polygon coverage is a subdivision of the major drainage basins in Queensland (Figure 23). Its original purpose was to provide location identifiers for the numbering system of bores and gauging stations. All bore numbers were prefixed with a four-digit number. The first three were used to locate the bore within a specific major river basin .The forth digit was used to located the bore into a subdivision of that major river basin as shown in the Sub-Basin Areas - Queensland coverage. This coverage is now used only as a means of numbering bores and gauging stations. Its capture scale is 1:100,000.

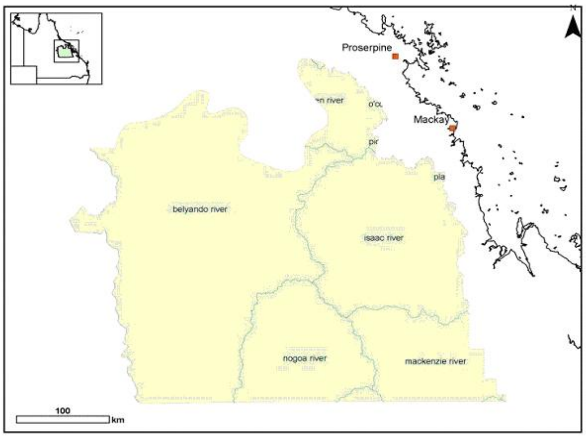


Figure 23. Sub-basin areas over the Burdekin-Fitzroy study area.

Source: Queensland Department of Natural Resources and Mines.

Contact: Stuart.Brothers@nrm.qld.gov.au

GEODATA TOPO 250K Series 2 Topographic Data

This coverage contains a medium scale vector representation of the topography of Australia (Figure 24).

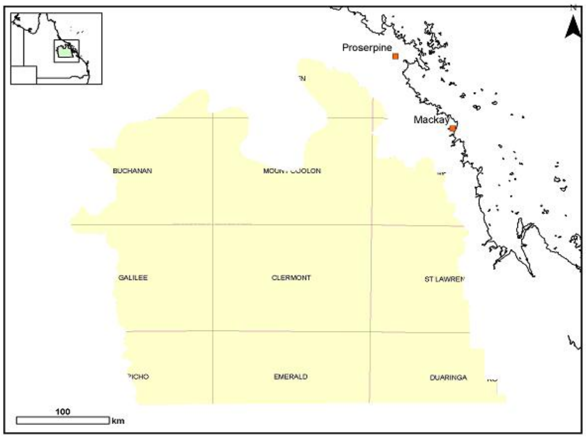


Figure 24. 1:250,000 topographic sheets over the Fitzroy Burdekin study area.

The data include the following themes: Hydrography - drainage networks including watercourses, lakes, wetlands, bores and offshore features; Infrastructure - constructed features to support road, rail and air transportation as well as built-up areas, localities and homesteads. Utilities, pipelines, fences and powerlines are also included; Relief - features depicting the terrain of the earth including 50 metre contours, spot heights, sand dunes, craters and cliffs; Vegetation - depicting forested areas, orchards, mangroves, pine plantations and rainforests; and Reserved Areas - areas reserved for special purposes including nature conservation reserves, aboriginal reserves, prohibited areas and water supply reserves (Figure 24).

These data are free for download from the Geoscience Australia website:
http://www.ga.gov.au/download/nmd_download/#dem

Vegetation - Pre-European Settlement (1788)

This coverage shows a reconstruction of natural vegetation of Australia as it probably would have been in the 1780s. Areas over 30 000 hectares are shown plus small areas of significant vegetation such as rainforest. Attribute information includes growth form of the tallest and lower stratum, foliage cover of tallest stratum and dominant floristic type (Figure 25).

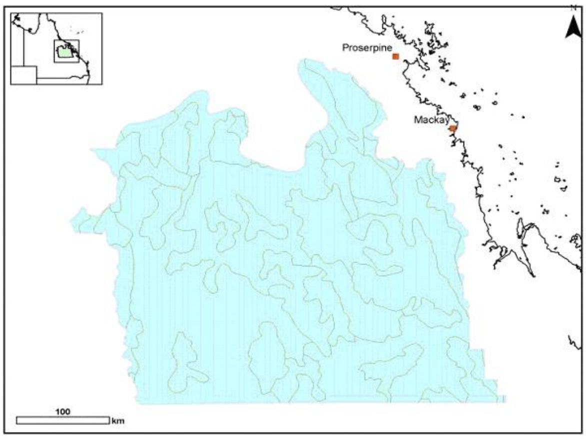


Figure 25. Pre-European settlement (1788) vegetation cover over the Fitzroy-Burdekin study area.

These data are free for download from the Geoscience Australia website:
http://www.ga.gov.au/download/nmd_download/#dem

Metadata: http://www.ga.gov.au/meta/ANZCW0703005425.html

Vegetation - Post-European Settlement (1988)

This coverage shows vegetation of Australia in the mid 1980s. Areas over 30,000 hectares are shown plus small areas of significant vegetation such as rainforest and croplands. Attribute information includes growth form of the tallest and lower stratum, foliage cover of tallest stratum and dominant floristic type (Figure 26).

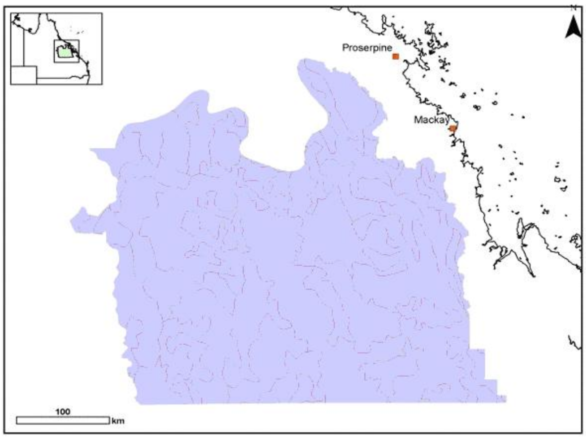


Figure 26. Post-European settlement (1988) vegetation cover over the Fiztroy Burdekin study area.

These data are free for download from the Geoscience Australia website:
http://www.ga.gov.au/download/nmd_download/#dem

Metadata: http://www.ga.gov.au/meta/ANZCW0703005426.html

4. GEOPHYSICAL DATA

4.1 Introduction

Existing geophysical data and related interpretations collected within Lower Burdekin and Upper Fitzroy catchments can provide additional information to be used for NRM applications within the region. The compiled data types includes airborne geophysical survey data, seismic surveys, gravity survey data, digitised interpretations and other GIS related information. As much of the existing geophysical data have been acquired for mineral exploration programs, re-interpretation of some of this information in the context of NRM has the potential to 'value add' to existing interpretations.

The primary aim of this chapter is to identify, collate and reference existing geophysical data relevant for NRM within the Burdekin-Fitzroy study area in order to create a resource (report and GIS) to be used for natural resource and land management decisions. The compiled datasets provide the background to present the identified geophysical data in the context of the physiographic regions classification in Chapter 5. The chapter concludes with a summary of the compiled data, identification of areas of data paucity, and recommendations for future work.

4.2 Data Sources

Geophysical data were obtained from a number of agencies:

Queensland Department of Natural Resources Mines and Energy (NR&M)

Includes airborne geophysical survey data, reports, geophysical interpretations, GIS layers, company reports and database information.

Geoscience Australia (GA)

Airborne geophysical survey data, gravity station data, reports, GIS data and database information.

CSIRO

Interpretations of geophysical data

Fugro Airborne Surveys (FAS)

Airborne geophysical survey data

CRC LEME

Interpretations of geophysical data (CRC LEME reports), publications, background information and interpretations of geophysical data.

AESIS, Australian Mineral Foundation Database

Company exploration reports

4.3 Data Layers in Interactive GIS

All of the geophysical data compiled during for this study has been included in the on-line GIS hosted on the Geoscience Australia website found at: http://www.ga.gov.au/map/burdekin-fitzroy. This section provides an overview of the most important layers.

Airborne Geophysical Surveys

Aeromagnetic data may be provide additional geologic and geomorphic information for NRM interpretations. Analysis of aeromagnetic data relies on the spatial patterns that an interpreter can recognise from processed images such as faults, dykes, lineaments and folds (Brodie, 2002). Geologic boundaries and structures are characterised by their relative change in magnetic contrast. Drill hole logs, geological ,mapping and petrophysical data are required to correctly interpret the data.

The first combined aeromagnetic and airborne gamma-ray spectrometry surveys within the Burdekin-Fitzroy study area were flown at regional scale by BMR at broad line spacings (1 to 3 km) as a part of a national program to acquire a full geophysical coverage of Australia. These surveys are now obsolete as the region has been fully re-surveyed (aeromagnetic and airborne spectrometry) at a line spacing of no greater than 400 m. These most recent geophysical datasets were complied from the Geoscience Australia and NR&M archives for this project. The NR&M sponsored surveys flown prior to 2000 are Ayr-St Lawrence (1996), Anakie (1990), and Drummond - Galilee (1997) (Figure 27). Post year 2000 NR&M sponsored surveys are the North Bowen Basin (2002) and the Central Bowen Basin surveys (2003). These surveys were acquired at 400m line spacing. Attributed information relating to the individual surveys may be obtained by querying the interactive GIS.

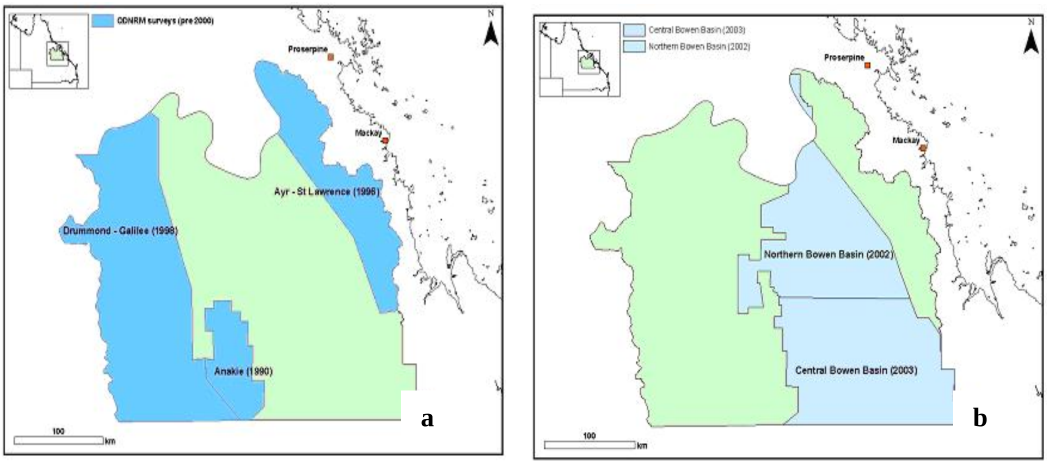


Figure 27. Regional aeromagnetic-radiometric surveys flown by NR&M in the Burdekin-Fitzroy study area. (a) Pre-2000. (b) Post-2000.

The survey data can be obtained from NR&M, contact: David.Searle@nrm.qld.gov.au

Fugro Airborne Surveys (FAS) also contributed two high resolution regional surveys to the project, Clermont and Charters Towers (200 m line spacing) (Figure 28). FAS have released the survey data at a quarter of the original resolution for use in this project. The high resolution survey data may be purchased from FUGRO Airborne Surveys on request: www.fugroairborne.com.au

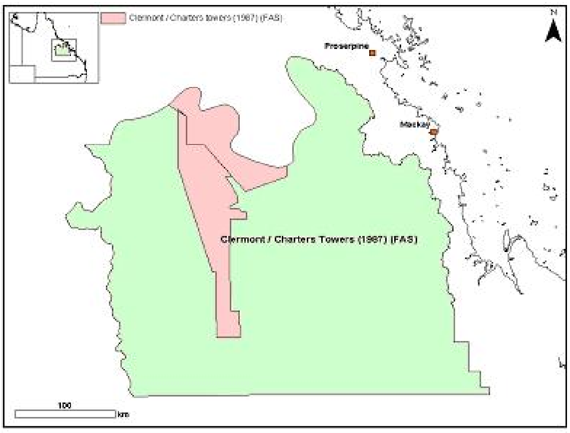


Figure 28. Aeromagnetic and airborne spectrometry surveys flown by FAS in the Burdekin-Fitzroy study area.

A number of small scale aeromagnetic and airborne spectrometry surveys flown by private companies are located within the Burdekin-Fitzroy study area (Figure 29). Most are open file and can be obtained from NR&M on request.

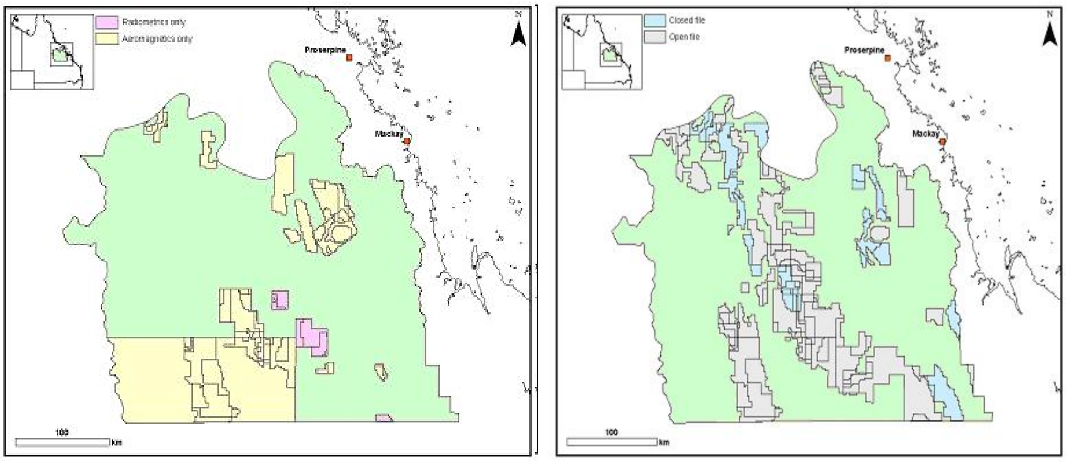


Figure 29. Company aeromagnetic and airborne spectrometry surveys in the Burdekin-Fitzroy study area (a) Non-combined. (b) Combined.

Source NR&M: www.nrm.qld.gov.au or contact David.Searle@nrm.qld.gov.au

Airborne Geophysics - Mosaics

This project concentrated on stitching together the most recent surveys at the best resolutions. This was performed using the GRIDMERGE routine from INTREPID v3.7 software. The result is full seamless aeromagnetic (total magnetic intensity, TMI) and airborne spectrometric (potassium, thorium, uranium) mosaics covering the entire study area at 80m resolution (1 pixel = 80m) (Figure 30). These are available for viewing through the interactive GIS on the Geoscience Australia website.

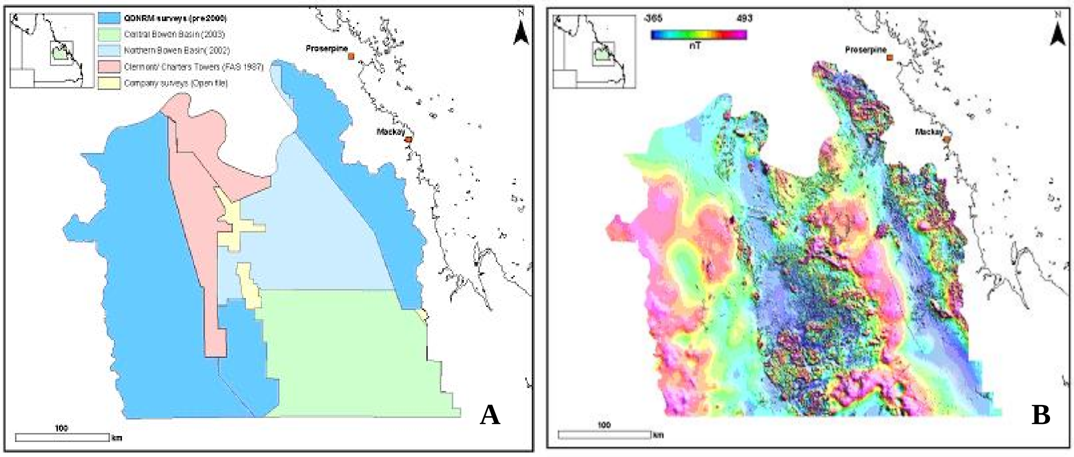


Figure 30. Aeromagnetic mosaic over the Burdekin-Fitzroy Study Area. (A) Surveys used. (B) The mosaic. Total magnetic intensity (reduced to pole), clipped to 99.9% input limits (Histogram equalised pseudo-colour image).

A series of filtered images (1st vertical derivative, 2nd vertical derivative & horizontal gradient) derived from the TMI data have also been produced interpretation purposes and included in the interactive GIS. The emphasis is to isolate the magnetic responses of shallow structures and geology due to their importance in NRM related studies. The 1st vertical derivative in particular enhances near surface features (higher frequencies) at the expense of the deeper ones (lower frequencies). Long-wavelength regional effects are effectively eliminated while and the responses of adjacent anomalies are enhanced (Milligan and Gunn, 1997). This type of filter is very useful in NRM studies as the higher frequency responses are typically associated with shallow geologic sources. Figure 31 gives the 1st vertical derivative aeromagnetics for the Burdekin-Fitzroy Study Area.

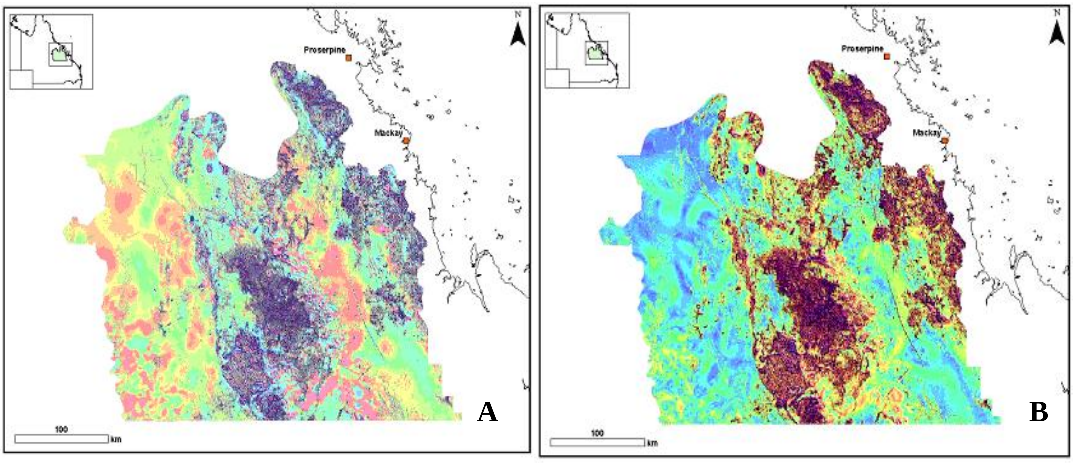


Figure 31. Aeromagnetics for the Burdekin-Fitzroy Study Area (A) 1st vertical derivative (colour) (reduced to the pole). (B) Total horizontal gradient (reduced to the pole)

The total horizontal gradient is an alternative method to filter the aeromagnetic data, and again enhances the high frequency anomalies (shallower sources) at the expense of the longer frequencies (deeper sources). The method is particularly effective for defining the edges of wide magnetic units, but less useful for narrow bodies (Milligan & Gunn, 1997). An overview of the theory and application of vertical and horizontal gradient filters is provided in Milligan and Gunn (1997).

The same surveys used for the aeromagnetic mosaic were used to create airborne spectrometry mosaics of the three gamma ray-bands; potassium, thorium and uranium. The individual surveys were stitched into a single mosaic using the GRIDMERGE routine from INTREPID v3.7 software. Four new spectrometry images have been produced, mosaics for potassium, thorium, uranium and a combination of the three called a ternary image. These mosaics are presented in the following figures: Figure 32 – Potassium, Figure 33 – Thorium, Figure 34 – Uranium, Figure 35 – Ternary image.

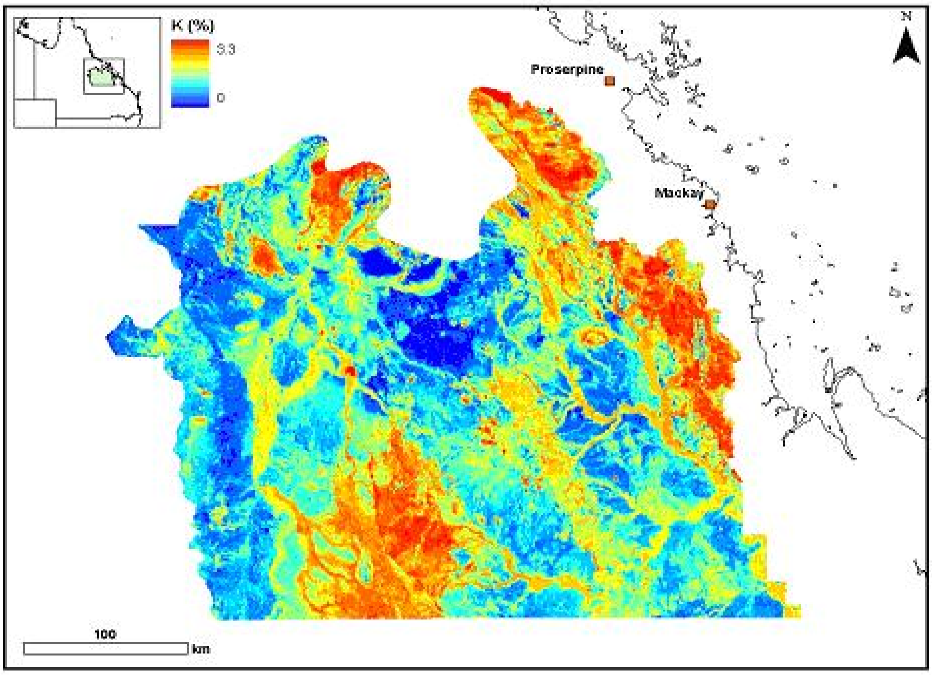


Figure 32. Potassium band airborne spectrometric mosaic for the Burdekin-Fitzroy Study Area (data clipped to 99.9% input limits).

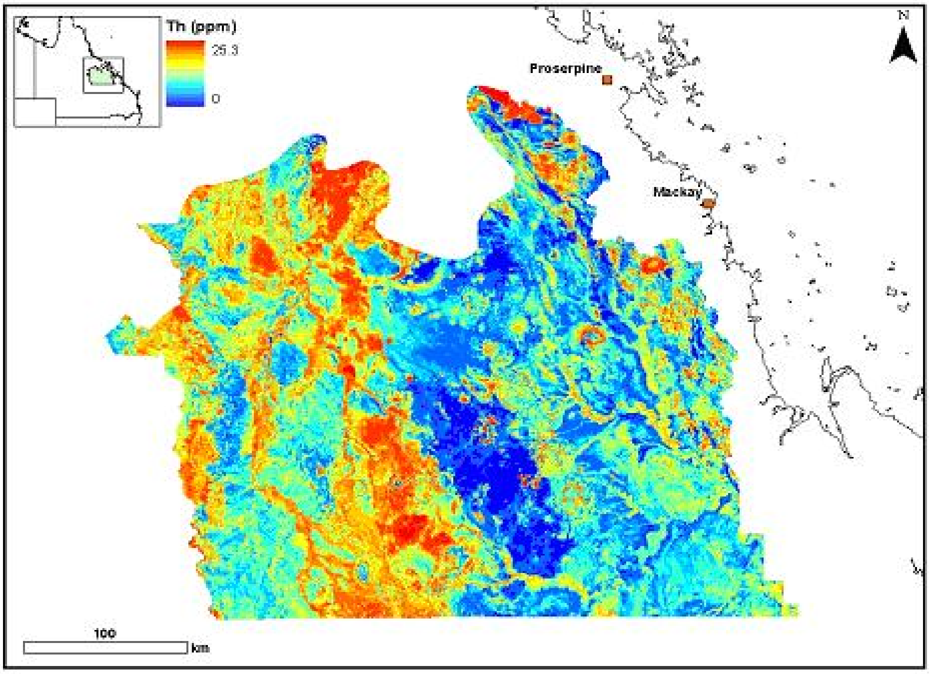


Figure 33. Thorium band airborne spectrometric mosaic for the Burdekin-Fitzroy Study Area (data clipped to 99.9% input limits).

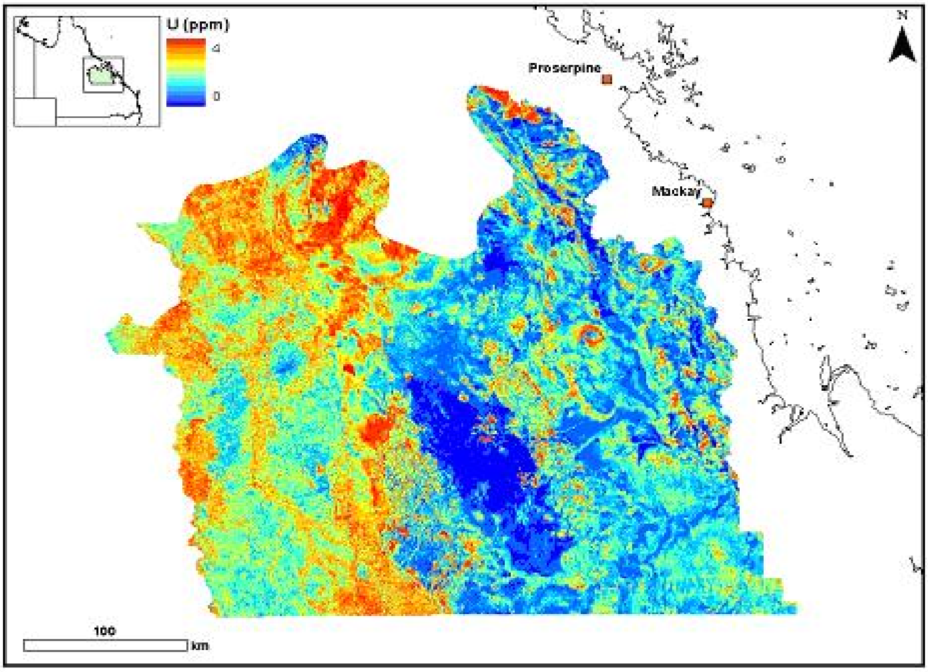


Figure 34. Uranium band airborne spectrometric mosaic for the Burdekin-Fitzroy Study Area (data clipped to 99.9% input limits).

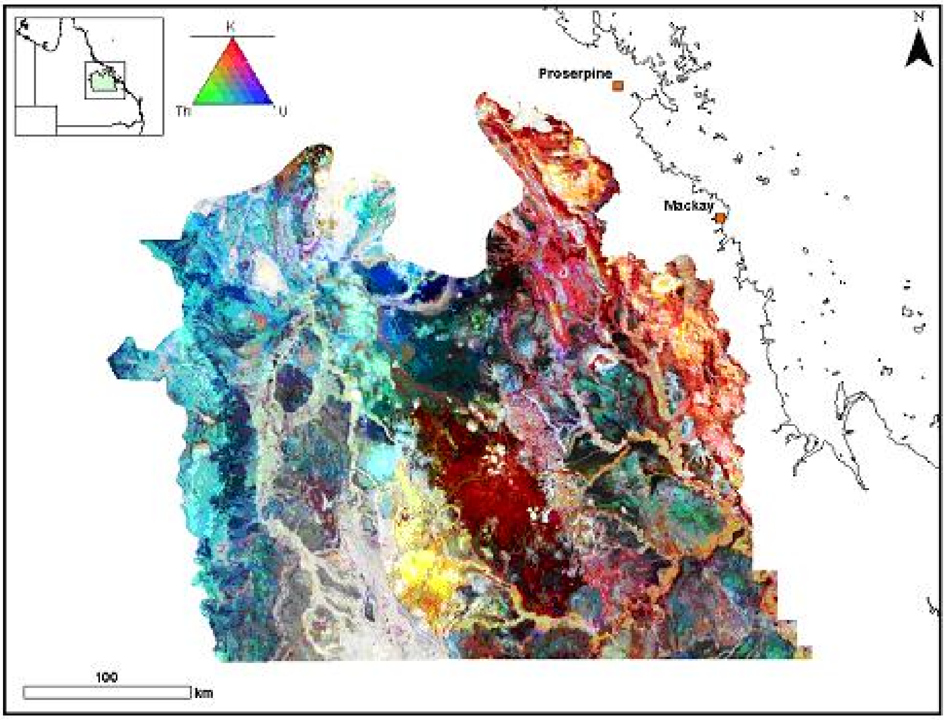


Figure 35. Ternary (K,Th,U) airborne spectrometric mosaic for the Burdekin-Fitzroy Study Area (data clipped to 99.9% input limits).

The airborne spectrometry images are extremely useful for rapidly mapping surface materials such as soils and geological outcrop down to around 30cm. Such images are routinely used for regional geological mapping. The four mosaics are available for use through the interactive GIS. Mapping scales are restricted by the footprint of the system (1 pixel = 80m). Previous mosaics performed by NR&M (unreleased) of the surveys covering the Burdekin-Fitzroy region have produced reasonable results; however the new mosaic shows a significant statistical improvement. Statistics are presented below for each radio-element band (unclipped to histogram limits) comparing the two.

K	NR&M mosaic (-1.2 to 6.5 %)	new mosaic (-0.8 to 4.4 %)
Th	NR&M mosaic (-13.8 to 86.6 ppm)	new mosaic (-1.6 to 44.0 ppm)
U	NR&M mosaic (-9.6 to 12.7 ppm)	new mosaic (-0.93 to 7.0 ppm)

The new airborne mosaics are considered to be of excellent quality, and will be extremely useful for future NRM work, especially if combined with other datasets within the interactive GIS environment. Figure 36 shows an example for the Emerald area where different overlays have been draped over the 25m hill-shade DEM for the region.

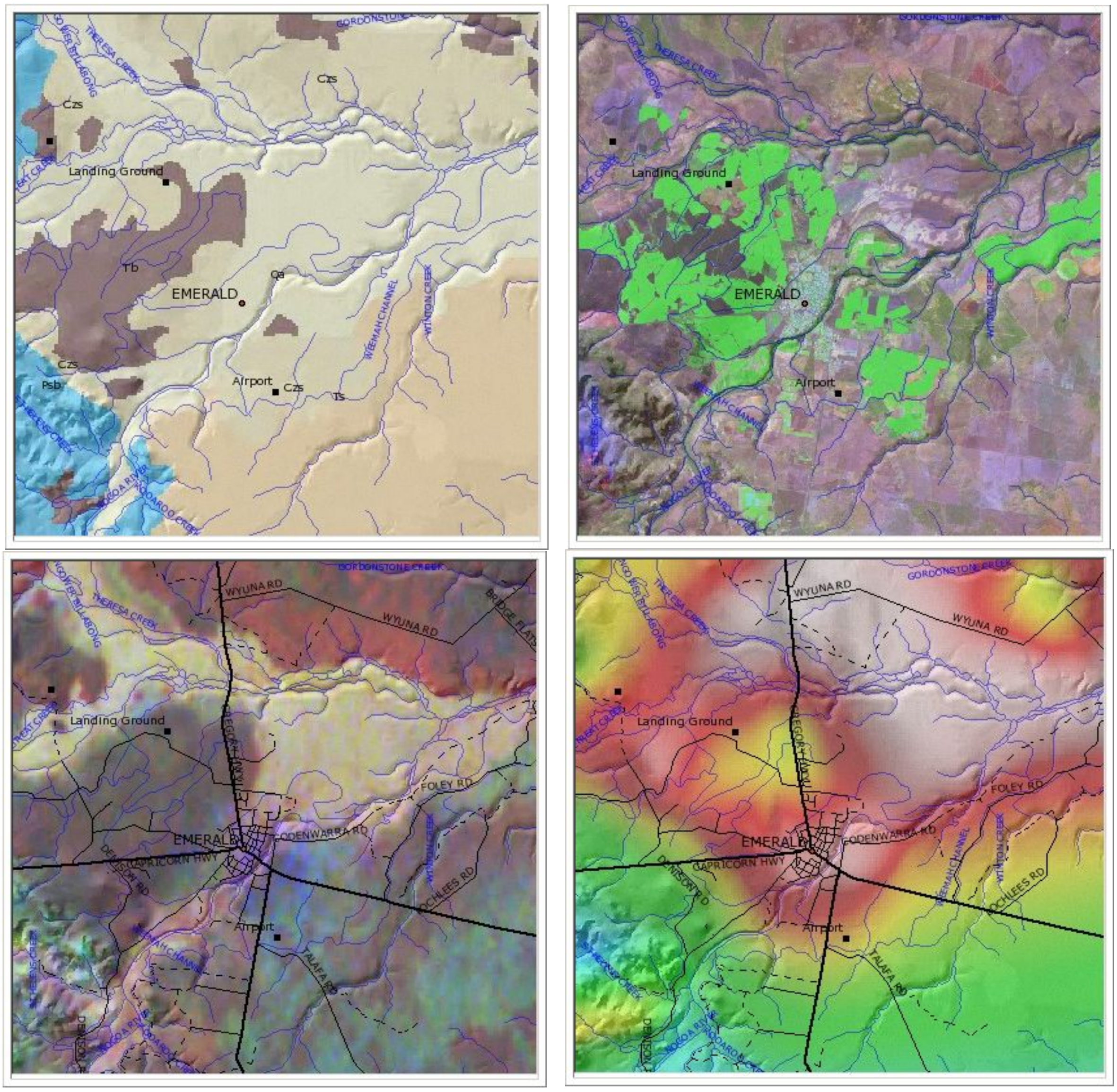


Figure 36. Screen captures from the interactive GIS over the Emerald area. A 25m hillshade DEM is semi-transparent under all of the backdrops and overlays (a) 1:1 million South Qld geology (b) Landsat TM- 741 (c) 3-band Gamma-ray spectrometric ternary image (d) Total magnetic intensity. Hydrology and roads have been overlayed to illustrate the use of the vector overlays. These may be queried using the "info" tool on the menu bar.

Gravity Survey Data

Gravity station data over the Fitzroy-Burdekin catchments is now part of the Geoscience Australia gravity station database, and is a compilation of all known government and company surveys covering the region. This data was grided for the purposes of this project and is available for viewing in the interactive GIS (Figure 37). The location of the 14,909 individual stations is available as an attributed vector overlay within the interactive GIS.

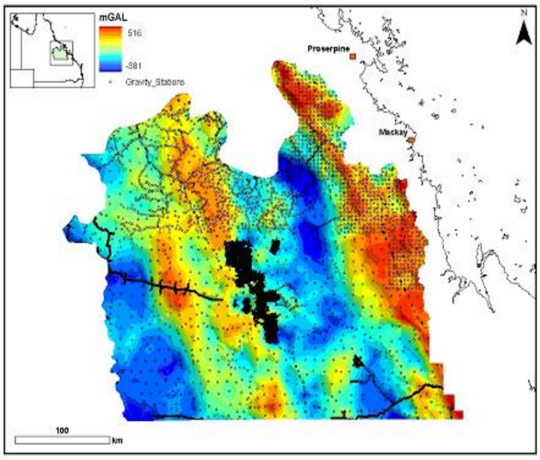


Figure 37. Bouguer gravity anomaly map and gravity station locations in the Burdekin-Fitzroy Study Area.

Seismic Survey Data

Seismic survey data over the region are a combination of Bureau of Mineral Resources (BMR) and open file company survey data. Most of this seismic data has been acquired at regional scale for mineral exploration activities, and is not overly useful for NRM. Seismic lines within the Burdekin-Fitzroy study area are shown in Figure 38, and are available as a vector overlay in the interactive GIS. Details relating to specific survey lines may be obtained by querying the interactive GIS. The BMR seismic sections are available through Geoscience Australia while the company sections are available through NR&M in *.TIFF (image) and other formats by request. The quality of some of the scanned sections is in some cases is quite poor due to their age.

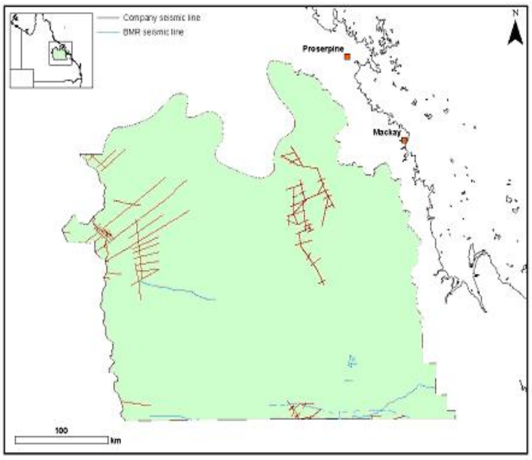


Figure 38. Seismic line locations within the Burdekin-Fitzroy Study Area.

Source NR&M www.nrm.qld.gov.au or contact John.Draper@nrm.qld.gov.au

Digital data

All of the digital data collected during this project has been incorporated within the interactive GIS hosted at the GA website: http://www.ga.gov.au/map/burdekin-fitzroy

NR&M also host a significant amount of digital information through an on-line GIS that includes petroleum and mineral exploration data, geophysical data, geological data, drilling information, topographic and cadastre information. The NR&M interactive resource and tenure maps can be found on-line at: http://www.webgis.nrm.qld.gov.au/webgis/webqmin/Run.htm

Reports

There is a large number of published and unpublished company exploration reports related to acquisition, processing and interpretation of geophysical information, which has been compiled into a bibliographic index accessible online. The link is on the GIS page.

Digital copies of many of the referenced reports are available through the QDEX interactive database, hosted on the NR&M website: https://extranet.nrm.qld.gov.au/qeri/controller/Home

Only a fraction of the full resource were reviewed during this study due to time constraints, difficulty of obtaining information and the large number of reports to query. For future projects, these company reports should be carefully reviewed to determine if any additional geophysical information can be obtained and re-interpreted in the area(s) of interest. Of the 35,000 company exploration reports covering the whole of Queensland, only 20% have been digitised.

Using the interactive GIS

The compiled geophysical data has been integrated into the online GIS that is available for use through the Geoscience Australia website at: http://www.ga.gov.au/map/burdekin-fitzroy . Once the application is started, the map window defaults to the extents of the Fitzroy-Burdekin study region with the 25m hill-shade DEM overlay. Most of the geophysical data layers (raster images) are accessed from the “Backdrops” menu bar which will expand when selected displaying the range of options. Layers may be toggled on/off using the check boxes, however only one backdrop can be turned on at a time. The “Update/Refresh Map” button must then be used to display the new selections. Some of the geophysical data are attributed vector layers (e.g. gravity station locations, airborne survey boundaries, and seismic line data), and can be selected under from the “Available Overlays” menu under “Geophysics”. This menu will further expand to show the range of options that may be toggled on or off using the check boxes. Unlike backdrops, any number of vector layers can be displayed simultaneously. These layers may be queried using the “info” tool, and the attributes relating to the feature will be displayed in a pop-up window. Note that some vector layers will only display at small map scales in order to reduce excessive screen clutter. If a particular vector layer does not appear to display, try further zooming in on the area of interest. A summary of the main features of the interactive GIS is provided below (Figure 39).

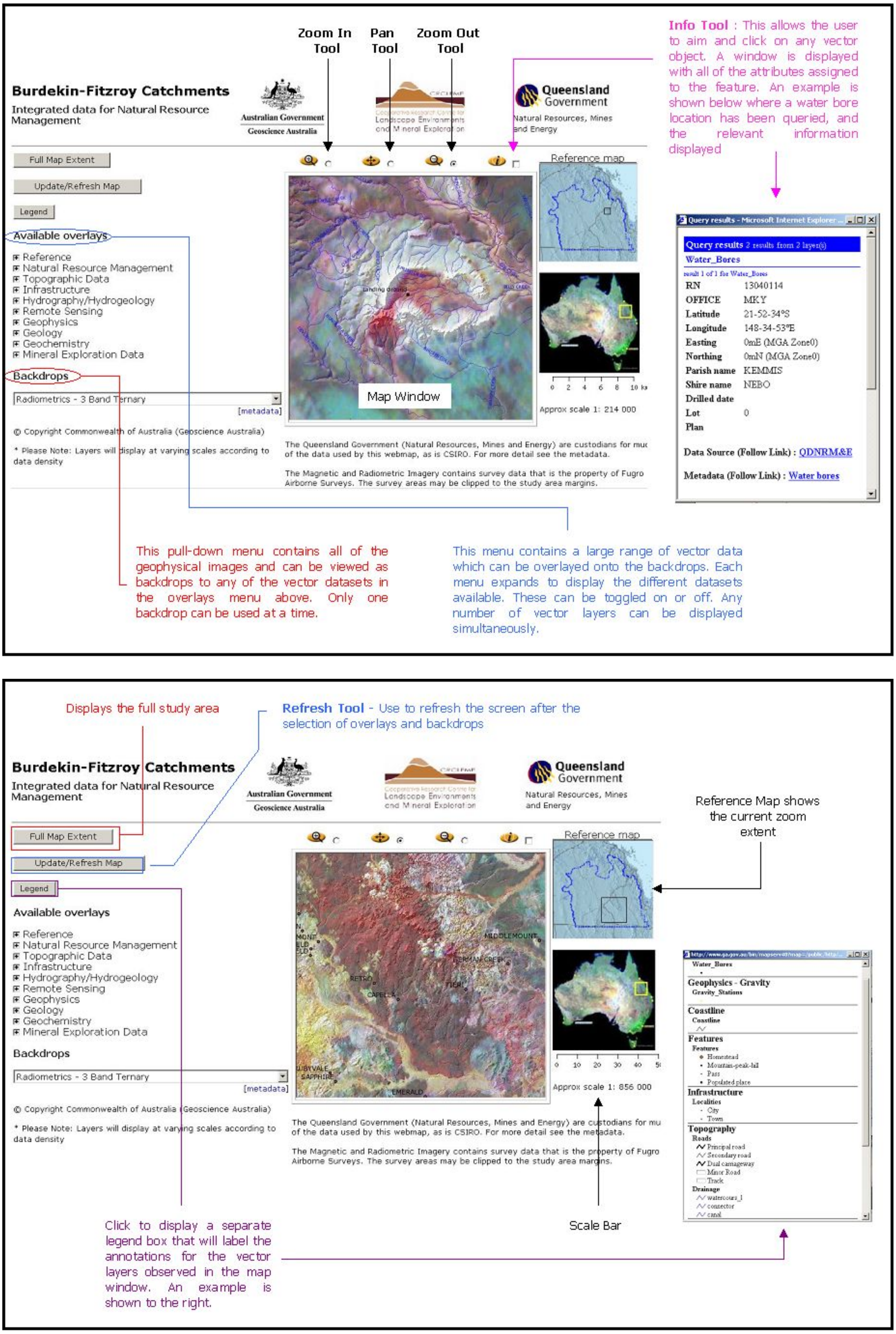


Figure 39. Screen captures from the interactive GIS application. Captions and arrows explain some of the features important to the user.

Something to note when using the GIS is the 25m hill-shade DEM overlay. This layer is unique being the only raster dataset available through the "Available Overlays" menu. This implementation has been used to allow the user to use the DEM simultaneously with other raster layers (backdrops). The DEM layer itself is partially transparent to facilitate this. Although the DEM itself may be turned off, it is recommended that this layer remain active when using the backdrops for the best visual effects. The DEM may also be viewed in colour by selecting the "Backdrops" menu then the "Topography/25m DEM colour" selection. Alternatively, any raster other backdrop can be selected.

Metadata is available for all of the geophysical data included in the interactive GIS. This information may be viewed by selecting the "Metadata" button found near the bottom left hand corner of the Map Window. A new window will appear displaying with metadata for all of the layers in the GIS (Figure 40). Links are provided under the subheadings to the relevant data custodians and their respective web-pages. Metadata for the vector "overlays" can also be viewed by selecting the links under the pull down menus (highlighted blue next to the check-boxes). Selecting a link will again open the metadata window, but the user will be taken directly to the relevant section without scrolling through the text.

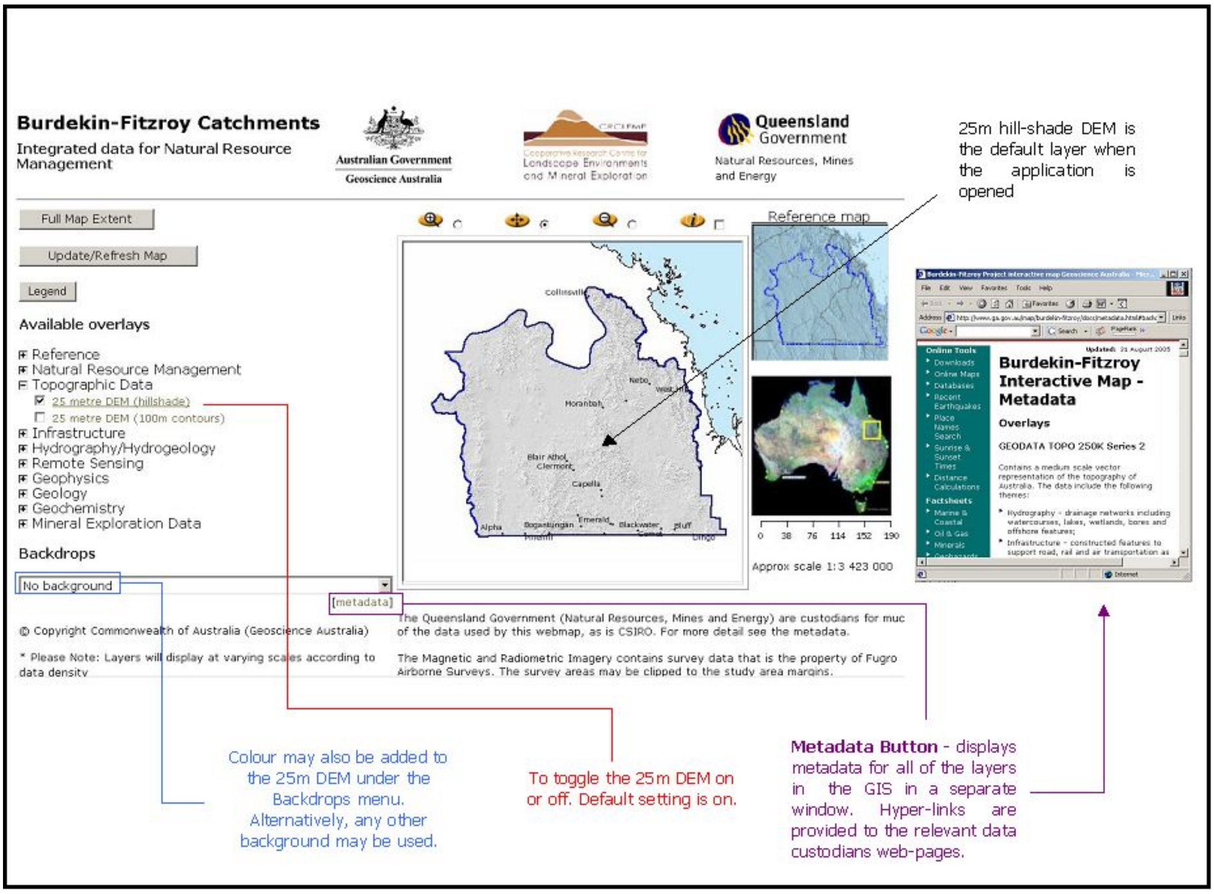


Figure 40. Screen capture from the interactive GIS application. Captions and arrows explain some of the features important to the user.

4.4 Geophysical Overview – Fitzroy/Burdekin Study Area

Geophysical surveys within the Burdekin-Fitzroy catchments have generally been performed for mineral exploration and regional geological mapping. Aeromagnetic data were initially acquired by BMR as a part of the national program to create a magnetic map of Australia. These surveys were eventually superseded by higher resolution airborne geophysical surveys flown by the Geological Survey of Queensland and private companies. These surveys included high resolution airborne spectrometry. Complete aeromagnetic and airborne spectrometry coverage at 400m line spacing now exists over both catchments.

The discovery of extensive coal deposits along with numerous gold discoveries within the Bowen and Drummond Basins saw a substantial increase in prospect scale geophysical acquisition programs including high resolution aeromagnetic and airborne spectrometry surveys. These programs were accompanied by a large number of extensive deep seismic surveys to prove up significant coal deposits within the region. High resolution gravity surveys were also performed mainly within the Bowen Basin as a part of these exploration initiatives. As a result there is a large amount of geophysical data available within the study area, some of which is useful for NRM related investigations.

High resolution aeromagnetic and airborne spectrometric data can be used as a regional mapping tool to validate geologic features, extend known features and suggest new possibilities in the Fitzroy-Burdekin catchments. Airborne magnetics is particularly useful to map geologic features where they crop out and also undercover. These features include lava flows, igneous intrusions, faults, and some crystalline basement rocks. Aeromagnetics is however not overly effective for differentiating between different facies within the sedimentary basins due to their relative low magnetic contrast. The gravity data are useful for mapping regional scale features such as basement rocks, structures, and large intrusions.

Basement

Crystalline-metamorphic basement within the study area comprises the Anakie Inlier, Ravenswood Arch, and the Connors Arch Complex. The presence and extents of these units have been largely interpreted from regional geophysical data. The structural relationships between these units are generally complex, and obscured by thick Palaeozoic sedimentary basins (up to 6000m thick) over much of the study area.

The Anakie Inlier forms the oldest metamorphic basement in the study area (Day *et al.*, 1983), and is composed of a north trending block of early to mid-Palaeozoic rocks surrounded by the younger strata of the Drummond and Bowen Basins (Day, *et al.*, 1983) (Figure 41). The unit comprises the Pre-Devonian Anakie Metamorphics (quartz-mica schists, phyllite, slate, limestone and volcanics), Mid-Devonian volcanics and sediments and Upper-Devonian intrusive granite (Fraser, 1997). The Anakie Inlier outcrops to the west of the Central Bowen Basin, however its extension under the Drummond and Bowen Basins is unknown.

The Connors Arch intrusive complex underlies the Bowen Basin and consists of Carboniferous intrusives that are sharply truncated by the margins of the Bowen Basin. The unit outcrops to the east and west of the North Bowen Basin.

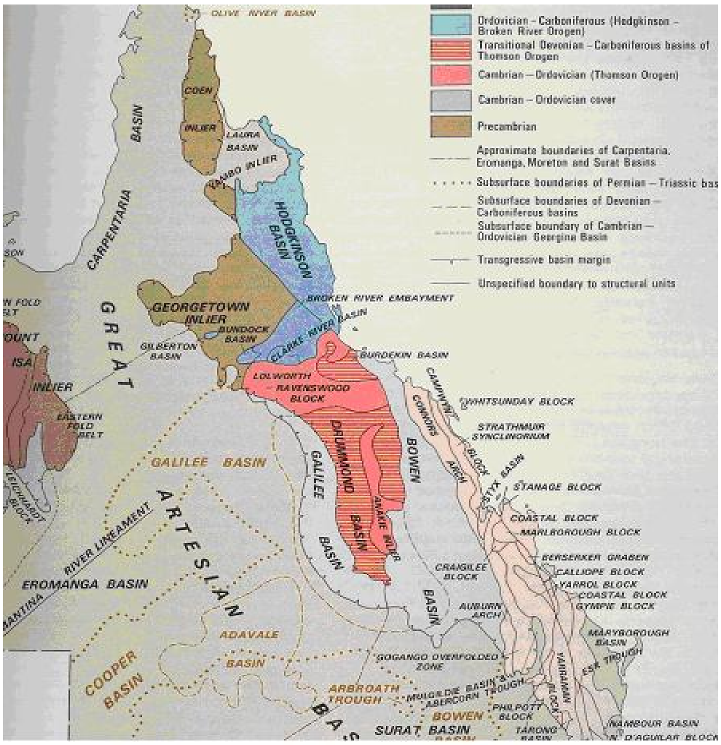


Figure 41. Structural framework over the Fitzroy-Burdekin catchments (Day *et al.* 1983).

Sedimentary Basins

Three large Palaeozoic basins (Bowen Basin, Drummond Basin and Galilee Basin) cover a significant amount of basement within the study area. The Drummond Basin (Figure 42) is the oldest and comprises Late Devonian to Early Carboniferous sediments deposited mainly to the west but also to the east of the Anakie Inlier over basement of early to mid-Palaeozoic metamorphic rocks and granite (Day *et al.* 1983). The basin consists of medium to thick bedded ignimbrites, rhyolitic and dacitic tuffs, sandstones, siltstones and shales (Hutton *et al.*, 1991). The rocks of the Anakie Inlier and Ravenswood Arch are basement to the Drummond Basin, which in turn is overlain by the Bulgonunna Volcanics and the Galilee Basin (Fraser, 1997). The Drummond Basin sediments have generally low magnetic susceptibilities and form a distinctive margin with the older Anakie Inlier. This margin in the southern part of the basin is characterised by a sharp transition in the aeromagnetics from relatively smoothly varying gradients (associated with the basin) to the anomalous responses of the granites of the Anakie Inlier. Broad, long wavelength responses observed in the TMI data are sourced from the underlying deep basement rocks while inter-sedimentary magnetic features are interpreted as folding of the weakly magnetic Drummond Basin sediments (Draper, 1999). Numerous intrusions, dyke complexes and basaltic flows are also interpreted from the aeromagnetic data. These dykes and sills were still being emplaced well into the Tertiary within the Drummond Basin (Olgers, 1969).

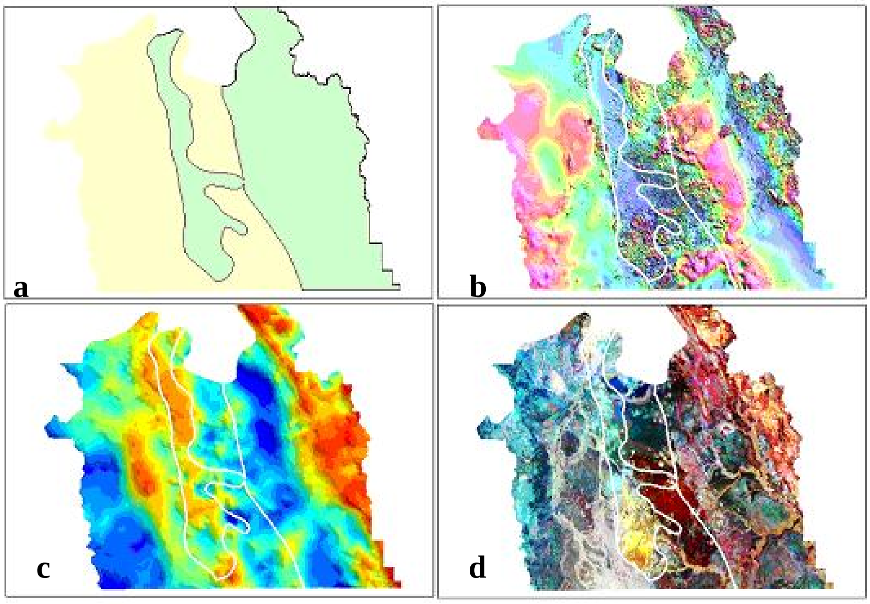


Figure 42. Drummond Basin (a) Basin extents shaded in yellow. (b) Total magnetic intensity, RTP (c) Bouguer gravity (d) Three band ternary airborne spectrometry.

The Bowen Basin is a large region of Permian and Triassic deposition of which the northern half is exposed (Day *et al.*, 1983). The basin covers a substantial part of the study area and contains sediments of generally low magnetic susceptibility. The Basin Bowen which has been subjected to detailed airborne geophysical, seismic and gravity surveys (Figure 43) to define coal bearing strata and sediments hosting gold mineralisation. The Bowen Basin is extensively intruded and also hosts extensive, highly magnetic Tertiary basaltic flows and sills which mask the much of the response from the deeper underlying geology. The NW-NNW orientation of the shallower structures (dykes and faults) and intrusives observed in the TMI data indicate a strong regional structural fabric. The basin is extensively covered with weakly magnetic regolith. Suites of Cretaceous and Tertiary intrusives are also easily interpreted from the aeromagnetic data (Malone, 1970). Broad long wavelength TMI anomalies are observed along the centre of the basin, and may be sourced from a deep structure sourced within or below the sedimentary sequence.

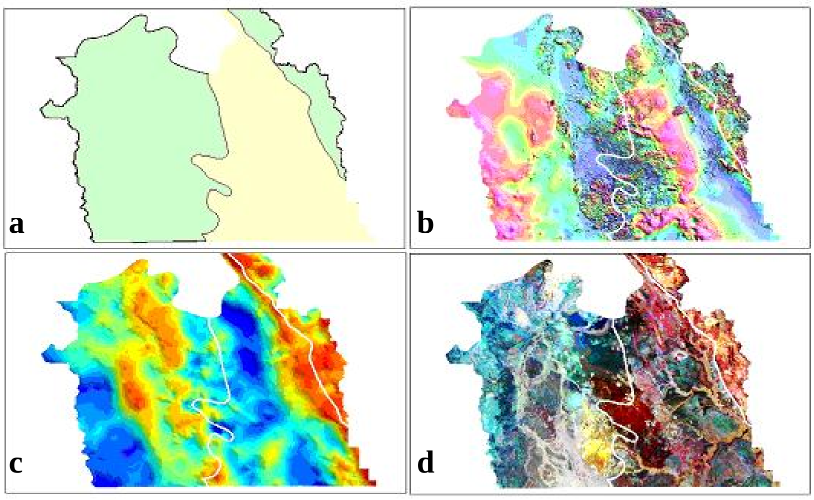


Figure 43. Bowen Basin (a) Basin extent shaded yellow (b) Total magnetic intensity, RTP (c) Bouguer gravity (d) Three band ternary airborne spectrometry.

Galilee Basin sediments overly those of the Drummond Basin, and are found in the western part of study area (Figure 44). The Galilee Basin formed as a large but shallow intracratonic basin during the Late Carboniferous, and received dominantly fluviatile sediments until the Middle Triassic (Day *et al.*, 1983). There is very little outcrop with the majority of the area covered by Cainozoic cover. Most of the interpretation of the structure of this basin has come from geophysical and drilling information. These sediments generally have weak magnetic susceptibilities, and the basin is characterised by north easterly and north westerly magnetic trends that reflect basement lineaments (Hawkins, 1982). The Galilee basin is characterised by relatively flat magnetic gradients in the aeromagnetic data.

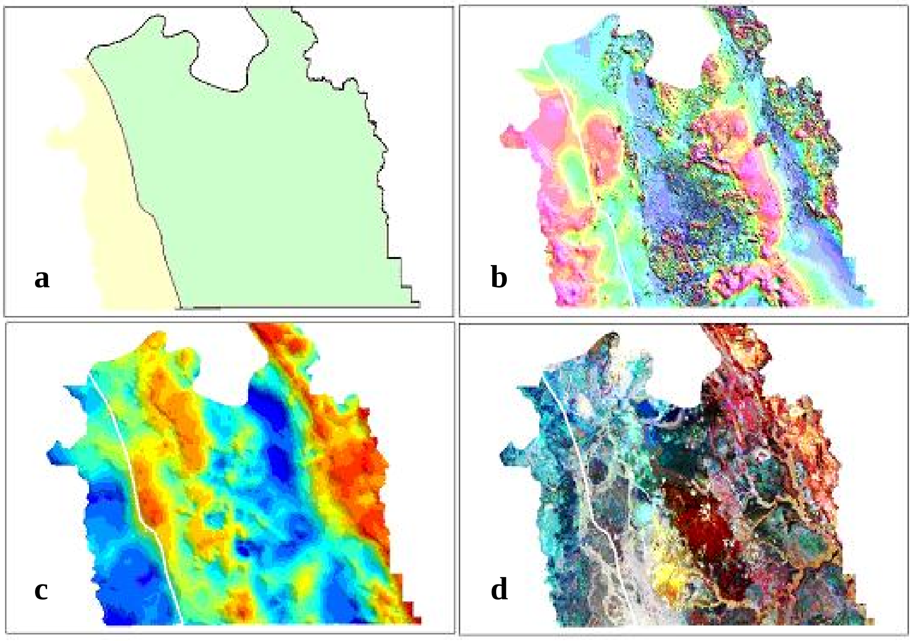


Figure 44. Galilee Basin (a) Basin extent shaded yellow (b) Total magnetic intensity, RTP (c) Bouguer gravity (d) Three band ternary airborne spectrometry.

Intrusions

Magnetic dykes have been extensively mapped throughout the study area from the aeromagnetic data. Dykes often pervade and infill structural weaknesses such as faults and fractures, particularly in the Bowen Basin where dyke swarms occupy tension fractures associated with major thrusts (Clare, 1985). The intensity and polarity of magnetisation varies from weak to strong and positive to negative respectively. The polarity reversals probably reflect emplacement over or between periods of magnetic pole reversals. Dykes and sills down to 0.1m thickness have been routinely mapped in the Bowen Basin where the Tertiary cover is thin using ground magnetic methods (Stanley, 1985). Dykes down to 1m thickness may be mapped beneath up to about 50m of Tertiary alluvium depending upon their magnetic susceptibility (Stanley, 1985).

Tertiary Volcanics

Tertiary basalts dominate the central and eastern zones of the study area, and are visible as high frequency aeromagnetic responses in the total magnetic intensity, 1st vertical derivative and horizontal gradient images, and are readily mapped based on textural differences, even under regolith cover (Figure 45). Flows are generally shallow and extensive, but sometimes thin out in areas back to sedimentary rock, observed as areas of flat magnetic character. Flows are readily distinguishable in the ternary airborne spectrometric data where they crop out. The fresher basaltic material is lighter in colour (higher K) than the weathered material which is significantly darker. High K responses often correlate with intrusive plugs or former volcanic centres for the basaltic eruptions (Figure 46). The increase observed in the K responses closer to eruption points may also reflect the thinning of the *in situ* basaltic regolith. Similar relationships have been noted in the Plio-Pleistocene basalts and regolith in western Victoria by Bennetts *et al.* (2003). Greatest basalt thicknesses may also be associated with the eruption centres. Magnetic response of basalts undercover will vary according to composition, depth of burial composition of overlying sediments, weathering and alteration (Stanley, 1985).

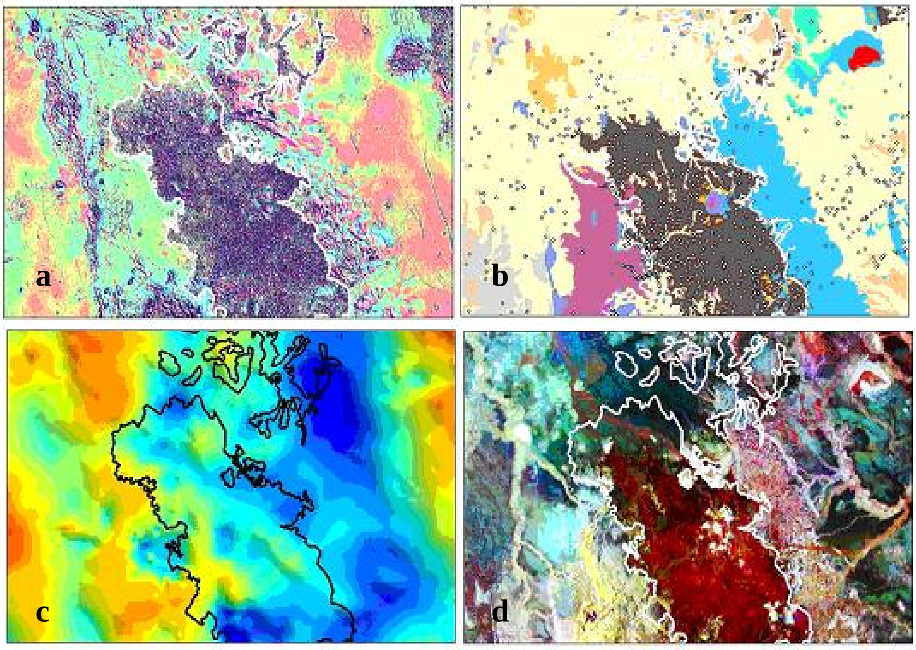


Figure 45. Tertiary basaltic flows within the Northern Bowen Basin. (a) 1st vertical derivative TMI (b) South Qld 1:1 million scale surface geology (c) Bouguer gravity. (d) 3 band ternary airborne spectrometry. Annotation are interpreted basalt margins (approximate).

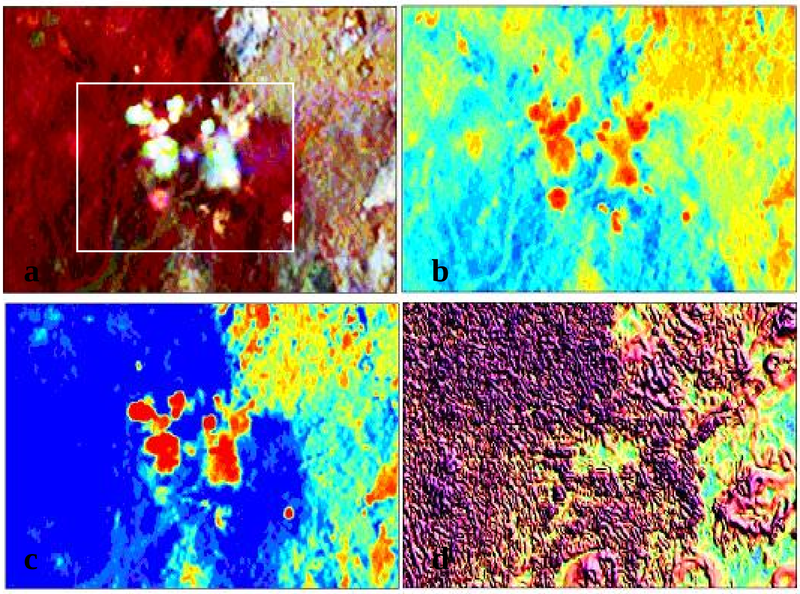


Figure 46. Intermediate composition intrusive plugs of the Peak Range Volcanics within Tertiary basalts, Central Bowen Basin. (a) 3-band ternary airborne spectrometry (b) Potassium band airborne spectrometry (c) Thorium band airborne spectrometry (d) Horizontal gradient of TMI.

Palaeochannels

There is very little palaeochannel mapping in the study area, and they not easily distinguished from the geophysical data, except in the Bowen Basin where Tertiary basalts have in-filled a former drainage system that was active in the early Tertiary (Figure 47).These flows show a characteristic dendritic structure suggesting former drainage patterns controlled the movement. Some of these palaeochannels and valleys may be up to 100m thick (Shu, 2002). Palaeochannels in other parts of the study area are do not appear to have a significant magnetic expression.

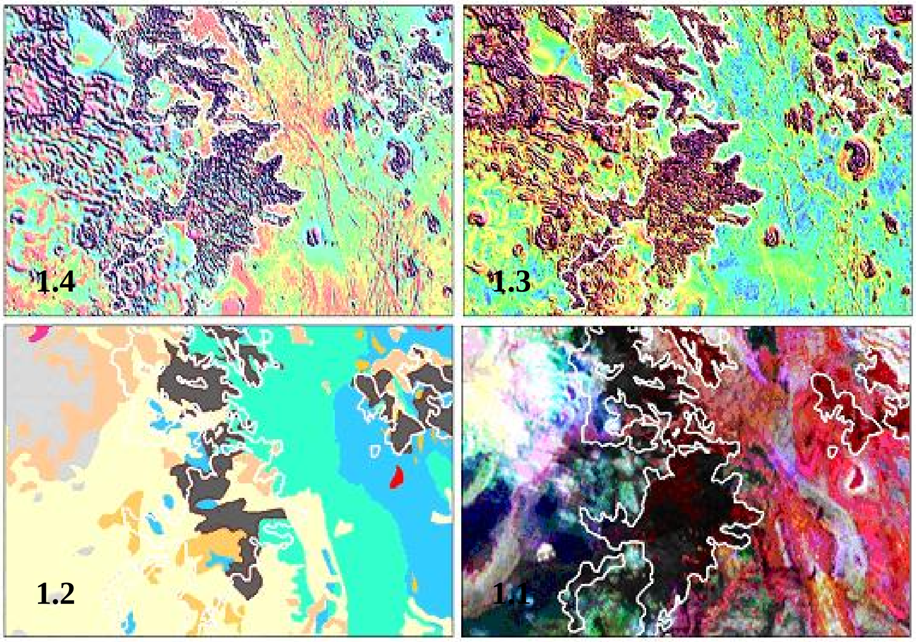


Figure 47. Tertiary basalt flows infilling a former Tertiary drainage system in the Bowen Basin. (a) 1st vertical derivative (b) horizontal gradient of TMI (c) South Qld 1:1 Million Geology (d) 3-band ternary airborne spectrometry. Interpreted extent of Tertiary basaltic flows (white annotation). Annotation provided by NR&M and CSIRO.

Regolith

The architecture and types of the regolith covering the study area are poorly understood. The main units in the northern areas are the Suttor and Southern Cross Formations, outcropping as flat-lying caps on mesa and upland areas (Fraser, 1997). Their 2D distribution is essentially well mapped, but the 3D architecture and thickness is relatively unknown except where bore holes intersect bedrock. Shu's (2002) study of landscape evolution around Clermont confirms that the bedrock at the base of the Tertiary was well incised and eroded before the onset of volcanism and subsequent sedimentation. Little is known of the bedrock architecture of the Galilee and Drummond basins. Shu (2002) suggests the bedrock of the Anakie Inlier and Drummond Basins are deeply weathered. Regolith over the Bowen Basin can be thicker than 100m.

The contribution that geophysical data can make to the understanding of regolith architecture and landscape evolution is worthy of future work over the region. Shu (2002) investigated the landscape evolution of the Mt Coolon area in the Bowen Basin and noted that many of the Tertiary basalts in the region had in-filled a drainage system operating during the early Tertiary. These flows filled a Tertiary drainage system of old river channels controlled heavily by regional structure. This implies that further investigation into the Tertiary volcanics could provide insights into the landscape evolution of other parts of the study area. Similar relationships were noted by Banks (1985) in his study of the Tertiary basalts around Gregory in the Central Bowen Basin. Banks (1985) noted discrete, valley fill deposits were extruded onto a dissected Permian topography. The distribution of these units may be a means of mapping former drainage systems that were active at the onset of early Tertiary volcanism. These drainage patterns may be preferential flow paths for groundwater and have implications for GFS and salinity mapping.

4.5 Analysis of Radiometric Data

Rationale

Spectrometers detect the abundance of potassium (K) thorium (Th) and uranium (U) that naturally occur at the Earth's surface through the measurement of the isotopic decay of daughter products of these elements. Potassium abundances are most often expressed as a percentage of total K present while uranium and thorium abundances tend to be represented in parts per million (ppm). Most of the measured radioisotopes are from the top 30 cm of the Earth's surface (Pickup and Marks, 2000), and hence are ideal for surficial mapping of the regolith and soils.

Radiometric data are most often represented as 3-band Ternary Images, which represent the relative amounts of K, Th and U as and RGB colour image (Figure 48). The radioelement concentrations differ depending on rock type and the degree of weathering.

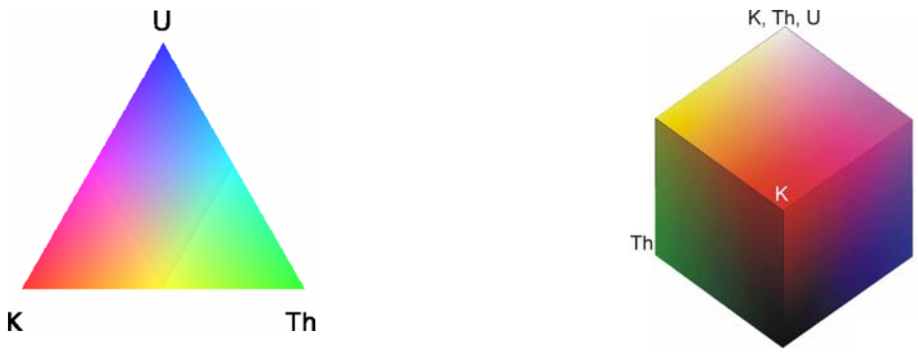


Figure 48: Radiometrics ternary colour triangle and cube indicating which colours correspond to which element. K = red, Th = green, U = blue. NB: these concentrations are relative, not absolute. Black indicates low to no concentrations of any of the elements and white indicates a presence of all three elements.

Natural Resource Management Applications

In the past, airborne radiometric surveys were predominantly used in mineral exploration. Radiometric data are becoming increasingly popular in environmental studies due to its ability to see through most vegetative cover and measure the soil geochemistry. Some environmental applications include: soils mapping on North Queensland (Wilson and Philip, 1999), for identifying large-scale erosional and depositional processes (Pickup and Marks, 2000), and the identification of salt stores for salinity research (Wilford *et al.,* 2001).

Using radiometrics can further enhance the regolith interpretation of an area as it can add information relating to the mineralogy, degree of weathering and the landscape setting of the regolith. As previously described, radiometric interpretations are invaluable for the understanding of areas of little to no relief such as riverine plains and sand plains. It can help to break the landscape into present and palaeo-landscapes which can be difficult to map when there are no topographic relationships on which to base interpretations. When the weathering processes and how this effects the distribution of radioelements are understood, the gamma-ray imagery is an effective dataset in the mapping of these palaeo-landscapes. In these areas soil and regolith types can vary due to stratigraphic and weathering relationships due to alluvial and sedimentary processes that will not be identified through traditional soil mapping (Bierwirth, 1996). These areas will have very different textural and chemical properties so are important to differentiate for identification of localised groundwater flow system. These are particularly important when investigating the potential for salinity hazards.

Statistical analysis

In order to characterise the radiometric signatures into groups of low, moderate or high values, the each band was classified in into 3 classes using the Jenks Natural Breaks procedure in ArcGIS (Table 2). This classification system forms the basis of the radiometric interpretation presented in the Physiographic Regions chapter.

Table 2: Low, moderate and high class levels of radioelements based on Jenks Natural Breaks classification

	low	**moderate**	**high**
K (%)	-0.94-0.59	0.60-1.59	1.59-5.61
Th (ppm)	-4.58-5.93	5.94-11.36	11.36-82.20
U (ppm)	-2.64-1.10	1.11-1.86	1.87-13.58

Statistics were calculated for the radiometric signatures of specific geological units in ER-Mapper (Table 3). The geological coverage used was the 1:1M Southeast Queensland Surface Geology compiled by Geoscience Australia (2003).

The following bedrock and radioelement trends were recognised in the data:

- regolith materials - low in K andU and had moderate concentrations of Th,
- felsic rocks - high K, and U and moderate Th
- intermediate rocks - moderate K, U and variable Th
- mafic rocks – moderate-high K, moderate Th and low-moderate U.
- sedimentary rocks - moderate K, Th and U

By using the geological coverage for calculating the statistics, a degree of error has been incorporated in the statistics. This was due to the geological unit boundaries being slightly out, and the rock units having varying degrees of weathering. To better refine the values; 1) the geological polygons need to be better registered, or more detailed geological coverage needs to be used, and 2) variation between fresh bedrock and that with a degree of soil profile development needs to be identified as a study by (Dickson, *et al.*, 1996) shows that radioelement concentrations vary significantly between fresh rock and the soil developed on this same rock unit.

Table 3: Summary of radioelement concentrations for the stitched radiometrics coverage in the Burdekin-Fitzroy region. The data are presented as mean, standard deviation and range.

Broad Group	**Sub-unit**	**Variable**	**Statistics**
Regolith	Alluvium	K (%)	0.69±0.52, -0.95-4.78
		Th (ppm)	7.26±2.94, -3.81-37.48
		U (ppm)	1.54±0.50, -0.72-6.36
	Sand plain	K (%)	0.23±0.29, -0.77-4.01
		Th (ppm)	5.89±2.10, -1.43–41.10
		U (ppm)	1.44±0.39, -0.79-6.89
	Tertiary sediments, undivided	K (%)	0.31±0.48, -0.32-3.84

		Th (ppm)	6.34±2.55, -0.65-39.62
		U (ppm)	1.49±0.49, -0.57-8.39
	Ferruginous duricrust	K (%)	0.32±0.34, -0.34-3.30
		Th (ppm)	8.02±2.33, 0.21 – 44.21
		U (ppm)	1.87±0.42, 0.08-6.05
	Lake deposits	K (%)	0.29±0.30, -0.24-1.21
		Th (ppm)	3.32±2.31, -0.47-8.74
		U (ppm)	1.13±0.40, 2.06-1.13
Felsic	Felsic intrusive	K (%)	1.92±0.79—0.94-5.23
		Th (ppm)	10.36±5.37, -2.51-44.93
		U (ppm)	1.98±0.77, -0.41-13.58
	Felsic intrusive, intermediate intrusive	K (%)	1.65±0.58, -0.03-4.16
		Th (ppm)	10.50±4.78, 1.38-43.01
		U (ppm)	1.27±0.61, -2.64-6.74
	Felsic extrusive	K (%)	1.78±0.80, -0.42-5.61
		Th (ppm)	11.76±4.68, -1.31-45.51
		U (ppm)	2.03±0.72, -0.79-8.05
	Felsic extrusive, clastic sediment	K (%)	0.88±0.74, -0.37-3.95
		Th (ppm)	8.16±3.08, -1.71-24.73
		U (ppm)	1.75±0.59, -0.84-4.75
	Felsic extrusive, intermediate extrusive	K (%)	1.27±-0.80, -0.24-3.57
		Th (ppm)	7.06±4.26, -1.29-17.92
		U (ppm)	1.27±0.83, -0.75-3.48
Intermediate	Intermediate extrusive	K (%)	1.28±0.63, 0.10-3.23
		Th (ppm)	8.15±1.97, 1.60-14.45
		U (ppm)	1.45±0.56, -0.18-3.82
	Intermediate extrusive, clastic sediments	K (%)	0.56±0.45, -0.25-3.17
		Th (ppm)	3.48±1.93, -0.68-17.70
		U (ppm)	0.85±0.34, -0.41-3.06
	Intermediate extrusive, felsic extrusive	K (%)	1.83±0.70, -0.1-4.69
		Th (ppm)	12.86±4.55, 1.46-35.94
		U (ppm)	2.38±0.73, 0.56-6.08
	Intermediate extrusive, volcaniclastic	K (%)	1.28±0.59, -0.43-3.62
		Th (ppm)	8.12±3.00, 23.20-22.11
		U (ppm)	1.29±0.50, 0.21-3.36
	Intermediate intrusive	K (%)	0.98±0.65, -0.01-4.19
		Th (ppm)	7.12±5.83, 0.32-58.46

		U (ppm)	1.36±0.90, -0.15-8.14
	Intermediate intrusive, felsic intrusive	K (%)	1.24±0.68, -0.95-4.79
		Th (ppm)	6.5±3.26, -4.42-41.25
		U (ppm)	1.21±0.47, -0.10-7.52
	Intermediate intrusive, volcaniclastic	K (%)	1.10±0.65, -0.18-3.35
		Th (ppm)	6.07±3.26, -0.40-19.39
		U (ppm)	1.37±0.62, -0.01-3.93
Mafic	Mafic extrusive	K (%)	0.43±0.36, -0.17-4.79
		Th (ppm)	3.58±2.13, -0.21-67.59
		U (ppm)	0.89±0.54, -0.67-8.70
	Mafic extrusive, felsic extrusive	K (%)	1.66±0.39, 0.51-2.77
		Th (ppm)	6.56±2.28, -0.29-17.22
		U (ppm)	1.27±0.45, -0.04-3.30
	Mafic extrusive, mafic intrusive	K (%)	1.66±0.39, 0.51-2.77
		Th (ppm)	9.43±2.36, 4.72-16.29
		U (ppm)	1.32±0.46, 0.13-2.75
	Mafic intrusive	K (%)	0.82±0.58, -0.03-2.40
		Th (ppm)	6.25±2.7, 1.99-13.49
		U (ppm)	0.97±0.27, 0.48-1.68
	Mafic intrusive, felsic intrusive	K (%)	1.71±0.44, 0.12-3.09
		Th (ppm)	9.72±3.19, 2.56-24.99
		U (ppm)	1.76±0.57,0.41-3.72
	Mafic intrusive, intermediate intrusive	K (%)	0.85±0.73, -0.20-3.36
		Th (ppm)	7.17±4.47, -0.99-20.33
		U (ppm)	1.22±0.82, -0.51,3.57
	Ultramafite, metasediment	K (%)	0.73±0.44, -0.19-1.84
		Th (ppm)	8.07±3.46, 1.19-16.87
		U (ppm)	1.46±0.83, -0.66-3.15
Sedimentary	Clastic sediment	K (%)	0.63±0.49, -0.92-4.78
		Th (ppm)	7.05±2.48, -1.56-82.20
		U (ppm)	1.59±0.47, -1.07-13.07
	Clastic sediment, metasediment	K (%)	1.17±0.55, -0.17-3.81
		Th (ppm)	5.70±3.03, 1.43-22.68
		U (ppm)	2.09±0.57, 0.02-5.92
	Clastic sediment, mafic extrusive	K (%)	0.94±0.45, 0.01-2.55
		Th (ppm)	5.70±3.03, 1.43-22.68
		U (ppm)	1.08±0.61, -0.21-2.99
	Chemical sediment	K (%)	0.72±0.14, 0.25-1.05
		Th (ppm)	5.62±0.45, 4.47-6.65

		U (ppm)	1.74±0.23, 1.23-2.46
Other	Volcaniclastic	K (%) Th (ppm) U (ppm)	0.42±0.27, 0.02-1.29 4.61±1.78, -0.11-9.91 1.04±0.30, 0.22-2.03
	Volcaniclastic, clastic sediment	K (%) Th (ppm) U (ppm)	1.17±0.63, -0.85-4.79 6.16±2.59, -3.93-28.05 1.25±0.45, -0.38-6.94
	Water	K (%) Th (ppm) U (ppm)	0.12±-0.26, -0.94-3.01 0.28±1.30, -4.58-16.67 0.24±0.28, -0.79-2.72

Emerald subset

In order to understand the geomorphic environments in the Burdekin-Fitzroy study area, a smaller region was selected and a subset of the radiometric image was assessed (Figure 49). The region coincides with the recently acquired Central Bowen Basin geophysical survey. It incorporates a range of radiometric signatures and variety of landscapes. It also covers varying geology including basalt, sedimentary sequences alluvial landforms and quaternary sand plains (Figure 50).

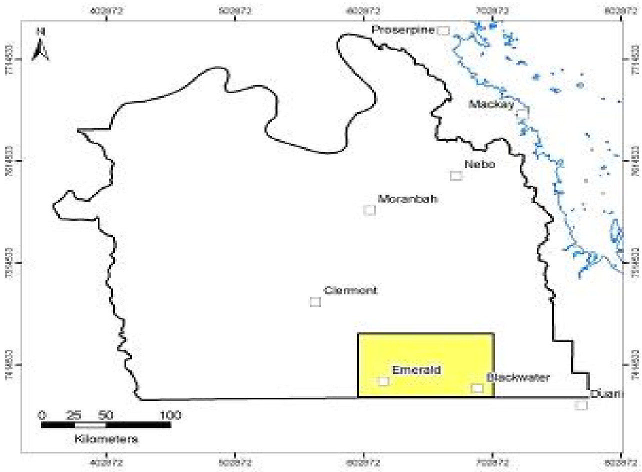


Figure 49: Location of the Emerald subset study area.

More detailed assessment of the radiometrics is outlined in the Physiographic Regions chapter. In this section, each region is characterised by its radiometric signature.

On a broad-scale the boundary between erosional and depositional landscapes was calculated to be at 1.2 degrees. This may not be true on a local scale where erosional scarps, steeply dipping alluvial fans or steep river banks are present. The following descriptions have been divided into categories based in whether they are related to an erosional or depositional regime.

Erosional Areas

Gamma ray responses in the area in erosional areas broadly reflect the bedrock below (Gibson and Wilford, 2002). Where erosion is reduced and weathering profiles are thicker, the radiometrics will not directly relate to the bedrock geology and will appear more subdued as K is lost from the weathered material.

The Tertiary basalts in the north-west are low in K, eU and eTh. Where the soil cover is thin, the basalt is brighter red in appearance (Figure 50 and Figure 51). This coincides with erosional gullies in the basalt and where there has been bank erosion near the river. As the basalt becomes more weathered and the clayey soil cover is thicker, the appearance dulls to a red-brown or black-brown. The concentration of the radioelements becomes very low where a soil profile has developed. (Dickson *et al.*, 1996) postulates that retention of U and Th within iron oxides of weathering profiles in central-eastern Queensland is particularly important over mafic rocks. Although difficult to confirm without field validation, eU and eTh associated with weathered Tertiary mafic rocks appear to have low eU and eTh which is contrary to this study.

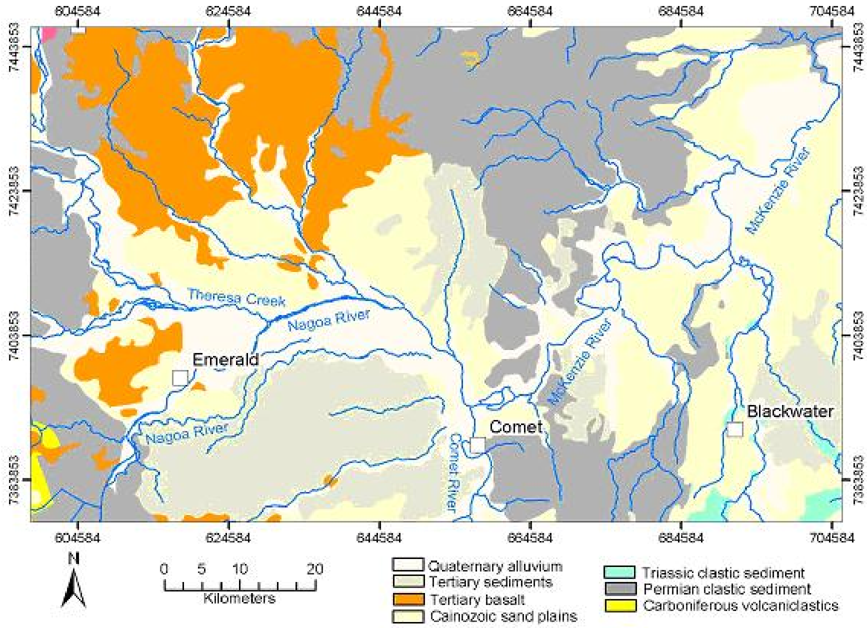


Figure 50: 1:1 000 000 geology for the Emerald sub area.

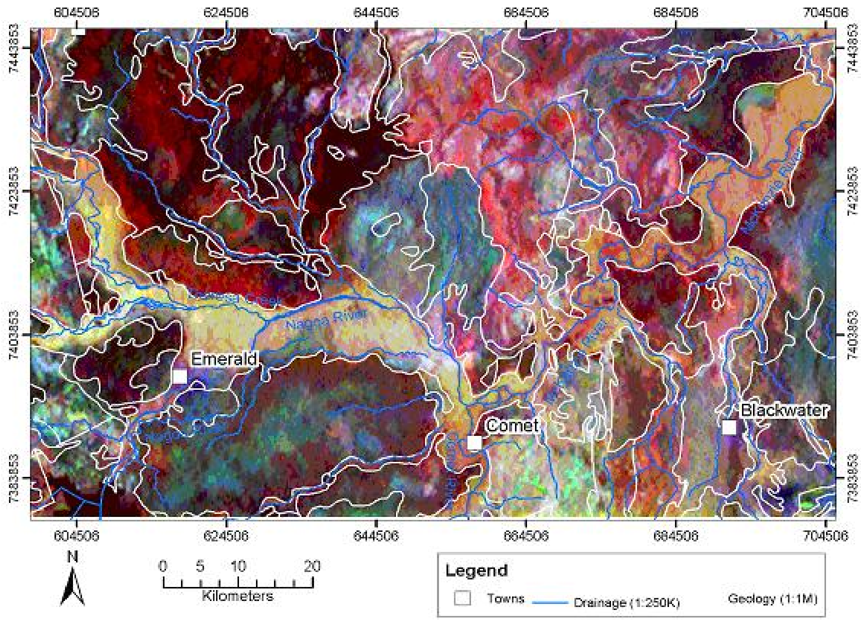


Figure 51. Radiometrics of the Emerald sub area.

The clastic sediments including sandstones and siltstones in the eastern portion of the subset have low - moderate in K, TH and U due to their relatively high silica content. The concentrations vary due to the varying nature of the sedimentary units. The quartzose sandstones would be lower in radioelement concentrations while the lithic sandstones, siltstones and mudstones are likely to have moderate concentrations. Dickson and Scott (1997) found that soil over Archaean shale does not affect the radioelement concentration. If assumed for the sedimentary units in this study, the radioelement concentrations closely reflect the concentrations in the fresh rock.

If the Ternary radiometric and surficial geology maps are compared, the Tertiary sands mapped southeast of Emerald are potentially mismapped. Without field validation, it is difficult to be sure, but the low K and higher Th could be the result of localised iron cemented sands on an extension of the Tertiary basalt.

Depositional areas

In areas of deposition the radiometric signature is not directly related to the bedrock materials below, rather it reflects the sediment source of the regolith materials and the degree of in-situ weathering (Pickup and Marks 2000).

Within a fluvial system, changing radiometric response within the sediments can reflect the texture of the sediments (Gibson and Wilford 2002). Alluvial sediments derived from different source rocks will invariably have a different geochemical, mineralogical and textural signature. Alluvial sediment in the west of the subset area are sourced from the granitic terrain and has greater amounts K-feldspar and mica in the channel, hence the K response is higher here than in the east. Apart from indicating a source high in K, higher K is also an indication that it is an active alluvial system (Wilson and Philip, 1999). As the channels become more distal to the granitic source rocks, the channels lose this characteristic signature. This is caused by the addition of sediments from mafic intrusives and the loss of radioelements during the weathering processes. Oxbows are evidence of channel switching on the McKenzie River. These oxbows and related overbank deposits contain higher amounts of finer materials like clays and silt and being older, these overbank sediments are low in K, Th and U.

Sand plains appear black to green in colour due to a high quartz content which results in low K and moderate eTh and eU. These sands have been weathered and leached of most of their K and may be remnants of prior landscapes (Cook *et al.,* 1996). Zircons and other residual heavy minerals may provide a source of eTh and eU (Pickup and Marks, 2000). Another source is pisoliths and clays as iron oxides are effective scavenges of eTh and eU (Pickup and Marks, 2000; Cook *et al.*, 1996).

Unsupervised Classification

An isoclass unsupervised classification was conducted on a subset of the ternary radiometrics image (Figure 49) to determine whether there were any patterns evident between radiometrics signatures and the surficial geology. A subset region was chosen as the whole study area was geologically quite variable resulting in a classification where no broad scale patterns were apparent. The unsupervised classification was conducted ER-Mapper with 12 classes defined for the classification and these broadly relate to geology (Figure 52).

The Permian aged sedimentary units cover the most classification classes. This stands to reason as they are internally quite labile and vary from clean sandstones to siltstones and carbonaceous shale units.

The character of the alluvial channel and flood plains changes from east to west as its sediment source and radiometric signature changes. Although this was already recognised in the assessment of the Ternary radiometric image, the classified image provides a graphical portrayal of this phenomenon. In the east the alluvial sediment is derived from felsic intrusives. The character of the sediments changes where the where the Nogoa and Comet River form the McKenzie River as sediments derived from mafic courses enter the system. This is clearly seen in Figure 52 as the flood plain goes from being green and cyan to blue and cyan. The channel itself is also more distinct after these rivers meet which may be more of a reflection of changes in channel morphology than a geochemical difference.

It is interesting to note that the Tertiary basalts and the oxbows on the McKenzie River have similar radiometrics signatures. This may be simply coincidence, or could be a reflection of similarities in texture of the fine textured cracking clays on the basalts and the fine textured clays in the oxbow.

Although a crude method of classifying the radiometrics, the unsupervised classification, was a useful graphical tool that differentiated between the various sources of sediment within a riverine system.

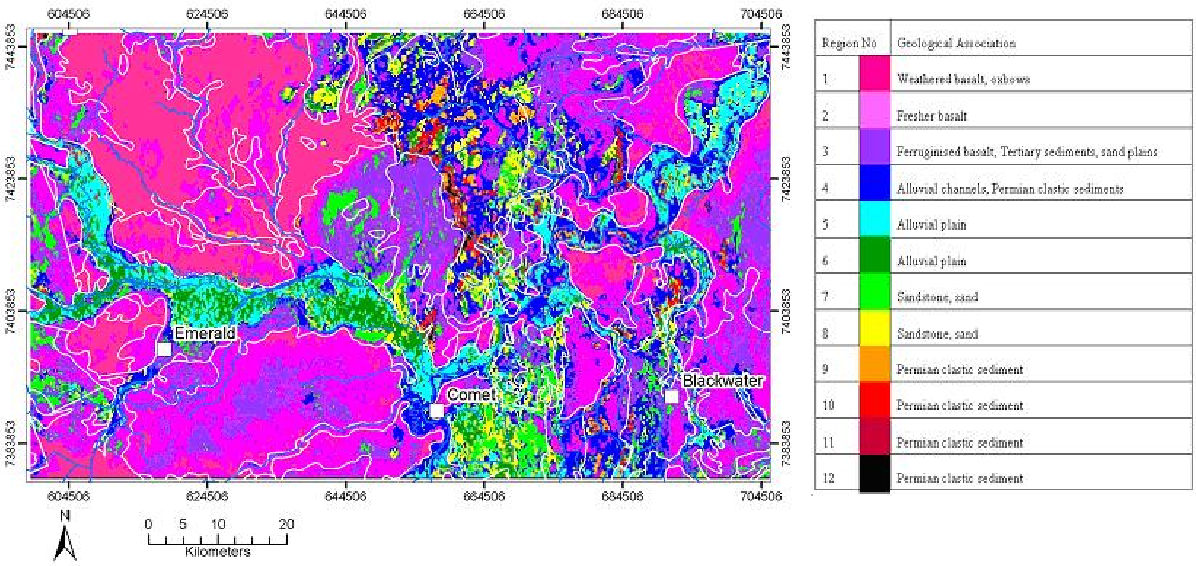


Figure 52. Unsupervised classification of Ternary radiometric image with 12 classes.

4.6 Physiographic regions and geophysics

There is some correlation between the physiographic region classification and the airborne spectrometric data, but generally the surface geology and landforms do not correlate with the aeromagnetic responses. The interpretation is that the present surface geology in many areas does not resemble the underlying geology. The aeromagnetics conform closely to the previously interpreted structural elements of the region. These responses suggest that the deeper basement structures that dominate the response are relatively different to that at the surface.

4.7 Gap Analysis

The geophysical data within the study area has been complied to create a resource for land management decisions. Due to the scale of the Burdekin-Fitzroy study area, and the enormous amount of information to collate and re-interpret in an NRM context, effective identification of data gaps should consider applying the methodology to smaller scale demonstration areas where information can be adequately identified, assessed, integrated with other datasets and re-interpreted. Lessons learned from the smaller demonstration areas could then be extrapolated into other areas. The problem attempting to identify data gaps at the scale of the study area is how these data gaps are quantified. What is considered data paucity at farm scale may not be at catchment scale, and vice versa. Future analyses of this type need to specifically address scale of investigation, and what are the specific NRM issues. Future "gap analysis" type of investigations should consider these underlying questions during the scoping phase and then direct the investigation to answer the issues at the appropriate scale.

The Burdekin-Fitzroy region is characterised by a range of magnetic responses related to geologic features of which some are of interest to NRM, some not. Aeromagnetic data within the study region is useful for mapping geological structure and lithology that were otherwise hidden undercover and not identified from the other data sources. Although, the aeromagnetics may provide useful information for NRM, the presence of a significant basaltic overburden diminished the effectiveness of the method for resolving shallow structure and underlying geology over some of the region.

Airborne spectrometry was shown to be most useful for mapping outcropping geological units, soils and re-transported materials. Airborne spectrometry data can be overlayed onto derivatives of the aeromagnetics (i.e. 1st vertical derivative) to test for correlations between the shallow magnetic responses and the surface materials. Predictions of the sub-surface distribution of mapped geology from observed surface spectrometric attributes cannot be reliably performed due to the considerable differences between the modern drainage and the depositional regimes operating during the Cainozoic.

Future geophysical acquisition should be focused on mapping the 3D architecture of the regolith materials. Airborne electro-magnetics (AEM) would be the preferred method and would provide useful information on regolith thickness and architecture by mapping the conductivity variability within these units. The method would also be useful for mapping saline groundwater or clays where they are present, and could be used to identify potential salt stores in the landscape. Appropriate forward modelling of available geophysical data and an examination of all other priori information would be considered essential before the planning of any such survey. This approach would determine the type of system to be used and the general survey specifications. An examination of rock petrophysics (if obtainable) should also be considered to appropriately calibrate and constrain geophysical models. The choice of system needs to be carefully considered. Frequency domain AEM systems may be encounter problems in the basalt dominated areas. Time domain AEM systems such as TEMPEST is may be less susceptible to effects of this overburden. TEMPEST in particular is probably the most suited to the regolith dominated areas, but consideration of other commercially available time domain systems such as SKYTEM and HOISTEM should be considered. Depth of investigation required will also be a contributing factor to system selection.

The usefulness of the current gravity station data for NRM at local scales in the Burdekin-Fitzroy catchments is limited due to its coarse resolution, therefore the acquisition of detailed gravity data should also be considered for further NRM work in the region. Such data may be useful for determining features such as depth to basement and major lineaments and structures (i.e. basement transfer zones).

Most of the seismic survey data for in the study area is not very useful for NRM applications. Draper (1999) notes the seismic surveys in the Drummond Basin are of a regional character and include Galilee Basin surveys which have the Drummond Basin as basement. It is not particularly useful for shallow investigations such as determining the depth of the transported overburden, *in situ* regolith or defining shallow structure. Most of the Bowen Basin surveys are of similar nature, however, some shallow seismic does exist for this area.. The usefulness of this information in an NRM context is debateable as the data are not very useful for resolving shallow geological structure (top 100-200m). The information may be useful however to validate current and future interpretations performed for NRM in the study area in the context of basin analysis and groundwater potential.

Future geophysical surveys should consider acquiring more ground based data to validate airborne surveys. Ground based methods would be useful for validation of airborne measurements for aeromagnetic, airborne gamma-ray spectrometry or electromagnetic surveys. This would also include down hole electromagnetic methods for groundwater and salinity studies.

Improvement to visualisation another key to improving NRM interpretation over the region. Utilisation of the high resolution DEM with other geo-science and hydro-geological layers in 3D is suggested. All of the data collected during this study should also be integrated into a 3D visualisation software package.

4.8 Conclusions

The findings of this study are:

- There is adequate aeromagnetic and airborne spectrometry coverage over the study area at sufficient resolution for NRM directed interpretations down to farm scale. Further acquisition of aeromagnetics or airborne spectrometry data should not be considered a priority. Localised, more focused studies should utilise the numerous prospect scale aeromagnetic surveys (where available) if they are of improved quality or higher resolution that the regional mosaic produced for this study.

- There is no useful airborne electromagnetic survey data over the study area.

- The 3D architecture of regolith material over the study region is poorly understood. Use of geophysical methods to map these materials are considered a priority for NRM. Conceptual models would substantially benefit from an improved knowledge of the 3D regolith architecture.

- The bedrock architecture within the Northern and Central Bowen Basin is generally complex (non-uniform) and was significantly eroded during the early Tertiary. The distribution basaltic flows may be indicative of the former drainage systems may now be areas of preferential groundwater movement. These basaltic flows may mapped from the aeromagnetic data depending on the units thickness, depth and degree of weathering.

- Airborne gamma-ray spectrometric data within the study area is useful for soil mapping, and may be combined with other data such as magnetics and topography to further understand the surface geology. The resolution of the airborne spectrometry coverage is sufficient for interpretation down to farm scale. Use of company high resolution airborne spectrometry surveys flown for mineral exploration should be re-interpreted and used for detailed studies of the distribution of surface materials.

- The seismic and gravity data in their current format were not overly useful for NRM studies.

- Very little information exists relating to the regolith architecture or depth within the Drummond and Galilee Basins. Little is also known of the groundwater potential. An improved structural and solid geology re-interpretation would be very useful over this region

4.9 Recommendations

- Regional acquisition of AEM should be considered a priority for future NRM investigations.

- Airborne gradiometer data would be ideal for future acquisition if magnetics were to be acquired.

- Collection and assessment of company drilling and ground geophysical survey data needs to be included in future work.

- A full re-interpretation of the central Bowen Basin solid geology and Drummond Basin should be performed based on the newly acquired aeromagnetic data and geological mapping.

- Airborne gamma-ray spectrometry should be combined with aerial photography or Landsat TM used to map soil and landform properties up to farm scale. Can be integrated with existing soil survey data.

- Re-interpretation of the geophysical data to map basaltic units should be performed at a closer scale than existing interpretations, and should incorporate the borehole information for validation..

- Inversions of magnetic data as future method for interpretation. Worming (overlay on grey-scale mag image) may recognise structures, high strain zones and irregular large faults.

- Improved filtering methods should be tested on the aeromagnetic data to extract additional information. The method demonstrated by Grauch (2002) of anomaly separation prior to depth estimation is suggested.

5. HYDROGEOLOGY AND SALINITY

5.1 Introduction

Considerable information related to groundwater flow systems (GFS) and other geological controls on groundwater resources exists for the study area. This information provides an understanding of geomorphologic landscape structures and land management units that relate to groundwater recharge, flow and discharge in the study area.

5.2 Hydrogeology of the Burdekin-Fitzroy Region

The hydrogeology of the study area is believed to be complex, and most of the information reviewed relates to the resources of the Bowen Basin. There is very limited information on the groundwater resources of the Drummond Basin or Galilee Basin, while groundwater potential of other parts of the study area is not well documented. Near surface groundwater resources within the study area are generally confined to the Cainozoic materials, and bores are most often located within alluvial materials. Deeper groundwater is known to move through structural weaknesses in bedrock.

Groundwater is contained within the fractures, joints, solution cavities and weathered zones of the porous and fractured rock aquifers within the Fitzroy basin (Pearce *et al.*, 1969). Davies (1985) noted two distinct aquifers in the Northern Bowen Basin, the first within unconfined sandy sediments perched above impermeable clays at the Tertiary – Permian unconformity, and the second confined aquifer within the coal seams of the Permian (at 40m depth in this case). Ishaq's (1985) study of aquifers around the Clermont area in the Bowen Basin confirms that the best prospects for yields of good quality water are from a gravely horizon found at the base of the Tertiary sediments (Table 4). However the lateral continuity of this horizon is poorly understood. The gravely horizon is also noted by Hanna (1985) around Gordonstone, Central Bowen Basin as sand and gravel beds occurring in the palaeo-valleys of the early Tertiary land surface (Bowen Basin) with high porosity and permeability and significantly high water flows. The salinity of the water is considered lower than that of the basalt aquifers (Hanna, 1985). Porous rock aquifers have been identified within the sedimentary sequences of the Bowen Basin (Pearce *et al.*, 1969), and are associated with moderate poor quality yields.

Table 4. Groundwater potential around Clermont, Bowen Basin (Ishaq, 1985).

Depth to aquifer	(m)	Yield	(m^3/day)	Quality	(TDS mg/L)
Very shallow	< 10	Very low	< 20	Very good	<1000
Shallow	10-30	Low	20-45	Good	1000 - 2500
Moderate	30-90	Moderate	45-350	Poor	2500 – 10,000
Deep	> 90	High	> 350	Saline	>10,000

The most readily identified fractured rock aquifers over the study area are Tertiary basalts of the Bowen Basin. Studies performed by Ishaq (1985) in the central Bowen Basin found that where basaltic flows in-fill former active drainage systems in the Tertiary now form preferential pathways for groundwater movement. These units, where fractured and faulted, may provide preferential areas for groundwater recharge and increased groundwater transmissivity, however the discrimination of fracture zones within these units is not easily inferred. Ishaq (1985) during his groundwater investigations around Clermont describes these basalts as providing the best prospects for moderate to high yields of good quality water compared to other aquifers in the region. Ishaq (1985) also describes the groundwater potential for the other fractured rocks in the region as highly variable with yield ranging from low to moderate and water quality from very good to poor.

Pearce *et al.* (1969) identifies Cainozoic sediments as significant hydro-geological units over the region, but concludes that these sediments are not important sources of groundwater, and debates their importance as aquifers or zones of recharge. Most of the important aquifers used for irrigation in the region are from alluvial deposits (Pearce *et al.*, 1969). Alternatively, groundwater investigations performed by Ishaq (1985) over four map sheets in the Bowen Basin show that the unconsolidated Cainozoic sediments contain limited, but good quality water. Recharge in this area for the unconsolidated aquifers is mainly from rainfall, with some contribution from stream flow and overlying alluvial aquifers (Ishaq, 1985).

5.3 Use of Geophysics - Hydrogeology

There are few previous investigations into the groundwater resources of the study area using geophysical methods, however there is an abundance of interpretive data for the Burdekin-Fitzroy catchments which could be used to improve existing hydrogeological models. Geologic and geomorphic structures that may be important in the context of shallow groundwater that could be identified from the regional geophysical data include:

- Hydrogeologic structures (e.g. trends, faults, fractures, dykes, intrusions, palaeochannels).
- Recharge areas (e.g. fractured aquifers, elevated landforms, exposed lithologies)
- Discharge areas (e.g. margins of elevated landforms).
- Porous rocks

Aeromagnetic data are particularly useful for mapping geologic structures that may be important to groundwater investigations particularly where regolith material obscures the underlying geology. Such data may also prove effective to map particular hydrogeological lithologies (e.g. basalts and intrusions), however the effectiveness of the method would depend on the scale of the investigation, data quality and relative magnetic contrasts between lithologies. As an example, the basalt filled palaeo-valleys of the Northern Bowen Basin are a known significant groundwater resource and represents a former landscape surface imparting significant control on present day groundwater movement. These units are readily mapped using the aeromagnetic datasets. The relationship between groundwater recharge and discharge areas and the distribution of basalts in the region may also be significant. Such relationships have been previously investigated in other basaltic rocks of similar age in Victoria by Bennetts *et al.* (2003). An improved structural interpretation from aeromagnetic data could also provide additional specific information that could be applied to groundwater studies and GFS modelling. Much of this information relates to the identification of important structural elements that may impart control over groundwater movement.

The considerable mapping of fault structures from aeromagnetic data, particularly at 1:100,000 scale, could be used as constraints in hydrological models. In aeromagnetic images, fracture zones are typically observed as subtle criss-crossing linear features in generally magnetically flat areas. Faults or fractures are most often detected indirectly as observed displacements in magnetic signature zones or by the presence of emplaced dykes that have exploited structural weakness. The migration of water through these zones could lead to a depletion or enrichment of magnetic minerals. Areas of interest include the Bowen Basin which is characterised by many large fracture zones and dyke swarms (Figure 53, Figure 54). Dykes and intrusions may also be potential zones of recharge particularly where in elevated landscape positions. Areas of faulting within older basement rocks (e.g. Anakie Metamorphics) may not be of much significance for groundwater movement as these rocks are noted for their poor groundwater resources (Olgers, 1969).

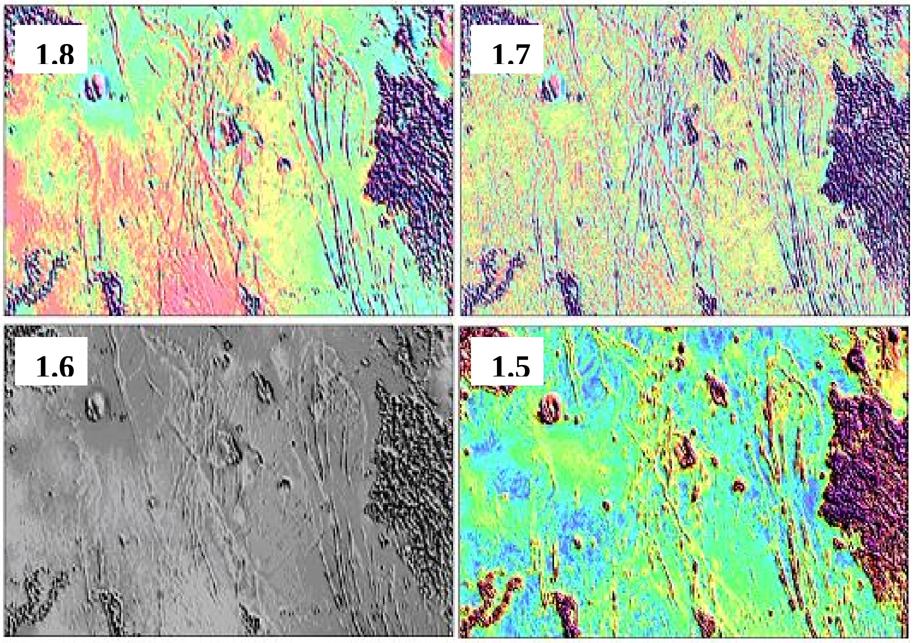


Figure 53. Example of magnetic dykes infilling fractures and lineaments in filtered TMI aeromagnetic data from the Northern Bowen Basin (a) 1st vertical derivative (b) 2nd vertical derivative (c) 1st vertical derivative (greyscale) (d) Horizontal gradient.

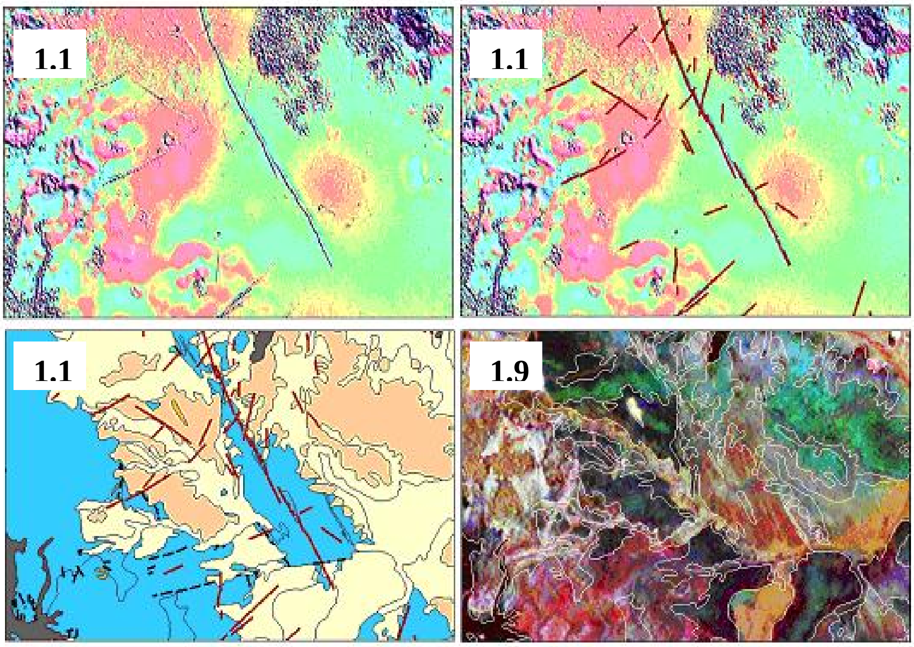


Figure 54. Example of interpreted dykes infilling major fault structures from TMI aeromagnetic data. (a) 1st vertical derivative aeromagnetics (b) 1st vertical derivative aeromagnetics with interpretation (c) 1:100K geological mapping with interpreted elements (d) 3-band Ternary airborne spectrometry. The large NW trending dyke in particular has no surface expression in the Ternary image.

Airborne spectrometric data could also be used to map important hydrogeologic units such as alluvial materials, some sedimentary lithologies, basaltic flows, exposed intrusions and dykes where they crop out. Airborne spectrometric data is also particularly useful to map exposed intrusions. As an example, the margins of basalt flows are often associated with discharge zones in elevated landscape positions

(Bennetts *et al.* (2003). Using a combination of topographic, geological and geophysical data, basalt margins may be inferred and mapped. Figure 55 and Figure 56 demonstrates how basalt margins may be identified from geophysical data when combined with topographic information in the Central Bowen Basin. In the example it is known from bore hole logs that the basalt overlies relatively flat lying (concordant) Permian bedrock, which may restrict the movement of water downward. The margins of the mapped basalts correlate well with the airborne spectrometric data and form topographic highs in this area demonstrating the relationship between changes in slope and the geology. Groundwater discharge may be occurring at the margins of the fresh material.

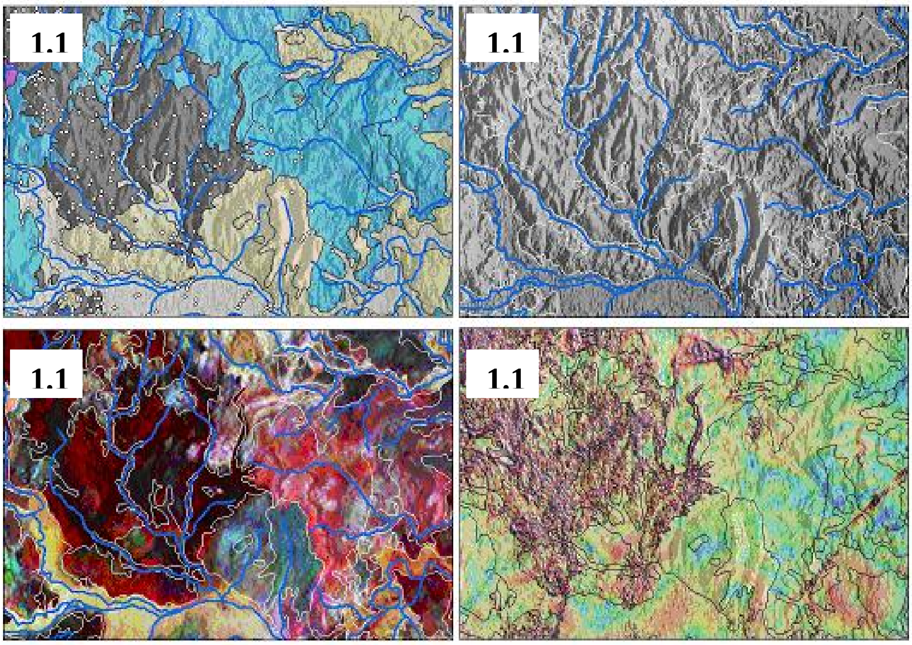


Figure 55. An example of how geophysical data may be used to map basalt flow margins in elevated landscape positions, Central Bowen Basin. (a) 1:1 million South Qld Geology, hydrology and water bores overlayed onto DEM. (b) 1:1 million South Qld geology, hydrology overlayed on DEM. (c) 1:1 million South Qld geology polygons and hydrology overlayed on 3 band ternary airborne spectrometry (d) 1:1 million South Qld geology polygons overlayed onto horizontal gradient aeromagnetics. Depending on the characteristics of the flows, these areas may be zones of groundwater discharge into the landscape.

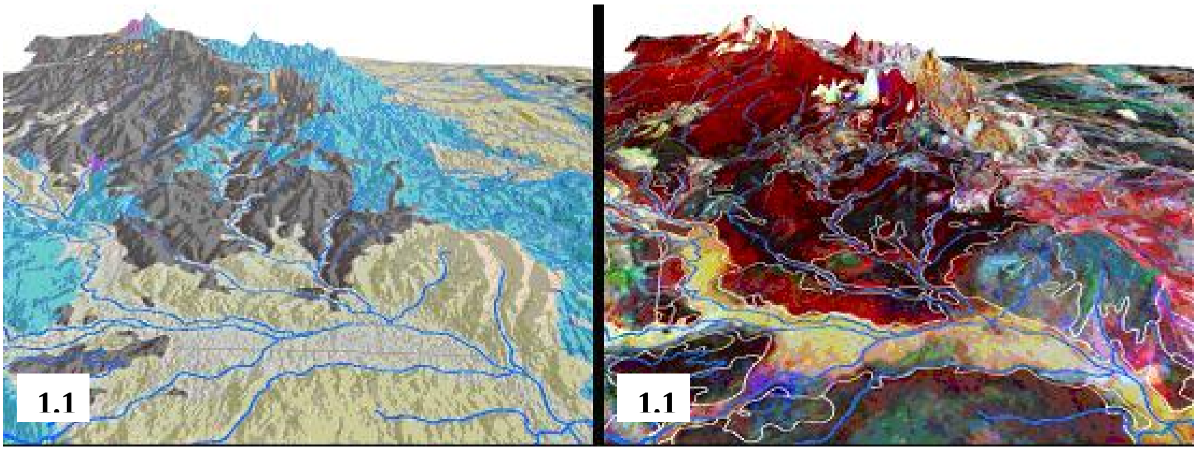


Figure 56. 3D representation of previous figure (a) 1:1 million South Qld geology and hydrology draped on airborne DEM (b) 3-band ternary airborne spectrometry, 1:1 million South Qld geology and hydrology draped on airborne DEM. Note how the more resistant volcanic plugs form topographic highs in the landscape.

Geophysical data has limited use to identify porous rocks associated with the sedimentary strata within the basins. Airborne spectrometry may be useful for identifying some of these stratigraphic units where they crop out, however the aeromagnetic data does not differentiate between the stratigraphic horizons individually due to a lack of significant magnetic contrast. As basin sediments are generally recognised as areas of flat or slowly varying magnetic gradients, this reflects the relatively low magnetic susceptibilities associated with these units. In areas of basalt capping it is not possible to infer the presence of the underlying porous rocks from magnetic data due to the high frequency responses of the basalts.

Interpretations from geophysical data within the study area may be used to further improve conceptual models of groundwater movement and provide constraints for groundwater flow system models. Assessments of recharge and discharge potential of particular landforms within the landscape can be made through proper integration of the available geoscience information, geophysics, hydrological, hydrogeological (GFS) and topographic information. This is one of the roles of the interactive GIS.

5.4 Salinity

Most of the previously outlined geologic and geomorphic features important to groundwater resources are important in the context of identifying salinity risk. Salt hazard models are based on a standard rule of identifying changes in transmissivity particularly of the regolith or near surface geology (Gordon, 1998). A reduction in transmissivity of an aquifer will cause water to accumulate resulting in increased soil salinity due to evaporation and lead to surface discharge of saline water for surface aquifers (Gordon, 1998). Interpretations need to be combined with accurate hazard prediction modelling. An improved understanding of the groundwater movement is considered to have implications for salinity hazard assessment in the region. Landforms at risk of salinisation or potential zones of saline discharge within the study area could include.

- Deeply weathered regolith or lithology
- Basalt flow margins (discharge zones)
- Sedimentary basin strata (i.e. Permian aquifers discharging saline water at the surface)
- Zones of dykes and faulting
- Zones of low hydraulic gradient (flat alluvial valleys)

Where there is high water movement salts are unlikely to concentrate, alternatively if water movement is restricted, saline water may accumulate (Gordon, 1998). Areas of intense faulting with associated dykes may potentially form a barrier to horizontal groundwater movement providing a preferential upward flow path causing discharge at the surface. In areas where saline water exists, such a constriction may result in such discharge. This restriction of groundwater movement may present a salinity problem as a consequence of flood irrigation (Stanley and Cattach, 1990). This concept is based on identifying areas where changes of aquifer (regolith and near surface geology) transmissivity, in particular a reduction, occurs in the landscape allowing water to accumulate (Gordon, 1998). In a surface aquifer this can contribute the risk of soil salinisation due to evaporation and potentially lead to saline water discharging at the surface (Gordon, 1998). Additionally, thin regolith may pose a salinity hazard along with palaeo-drainage discharge zones. The following section will demonstrate how geophysics may be used to define landforms at risk.

5.5 Use of geophysics - salinity

Airborne gamma-ray spectrometric and aeromagnetic data can provide additional information for salinity investigations through the identification of geologic and geomorphic landforms that may be at risk of salinisation, and to identify lithologies which may be repositories for salt. The identification of geologic and geomorphic landforms and structures that influence groundwater movement may be combined with other datasets to produce models of potential salinisation. An understanding of the subsurface geology and its 3D structure combined with GFS modelling is central to the prediction of landforms at risk.

Airborne spectrometry, combined with other data, may assist in the identification of landforms at risk of salinisation. The coal bearing strata of the Bowen Basin are known confined aquifers associated with highly saline water as noted by Ishaq (1985). Areas of outcropping carbonaceous or coal bearing strata may be detectable using airborne spectrometry and may be zones of saline discharge. Zones of deeply weathered regolith or lithology may be interpreted using the airborne spectrometric data also. This is particularly the case with the basaltic rocks where zones of deeper weathering are interpretable from the airborne spectrometric data. Basalt flow margins should also be detectable using airborne spectrometry where outcropping. Alluvial material is clearly resolved in airborne spectrometric data, and if combined with topographic and other information (e.g. depth to bedrock and GFS) could provide some indication of salinity risk. Aeromagnetics can also provide structural information to any landform salinity modelling.

5.6 Conclusions

The current GFS models for the area are not detailed enough to make accurate predictions related to groundwater movement and salinity risk within the study area. For this study however, landforms that may be important in the context of shallow groundwater that can be identified from the available geophysical are presented as illustrative examples. Once improved GFS models are developed, the geophysical data may then be used to identify landforms where the GFS is more clearly understood. This would also subsequently improve salinity risk prediction within the area.

The Cainozoic sediments are the main source of shallow groundwater, and areas of thin cover may also be of interest for recharge particularly where the underlying bedrock is intruded and faulted. Estimates of the thickness of the Cainozoic and discrimination of bedrock topography may be useful to make predictions on groundwater movement. The Tertiary basaltic units may have a role in groundwater recharge and discharge and are considered to be quality aquifers. Mapping of these units undercover is would improve the known groundwater resources over the region. Studies from similar Tertiary basalts in Victoria reveal that recharge occurs in areas of fracturing and jointing (i.e. volcanic centres) while discharge occurs at the margins of the flows (where exposed). Similar processes may be occurring in the basaltic rocks within the study area. Current interpretation of the distribution of these units undercover is still inadequate and should be updated. Approximations of the thickness of these units should also be performed either through analysis of the available drilling information, with attempts to constrain the model.

The identification of areas of restricted groundwater flow or reduced transmissivity may be important in the context of salinity risk in this region. Topographic data could be combined with structural information to improve the predictive ability of conceptual risk models. Regolith depth to bedrock information where integrated with structural, GFS, and hydrological data may improve modelling of salinity risk for broad alluvial areas. Areas of discharge are also important and should be properly investigated. Future acquisition of geophysics for groundwater and salt mapping should consider either ground EM or AEM methods to map the subsurface conductivity patterns in targeted areas. Inferences regarding zones of potential salinisation can be inferred also from any improved understanding of the groundwater flow systems. Confidence in these interpretations must be quantified to provide credibility on the reliance of such products for land management decisions. Airborne gamma-ray spectrometric data are useful for mapping important geologic and geomorphic units where they outcrop, but any inference of the subsurface geology based on spectrometric surface attributes must be treated with caution, and correctly validated.

Existing GFS models and salinity hazard maps for the area are not yet considered detailed enough to integrate with the geophysical information to make effective predictions related to salinity risk. We need to relate groundwater responses, depth to the water table, geology and salinity to landforms and soil data to identify risk areas for future salinity development and potential salinity management options (Gordon, 1998).

5.7 Recommendations

- Produce a water resource target map and improve the existing salinity hazard maps for the region.

- GFS models should be reviewed and constrained by the existing geological information, geophysics, drilling and borehole information, remotely sensed data, and interpretive layers produced from geophysical data.

- Investigation into areas where Permian coal bearing strata outcrop or sub-crop to assess if a saline water discharge is occurring. This type of landform should be considered in future salinity risk assessments.

- Investigation into the recharge and discharge processes occurring within basaltic aquifers. Recharge and discharge and water quality information need to be spatially correlated with mapped and inferred basaltic rocks to test correlations with particular landform types (eg. whether saline water discharges at flow margins, and recharges within heavily fractured outcrops).

6. MINERAL EXPLORATION DATA

6.1 Available Data

Coal Exploration Permits

There are currently 161 coal exploration permits issued in the Burdekin-Fitzroy study area (Figure 57). Current coal exploration permits may be queried through the GA interactive GIS. Updates can be accessed from the NR&M Interactive Resource and Tenure Maps.

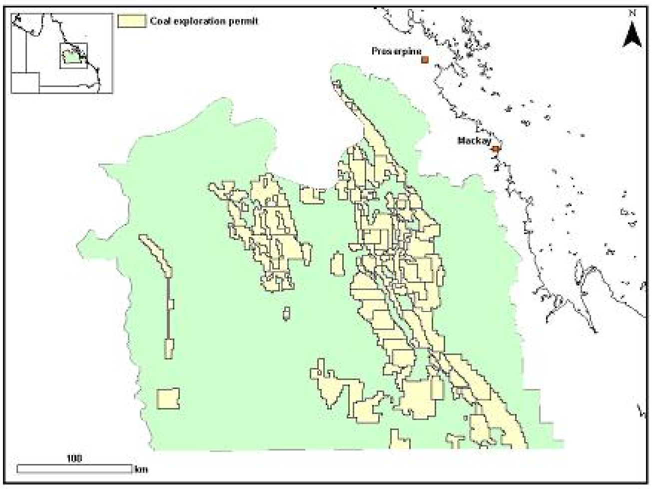


Figure 57. Current coal exploration permits in the Burdekin-Fitzroy study region.

Source NR&M :

http://www.webgis.nrm.qld.gov.au/webgis/webqmin/frameset/ie/complexframe_qmin.htm

ATP Exploration Titles

There are currently 39 authorities to prospect (ATP) exploration titles in the Burdekin-Fitzroy study area (Figure 58). Current ATP exploration titles may be queried through the GA interactive GIS. Updates can be accessed from the NR&M Interactive Resource and Tenure Maps.

There are also numerous historical ATP exploration titles in the Burdekin-Fitzroy study area (Figure 58). This information can also be accessed from the NR&M Interactive Resource and Tenure Maps.

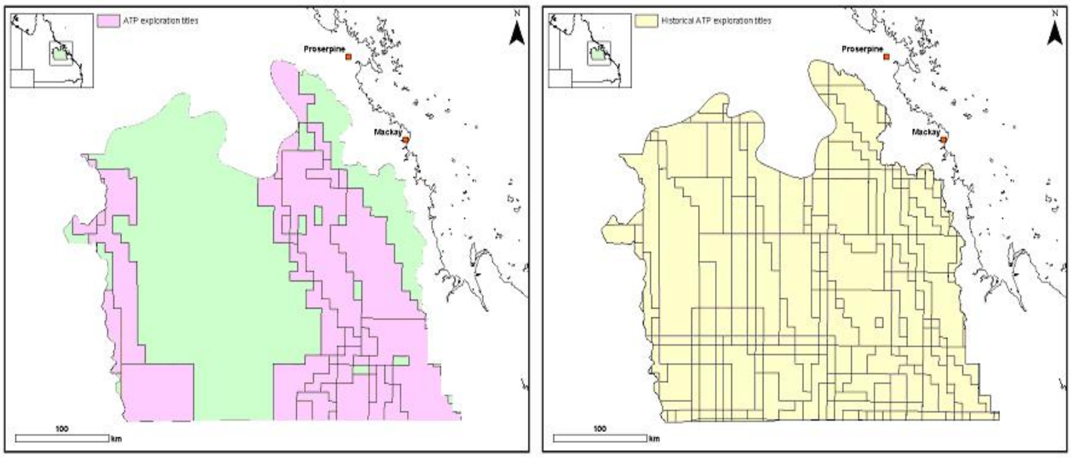


Figure 58. Authorities to prospect (ATPs) (a) Current ATP exploration titles in the Burdekin-Fitzroy study region. (b) Historical ATP exploration titles in the Burdekin-Fitzroy study region.

Source: NR&M

http://www.webgis.nrm.qld.gov.au/webgis/webqmin/frameset/ie/complexframe_qmin.htm

Petroleum Leases

There are currently 2 petroleum leases in the Burdekin-Fitzroy study area (Figure 59). Current petroleum leases may be queried through the GA interactive GIS. Updates can be accessed from the NR&M Interactive Resource and Tenure Maps.

Source NR&M :

http://www.webgis.nrm.qld.gov.au/webgis/webqmin/frameset/ie/complexframe_qmin.htm

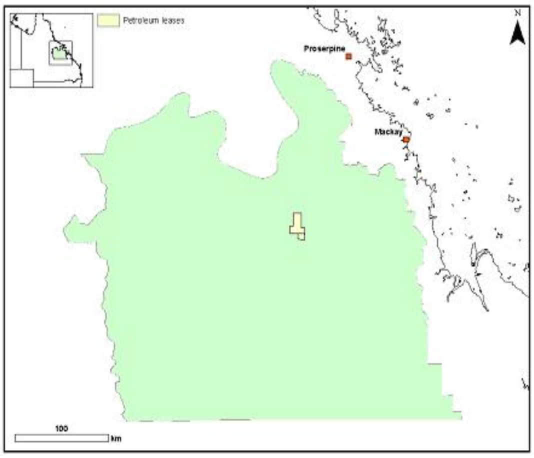


Figure 59. Petroleum leases in the Burdekin-Fitzroy study region.

Mining Leases

There are a large number of mining leases in the Burdekin-Fitzroy study area (Figure 60). Current mining leases may be queried through the GA interactive GIS. Updates can be accessed from the NR&M Interactive Resource and Tenure Maps.

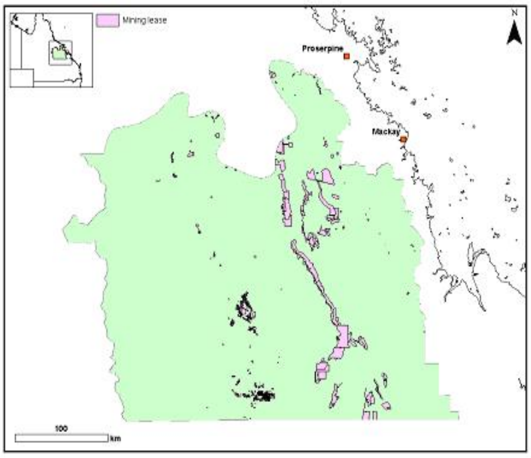


Figure 60. Current mining leases in the Burdekin-Fitzroy study region.

Source: NR&M

http://www.webgis.nrm.qld.gov.au/webgis/webqmin/frameset/ie/complexframe_qmin.htm

Mineral Development Licences

There are numerous mineral development licences in the Burdekin-Fitzroy study area (Figure 61). Current licences may be queried through the GA interactive GIS. Updates can be accessed from the NR&M Interactive Resource and Tenure Maps.

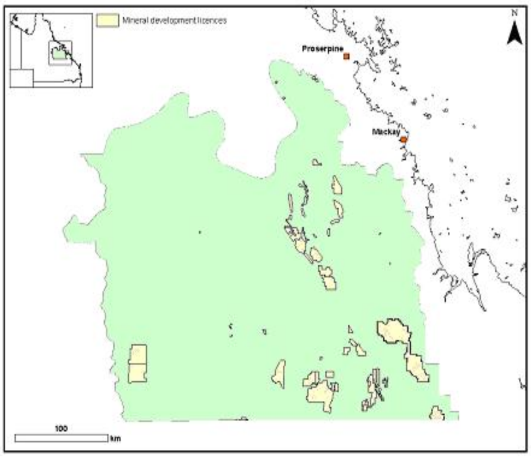


Figure 61. Mineral development licences in the Burdekin-Fitzroy study region.

Source: http://www.webgis.nrm.qld.gov.au/webgis/webqmin/frameset/ie/complexframe_qmin.htm

Exploration Drill holes

Three different types of drill holes were identified from the QPED database as being located within the Burdekin-Fitzroy study area; stratigraphic, petroleum and coal seam gas. A range of attributed information is available for these drill holes (Figure 62).

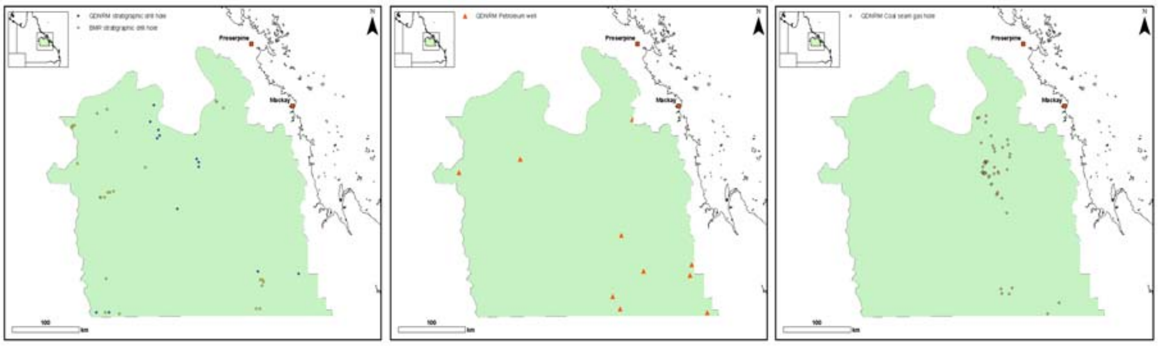


Figure 62. Drill holes in the Burdekin-Fitzroy Study Area. (a) Stratigraphic drill hole locations. (b) Petroleum well locations. (c) Coal seam gas hole locations.

Source www.nrm.qld.gov.au or contact : kinta.hoffmann@nrm.qld.gov.au

Current Mineral Exploration Permits

Current mineral exploration permits in the Burdekin-Fitzroy study area (Figure 63). Current licences may be queried through the GA interactive GIS. Updates can be accessed from the NR&M Interactive Resource and Tenure Maps.

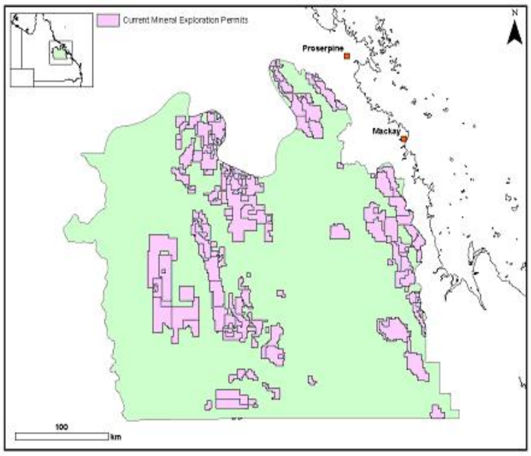


Figure 63. Current mineral exploration permits in the Burdekin-Fitzroy study region.

Source: http://www.webgis.nrm.qld.gov.au/webgis/webqmin/frameset/ie/complexframe_qmin.htm

6.2 Mineral Occurrences and Mines

About 600 recorded mineral occurrences, deposits, and mines occur within the study area and the data are derived from the 2004 version of the Queensland Mineral Occurrence and Mineral Resources Database provided to GA for its update of the MINLOC mineral occurrence database. Additional resource data were obtained from GA's OZMIN database. Information on new mine developments was is also derived from GA's publication on Australia's Identified Mineral Resources (AIMR) prepared by the Mineral Resources and Advice project and the 2003 version can be located at: http://www.ga.gov.au/rural/projects/AIMR2003.jsp . Some of the material on recent coal developments, included in this summary, will be available in the AIMR2004 to be release by early 2005.

The majority of mineral locations within the study area are very small occurrences but a significant number constitute very large coal mining operations of major national economic significance. Coal mining activities within the study area constitute a massive land use activity.

Coal and other non metallic minerals

The extensive coal deposits of the Bowen Basin are by far the most significant commercial mineral commodity in the study area. About 80 coal occurrences recorded in the database fall within the study area, and virtually all of these are within the Bowen Basin. Included with these occurrences are about 28 deposits that support major operating coal mines such as Goonyella, Blair Athol and Newlands among many other operations within the study area and constitute a coal mining industry of major national importance. Coal production is used both for electricity power generation and for export. The mining operations are based on deposits ranging in size from very large of more 1,000 million tonnes to much smaller deposits of less than 100 million tonnes (Table 5).

Table 5. Coal deposits being mined in the study area

Mine Name	Lat	Long	Locality	Comments
Coking coal				
Peak Downs	-22.24	148.20	40 km southeast of Moranbah and 160 km southwest of Mackay	Very large >1000 million tonnes coking coal

Goonyella	-21.81	147.96	25 km north of Moranbah and 150 km southwest of Mackay	Very large >1000 million tonnes coking coal
North Goonyella	-21.65	147.98	40 km north of Moranbah and 180 km west of Mackay	Large 500 - 1000 million tonnes coking coal
German Creek	-22.91	148.59	25 km southwest of Middlemount	Large 500 - 1 000 million coking coal
German Creek East	-22.92	148.65	13 km south southwest of Middlemount	Large 500 - 1 000 million coking coal
Hail Creek	-21.51	148.41	35 km north west of Nebo	Large 500 million tonnes coking coking coal
Moranbah North	-21.89	147.99	16 km north of Moranbah	Medium 100 - 500 million tonnes coking coal
Crinum	-23.21	148.37	62 km northeast Emerald	Medium 100 - 500 million tonnes coking coal
Gregory	-23.17	148.36	62 km northeast of Emerald	Medium 100 - 500 million tonnes coking coal
Oaky Creek	-23.07	148.53	15 km east of Tieri and 200 km west northwest of Rockhampton	Medium 100 - 500 million tonnes coking coal
Norwich Park	-22.62	148.43	25 km southeast of Dysart and 180 km south southwest of Mackay	Medium 100 - 500 million tonnes coking coal
Saraji	-22.37	148.29	22 km north of Dysart and 165km south southwest of Mackay	Medium 100 – 500 million tonnes coking coal
Kestrel	-23.26	148.36	45 km north Northeast of Emerald	Medium 100 - 500 million coking coal
Riverside	-21.73	147.96	30 km north of Moranbah	Small 10 - 100 million tonnes coking coal
Burton	-21.59	148.17	147 km southwest of Mackay and 40 km south of Glenden	Small 10 - 100 million tonnes coking coal
Pipeline	-20.64	147.87	10 km southeast of Collinsville	Very small <10 million tonnes coking coal
Curragh	-23.47	148.85	14 km north of Blackwater AND 200 Km west of Rockhampton	Small 10 - 100 million tonnes coking coal
Blair Athol	-22.69	147.53	22 km northwest of Clermont AND 280 km southwest of Mackay	Very large >1 000 million tonnes noncoking coal (thermal coal)
Non coking coal				
Ensham	-23.47	148.50	40 km northeast of Emerald	Very large >1 000 million tonnes noncoking coal (thermal coal)

Newlands	-21.19	147.91	32 km northwest of Glenden And 198 Km West Of Mackay	Medium 100 - 500 million tonnes noncoking coal (thermal coal)
Coppabella	-21.84	148.43	25 km southwest of Nebo, 150 km SW of Mackay.	Medium 100 - 500 million tonnes noncoking coal (thermal coal)
Kemmis/Walker	-21.73	148.39	40 km west of Nebo	Medium 100 - 500 million tonnes noncoking coal (thermal coal)
Yarrabee	-23.32	149.03	47 km northeast of Blackwater	Small 10 - 100 million tonnes noncoking coal (thermal coal)
South Walker Creek	-21.76	148.44	20 km east of Coppabella and 35 km west of Nebo	Small 10 - 100 million tonnes noncoking coal (thermal coal)
Jellinbah East	-23.41	148.95	25 km northeast of Blackwater	Small 10 - 100 million tonnes noncoking coal (thermal coal)
Eastern Creek	-21.13	148.00	30 km north of Glenden and 130 km west of Mackay	Small 10 - 100 million tonnes noncoking coal (thermal coal)
Foxleigh	-22.93	148.76	12 km south of Middlemount	Small 10 - 100 million tonnes coal
Moorvale	-22.00	148.36	20 km east of Moranbah.	Small

Extensive resources of coal extend beyond the deposits currently being mined and exploration for coal and development of new deposits is an important ongoing land use activity. About 68 deposits of coal are listed in the OZMIN database for which resources have been recorded within the study area. New coal mines are being brought into production and existing operations expanded. Some recent developments include the opening of the Hail Creek open-cut coal mine by Pacific Coal in late 2003 and coal operations were also being expanded at the Kestrel mine. BHP Billiton Mitsubishi Alliance is planning to open another coking coal mine at Broadmeadow in late 2005. Existing operations are also being expanded by Xstrata Coal at Newlands and the company is proposing to develop the Suttor Creek deposit to replace its Main deposit which will cease in 2004. In addition, Macarthur Coal commenced open cut operations in 2003 at Moorvale, 20 km east of Moranbah.

Apart from coal, other non-metallic commodities in the study area include about 20 occurrences of calcareous materials (lime, limestone, marble), oil-shale (4), diatomite (2), sapphire (2), opal and zeolite. According to the information in the database, mining operations include earthy lime (4), sapphire and zeolite. Resources have been recorded in the OZMIN database for the Duaringa oil shale deposit.

Metallic minerals

Minor occurrences of metallic minerals make up the largest group with the dominant commodities being:

- Nearly 380 recorded occurrences of gold, and
- Over 80 occurrences where copper is recorded as a major commodity.

Occurrences of the metallic minerals are largely confined to felsic and intermediate intrusions and volcanics of the Connors Auburn Province in the far northeast portion of the study area and in high grade metamorphics and felsic intrusives of the Anakie Province and the Drummond Basin in the central portion of the study area. A few of the metallic mineral occurrences are also associated with isolated or concealed felsic to intermediate igneous intrusives.

The information in the database indicates mining operations for 3 of the gold locations with another 15 gold locations having care and maintenance status. Most of this activity is confined to very small intermittent alluvial gold mining, most of which appear to have less than 0.5 tonnes of gold resources.

Apart from mining there is a significant exploration activity for gold and other metallic minerals.

Other minor occurrences of metallic minerals include silver (4), antimony (3), tungsten (3), as well as magnetite, molybdenum, bismuth, chromium, rare earths and uranium. Resources have been recorded in the OZMIN database for eight gold deposits and one copper deposit.

7. PHYSIOGRAPHIC REGIONS

7.1 Background

Jennings and Mabbutt (1977) compiled the first physiographic region maps of Australia (Figure 64). This map was created by assigning boundaries to units that had relatively internally consistent landform characteristics. The resultant physiographic regions were the best achievable with the available technologies of the day and as a result, were only approximations of the regions concerned.

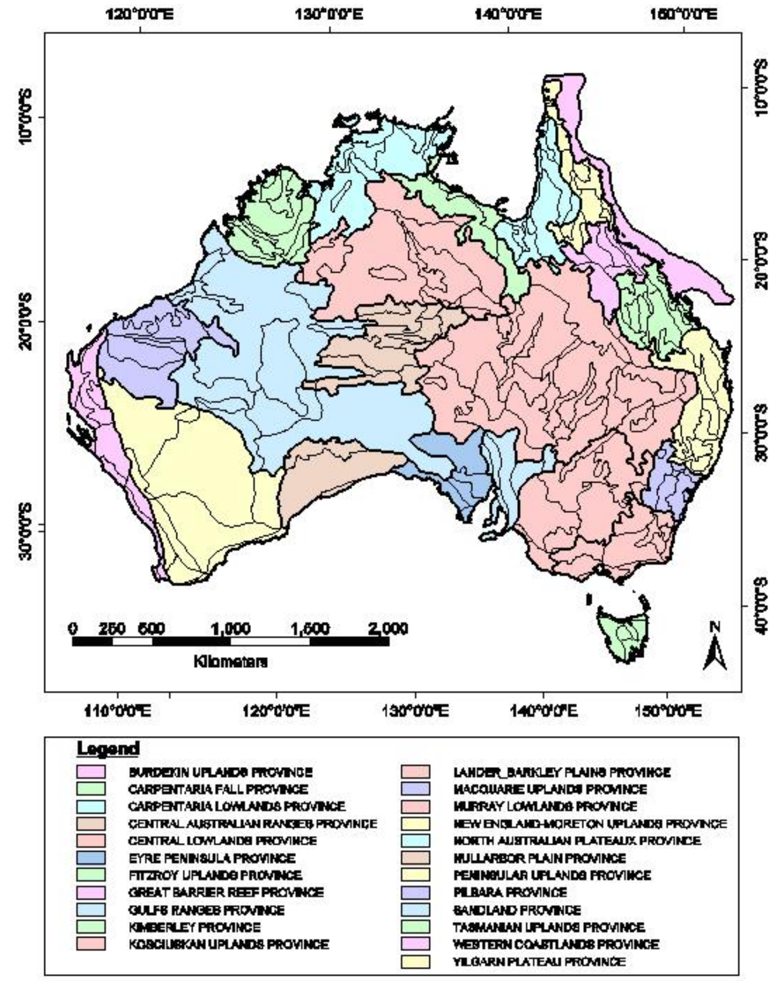


Figure 64. Physiographic Regions of Australia, (Jennings and Mabbutt, 1986)

With the advent of better technologies, an opportunity arose to redefine the boundaries that were created by Jennings and Mabbutt. This is a timely exercise as there is opportunity for the redefined boundaries to be incorporated into Australian Soil Resource Information System (ASRIS) (CSIRO, 2003). This project was initiated by the National Land and Water Resources Audit (NLWRA) and aims to provide an Australia-wide hierarchy of spatial units to enable more complete land suitability and soil resources information. The Burdekin-Fitzroy study area was used as a test area at the Land Division and Province level with the aim to help determine appropriate methodologies for input into ASRIS.

7.2 Methodology

To redefine the boundaries of Jennings and Mabbutt's physiographic regions coverage, it was overlayed on a hill shade derivative of Australia's 9 sec DEM. The intention was to refine these boundaries and not to create new polygons. Using Jennings and Mabbutt's coverage as a guide, the boundaries were redefined at a 1:700,000 scale. As there are plans are in place for the whole of

Australia coverage to be prepared, the 1:700,000 scale was deemed appropriate. Figure 65(a) shows the original Jennings and Mabbutt coverage, and Figure 65(b) shows the redefined coverage.

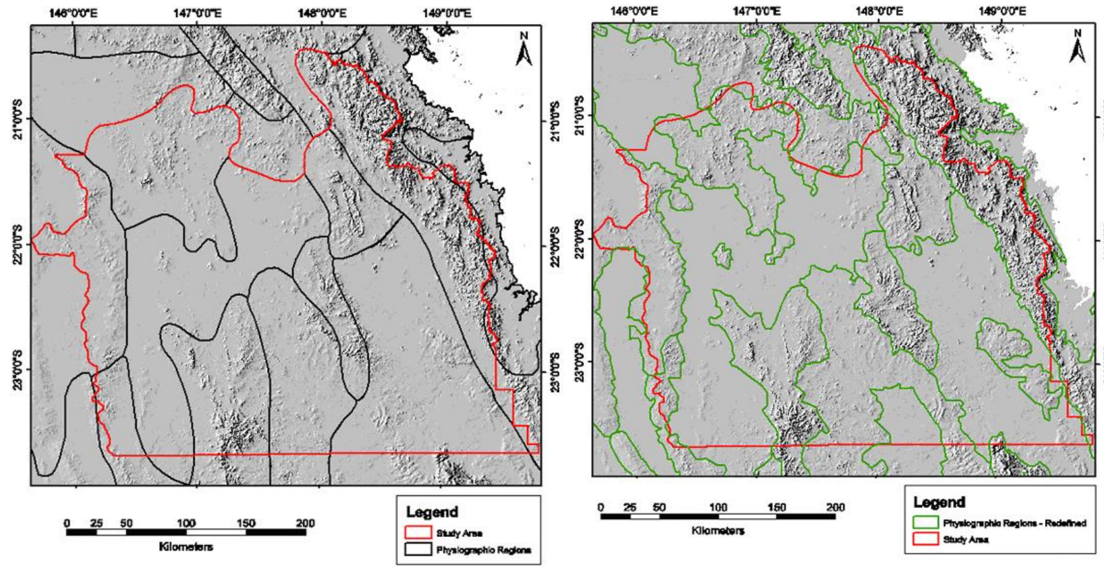


Figure 65. Physiographic regions in the Burdekin-Fitzroy study area with a hill shade of the 9 sec DEM as a backdrop. (a) After Jennings and Mabbutt (1986). (b) Redefined for this study.

It was important to create the physiographic regions dataset without inferring any information about the geology, hence a simple hill shade was used as the primary dataset. Many new datasets are derivations of existing datasets e.g. GFS and the National Regolith coverage, which have inferences of the geology. As not all the geology has been mapped correctly, these errors are then transferred into these new datasets. The new NASA Shuttle Radar Terrain Model (SRTM, 2005) will be used in further refinements.

Value adding for NRM

By redefining the physiographic region boundaries, this dataset was renewed and made more relevant for studies relating to natural resource management issues. It can be used as the basis for further subdividing the landscape into units for further research and a catchment management level. It will also be an integral part of Australia-wide land resource assessment through the ASRIS framework.

Scale

Scale is often determined by the purpose of the study. A study for determining the priority areas for investing money for salinity remediation exercises would be more detailed than a continental scale regolith mapping exercise. The scale of the study will also be determined by the complexity and detail of the data being used. For example, a study with the 9 second continental scale DEM combined with a radiometrics image with a line spacing of 1 km will not allow as detailed studies as could be achieved with a 25m DEM coupled with radiometric flown at 400 m intervals. Furthermore studies are limited by their data resolution. The CSIRO Land Systems studies were routinely surveyed and patterns recognised at 1:500,000 to 1:85,000 scale as this was the scale of the aerial photographs used.

Often not given much thought is the determination of the scale of a study by assessment of the landscape complexity as described by (Speight, 1990). The complexity in this case relates to the number of landform elements, i.e. valley floors, lower to upper slopes and crests, within a region. For example, areas of little to low relief are generally internally consistent over greater areas. Areas of higher relief can in turn be broken into the same discrete units as the lower relief terrains, the only difference being that the units repeat over a much smaller area. Using this classification, the one study area would be studied at different scales which are dependant on the scale of a landscape. As the physiographic regions coverage was designed to break the landscape into discrete, like packages, this coverage is ideal for determining the scale at which studies should be conducted. Figure 66 identifies the physiographic regions in order of complexity.

Breaking a region into landform elements does not acknowledge, however, that these less complex areas like alluvial plains can still be internally quite complex. When radiometrics are used to classify these areas of relatively low complexity, they become rather more detailed (Figure 67). Using the radiometrics, active channels and inactive palaeochannels can be identified. These elements can have very different characteristics like texture and composition which in turn affect the groundwater flow systems.

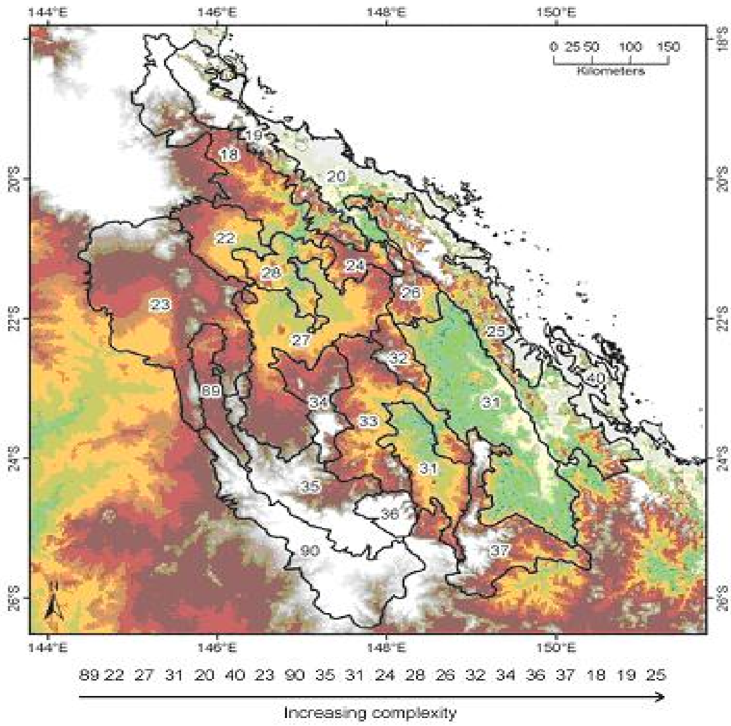


Figure 66. Physiographic regions for south east Queensland with complexity ranking. Regions with seemingly low complexity like physiographic region number 27 are revealed as more complex when radiometric data are studied (bottom).

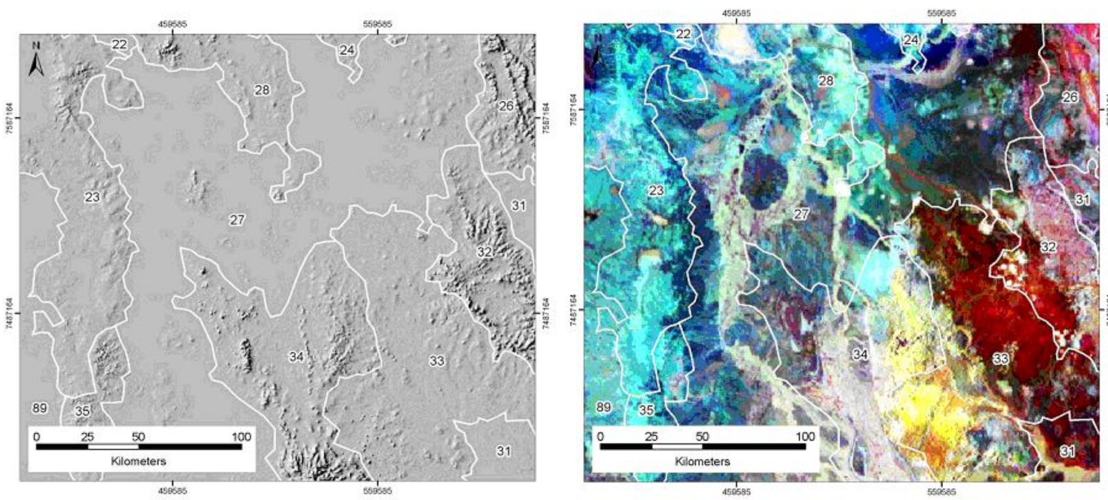


Figure 67. Complexity of physiographic regions. Left – on the 9 second DEM. Right – on radiometrics. Note the greater complexity in the radiometric image.

7.3 Physiographic regions in the study area

In this section each physiographic region is located and described. The area covered by the redefined physiographic regions is shown in Figure 68 in relation to the Upper Burdekin-Fitzroy study area.

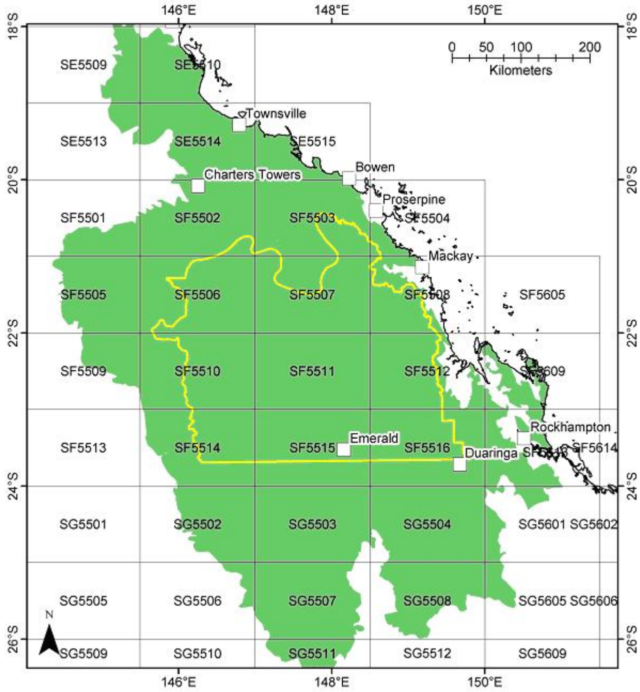
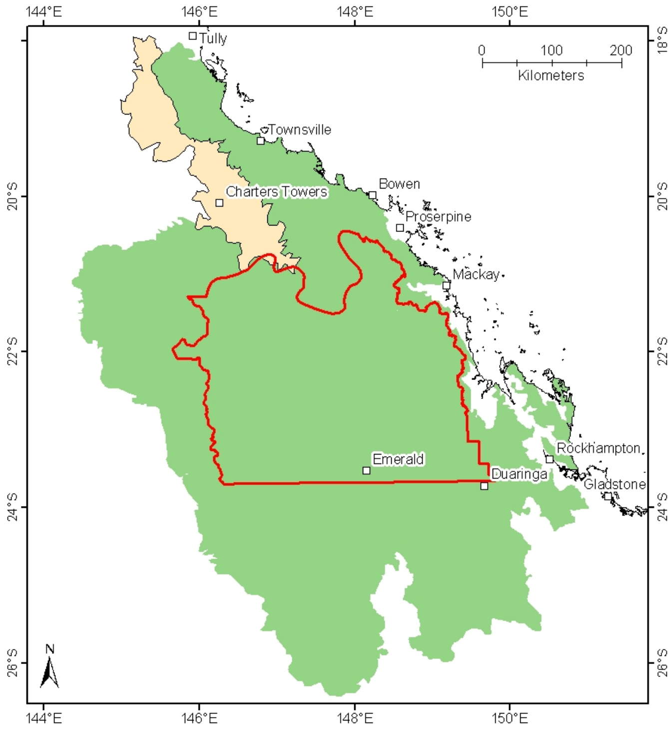


Figure 68. Location of redefined physiographic regions relating to Burdekin-Fitzroy study area.

Physiographic Region 18 (20,461 km^2)



Land Division

Eastern Uplands

Land Province

Burdekin Uplands Province

Land Zone

Burdekin Hills and Lowlands

Description

In East, hills and foot slopes on volcanic and mixed sedimentary rocks with igneous intrusions; in West, dissected laterite-capped tablelands, largely sandstone.

Lithology

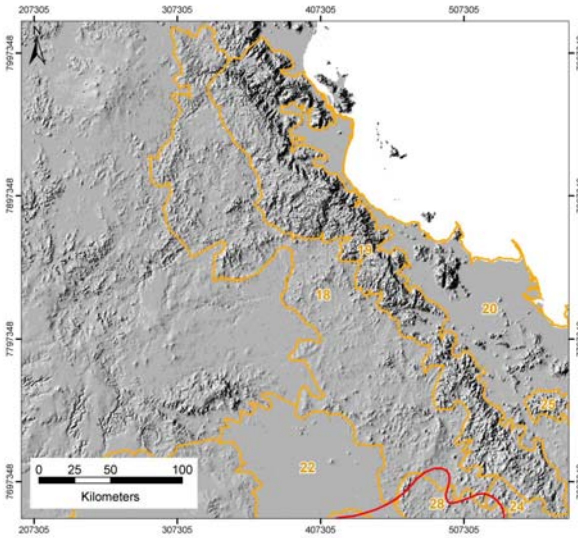
Ordovician to Devonian felsic intrusives predominate in the south. Late Devonian feldspathic-quartz rich sandstone exists in the centre of the region. Minor channel and flood plan alluvium and ferruginous duricrust and siltstone are also present in the south.

Aeromagnetics

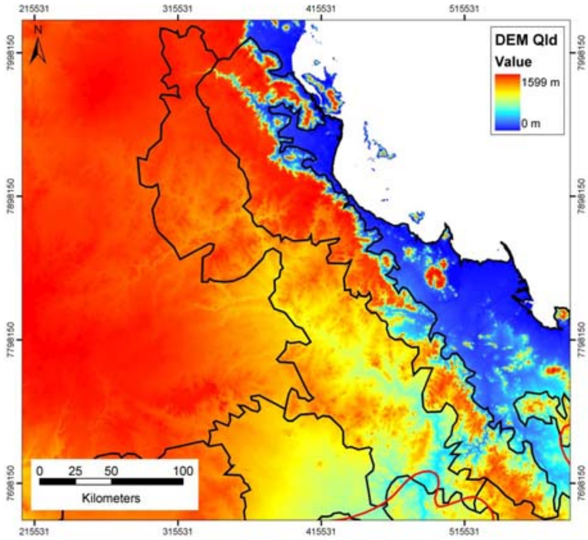
Aeromagnetic data covers the southern area of Region 18. Anomalous magnetic responses and circular intrusions represent with the Ravenswood Granodiorite complex. This unit exhibits textural variability (semi-random internal anomaly character) with distinctive lineaments and dykes. The response from intrusive complex is also observed at depth under sedimentary cover. The relatively high amplitude, short wavelength responses suggests generally shallow depth. This unit contrasts sharply with the margins of the Drummond Basin where the Carboniferous sedimentary rocks are of lower magnetic susceptibilities and characterised by flatter magnetic gradients. Cambrian metasediments are represented as flat magnetic gradient within the intrusive units. There are significant linear anomalies associated with the Carboniferous sediments which may represent folding of these weakly magnetic rocks.

Radiometrics

The radiometrics covers the southern area of Region 18. The black areas are associated with water in Burdekin Falls Dam, and the low radioelement concentrations are related to the residual sands on an erosional remnant near the dam. Felsic extrusives like rhyolite are high in all radioelements and are white to pale pink in colour. The monzogranite is highly variable in composition and varies from orange and pink with moderate concentrations of K, Th and U to yellow containing high concentrations of K and Th. The oranges and pinks may indicate a higher degree of weathering and soil development on the monzogranite. The ferruginous duricrust is low in K and U and moderate to high in Th. This is possibly due to element scavenging by the iron oxides and relative enrichment of Th due to weathering.



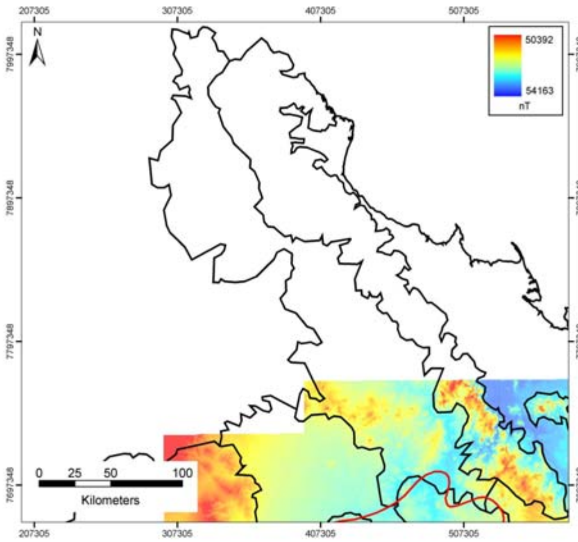
9 Sec DEM – hillshade



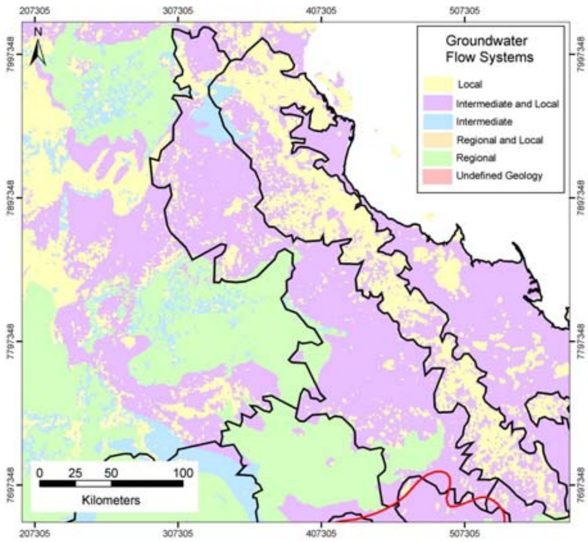
9 sec DEM

Landsat TM7 imagery not processed

radiometrics are not available

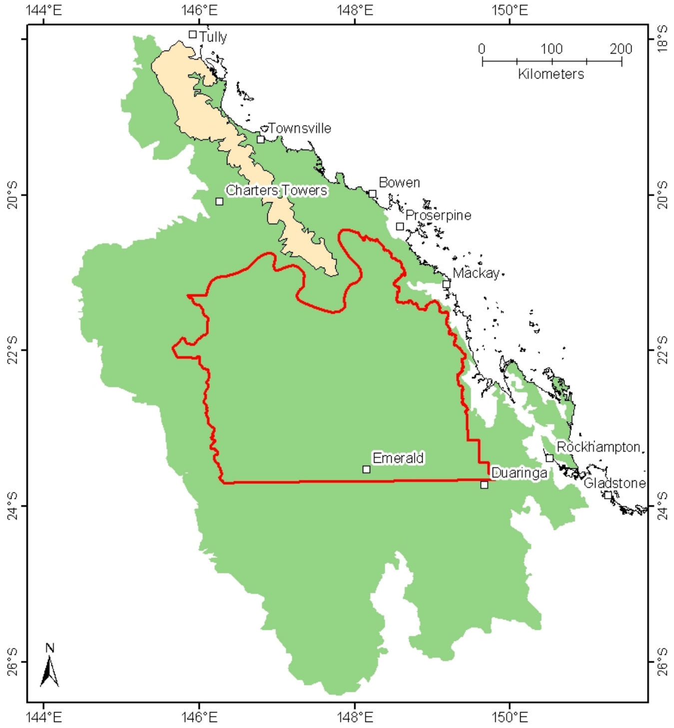


Aeromagnetics (Total Magnetic Intensity)



Groundwater Flow Systems

Physiographic Region 19 (14,973 km²)



Land Division

Eastern Uplands

Land Province

Burdekin Uplands Province

Land Zone

Hervey Tablelands

Description

Granitic uplands, rugged ranges on volcanic rocks and minor dissected laterite-capped plateaux forming steep E upland margin.

Lithology

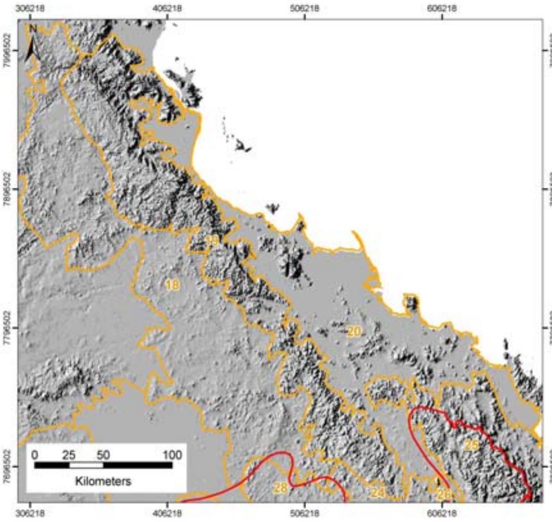
Carboniferous-Triassic felsic extrusive volcanics and felsic and mafic extrusives with associated clastic sediments predominate. Minor channel and flood plan alluvium also present.

Aeromagnetics

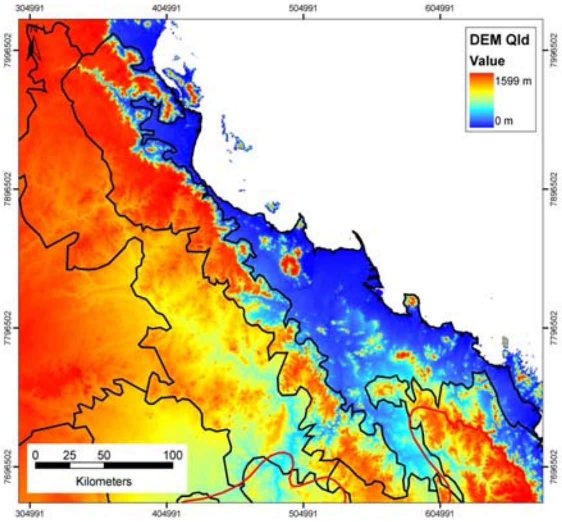
Aeromagnetic data covers only the southern part of Region 19. The dominant response is from the extensive Early Permian Bulgonunna Volcanics which unconformably overly the Drummond Basin sediments. This sequence of porphyritic rhyolitic-to-dacite flows is dissected by numerous magnetic lineaments. The unit is interpreted to be at shallow depth to outcropping. Some of the Connors Arch intrusive complex is observed as the higher frequency, shorter wavelength responses (more even character) to the east of the region. Responses from the more magnetically benign Bowen Basin sediments are observed on the western margin of the region. These sediments show relatively flat magnetic character and form a distinctive margin with the neighbouring geological units.

Radiometrics

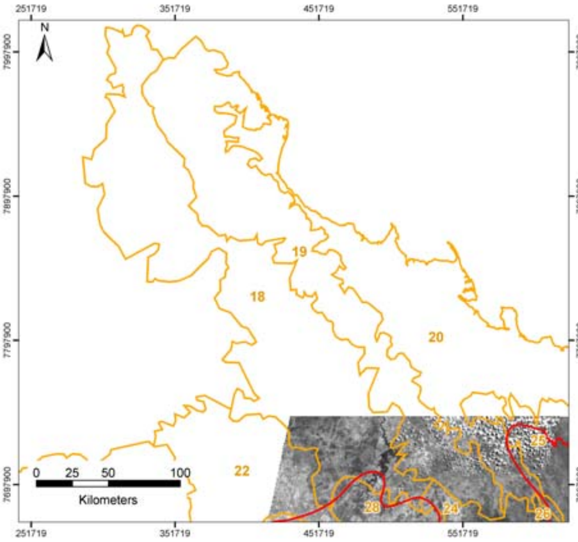
Only southern half of this region has radiometrics coverage. The image is derived from for private company data so cannot be displayed. High concentrations of K and U and very high Th relate mostly to the felsic intrusives and extrusives, and are observed as white with patches of pale yellow and green on the radiometrics image. Alluvium is depleted in K while still U and Th are moderate in concentration.



9 Sec DEM – hillshade

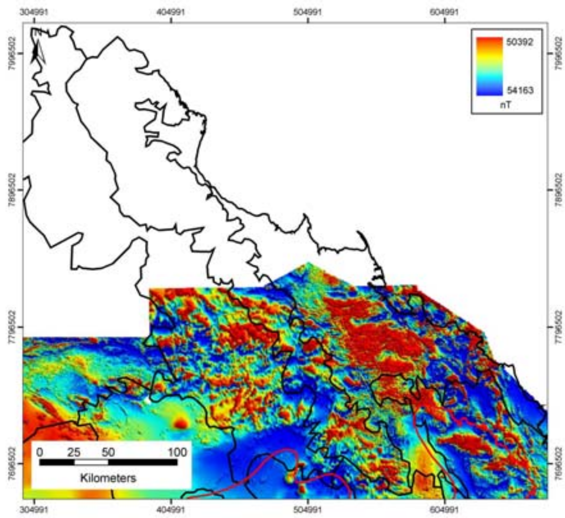


9 sec DEM

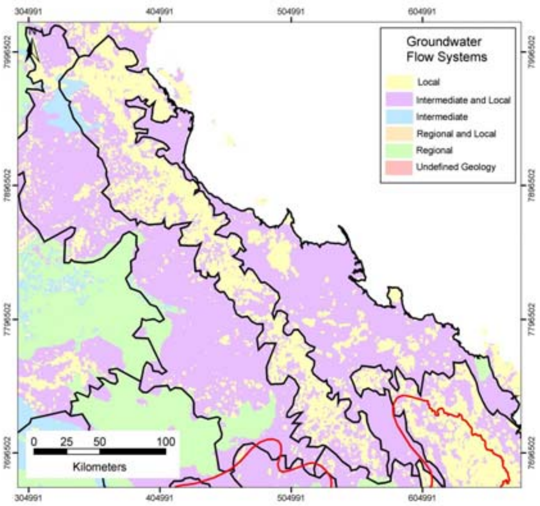


Landsat TM Band 8

Radiometrics not available

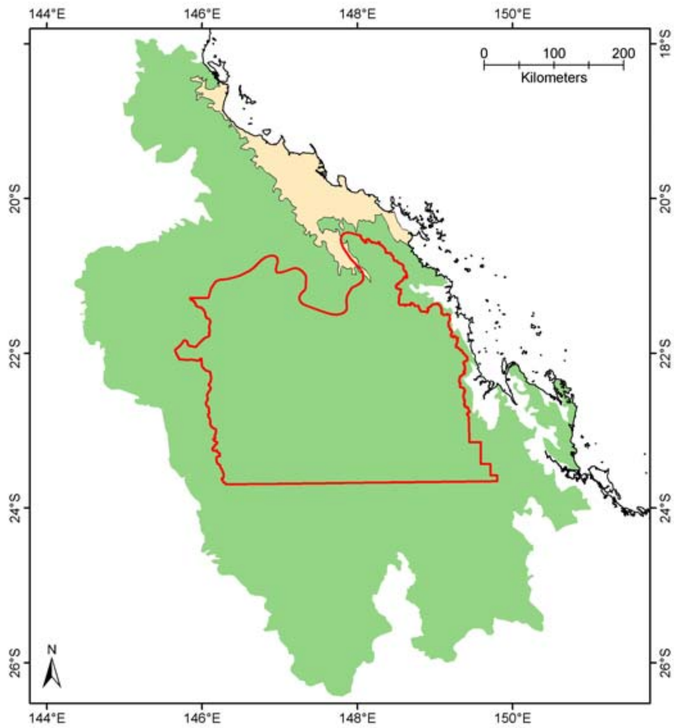


Aeromagnetics (Total Magnetic Intensity)



Groundwater Flow Systems

Physiographic Region 20 (14,297 km^2)



Land Division

Eastern Uplands

Land Province

Burdekin Uplands Province

Land Zone

Townsville Lowlands

Description

Alluvial and deltaic plains with scattered high hills of volcanics and granite.

Lithology

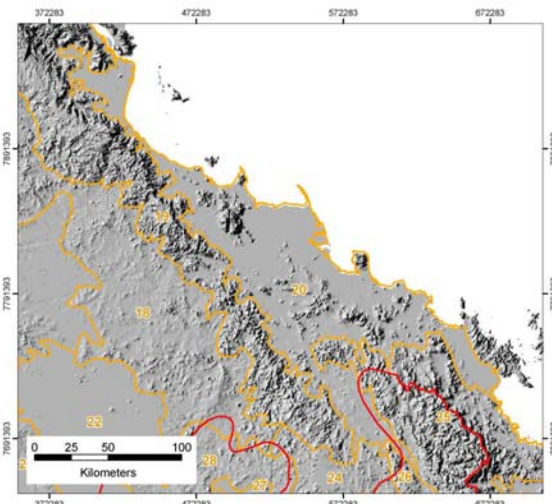
Dominated by coastal channels and plains with occurrences of Carboniferous - Cretaceous felsic and intermediate intrusives, Permian basalts, volcaniclastics and sandstones.

Aeromagnetics

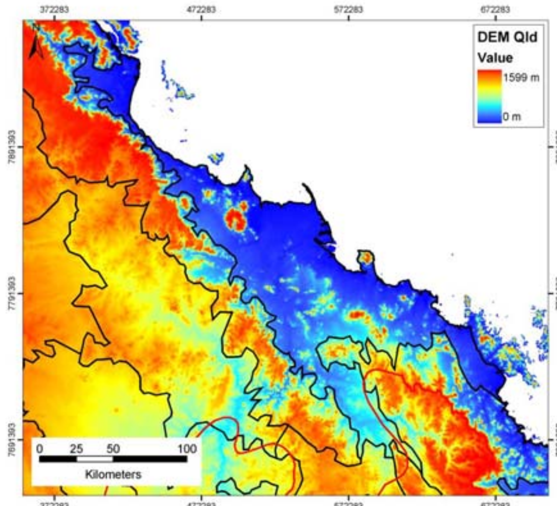
Aeromagnetic data covers the southern area of region 20. The responses are dominated by high frequency, short wavelength anomalies of the Connors Arch intrusive complex. This unit is characterised by a strong east-west structural fabric which becomes more NW trending towards the coast. Circular intrusions and large dyke structures are observed as magnetic highs. This intrusive complex is interpreted to be at shallow depths to outcropping which is confirmed from geological mapping. There is an abrupt change of magnetic character with the transition from the intrusive basement to the Bowen Basin sediments. The Bowen Basin sediments are characterised by flatter magnetic gradients with strong structural NW-NNW control expressed as linear magnetic anomalies. Many of these linear anomalies are interpreted as mafic dykes and dyke intruded faults. Numerous intrusives are observed as circular/elliptical anomalies of varying scale within the Bowen Basin. These intrusions generally observed as magnetic lows and show structural relationships with magnetic dykes. Extrusive basalts are observed as localised shallow, thin high frequency, short wavelength responses with dendritic flow patterning in the Bowen Basin.

Radiometrics

Only southern half of this region has radiometrics coverage. Emerald green areas are associated with sand plains which are low in all radioelements. The concentrations of K, Th and U in alluvium is highly variable and dependant on the source. Alluvial plains in the central east part of the region have moderate - high U and Th and low - high K. An alluvial fan in the southeast extends from the mountain ranges and is characterised by low K and U on the moderately weathered alluvium and mod-high K and U and mod Th on the active parts of the fans. The felsic intrusives are yellow-red in colour and have moderate - high K, Th and U. The volcaniclastics and associated clastic sediments are deep red in colour and generally low in all radioelements.

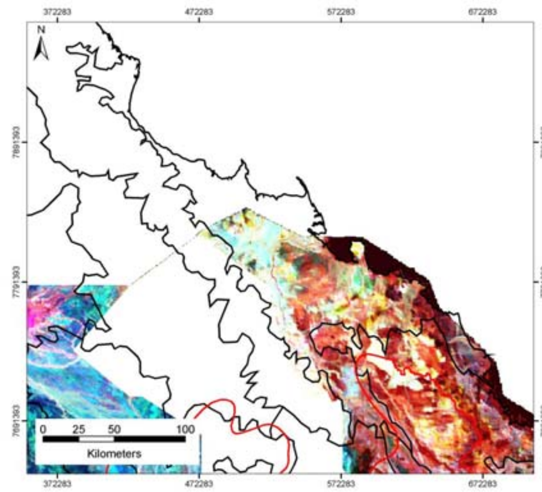


9 Sec DEM – hillshade

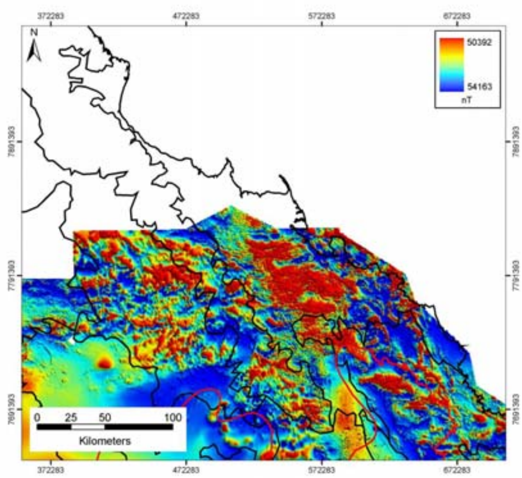


9 sec DEM

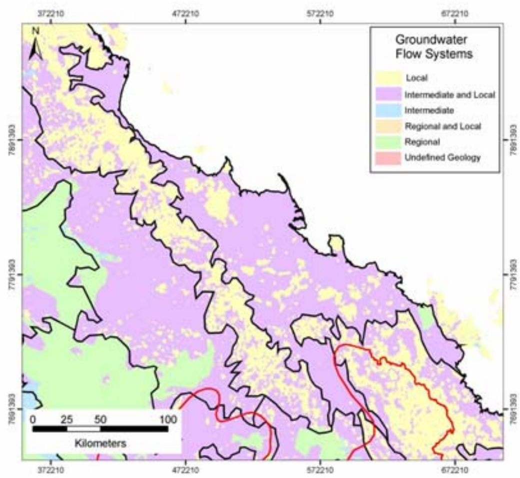
Landsat TM7 satellite imagery not processed



Radiometrics

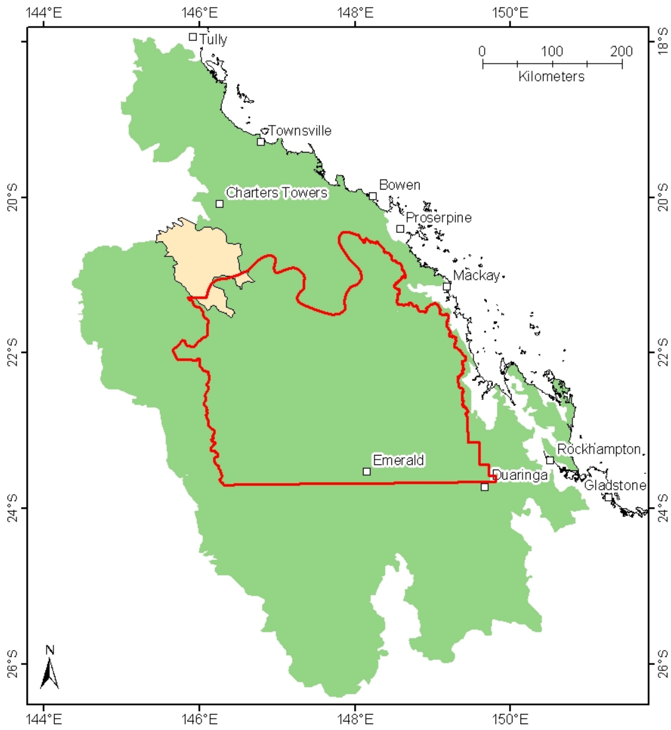


Aeromagnetics (Total Magnetic Intensity)



Groundwater Flow Systems

Physiographic Region 22 (8,858 km²)



Land Division

Eastern Uplands

Land Province

Burdekin Uplands Province

Land Zone

Cape River Plains

Description

Ferruginous duricrust with convergent drainage and with minor alluvial channel deposits.

Lithology

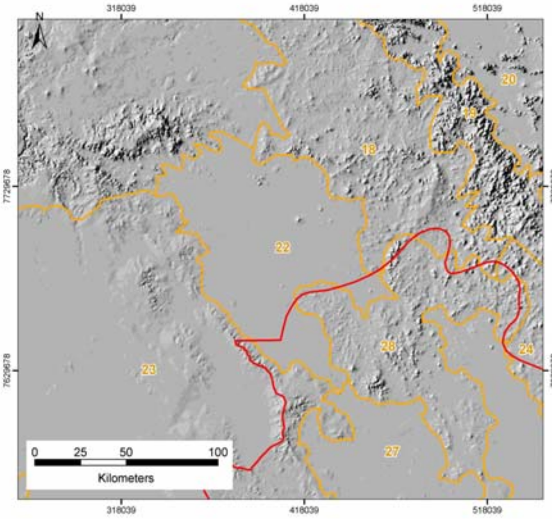
Dominantly Cainozoic duricrust with overlying alluvial channels. Sand plains are located to the south of the region, with minor rhyolite and clastic sediments in the north.

Aeromagnetics

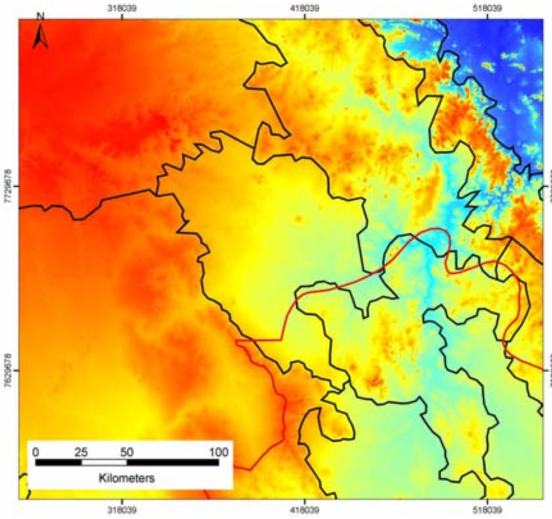
Aeromagnetic data covers most of Region 22. A majority of the anomalous responses are related to basement igneous rocks, possibly the Ravenswood Granodiorite complex or a correlate. The southern part of this physiographic region is characterised by low magnetic gradients representing lower magnetic susceptibilities of the Drummond and Galilee Basin sedimentary rocks. There are some distinctive inter-sedimentary magnetic anomalies visible within these magnetically quiet areas. These features may be fold or thrust type structures in the weakly magnetic sediments. Some isolated small intrusions are observed within the basin sediments. Some of these intrusions are characterised by demagnetised alteration halos with significant magnetite destruction areoles and radial linear magnetic anomalies interpreted as ring dykes. The dykes form both N-S and later cross-cutting E-W structures up to a few km in length.

Radiometrics

Active alluvial plains are generally high in K and Th and moderate in Th, characteristic of the felsic intrusive of which they are derived. With distance from the source, the K signature fades as the sediments become more weathered. Although the topography is subdued the radiometrics delineates active and palaeo channels, the older channels have low K due to weathering processes. Moderate Th, and moderate-high U in the palaeo channel systems may result from scavenging by iron oxides in the duricrust. The dark blue area to the southwest of the region is characterised by very low K, low Th and moderate U appears to be a much older surface than the rest of the region.



9 Sec DEM – hillshade



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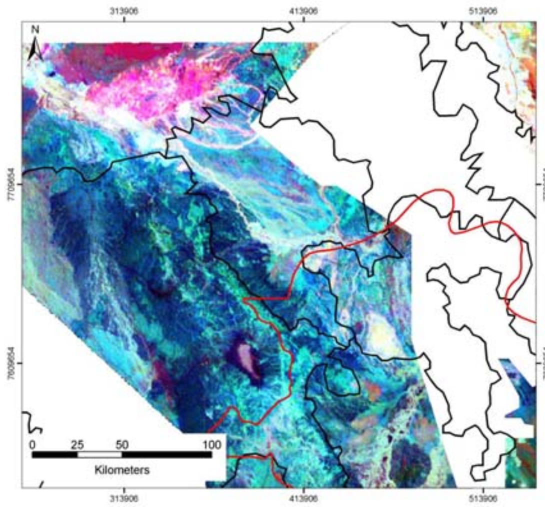
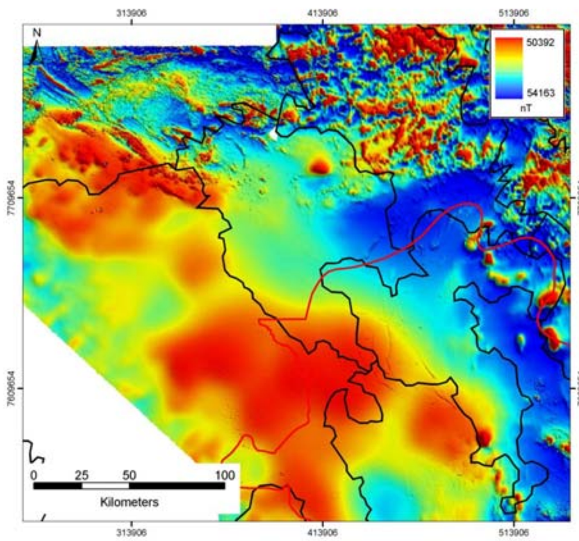
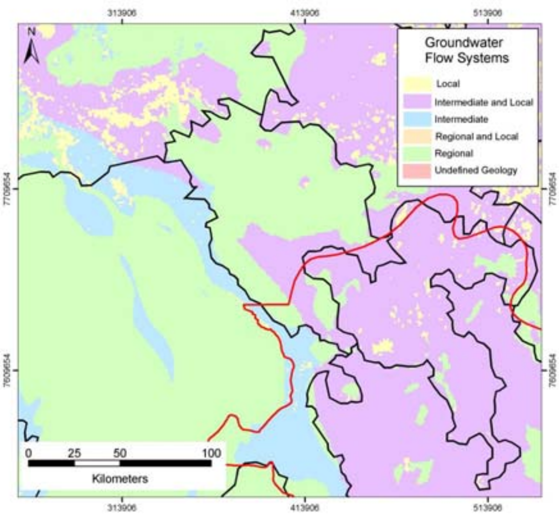


Radiometrics

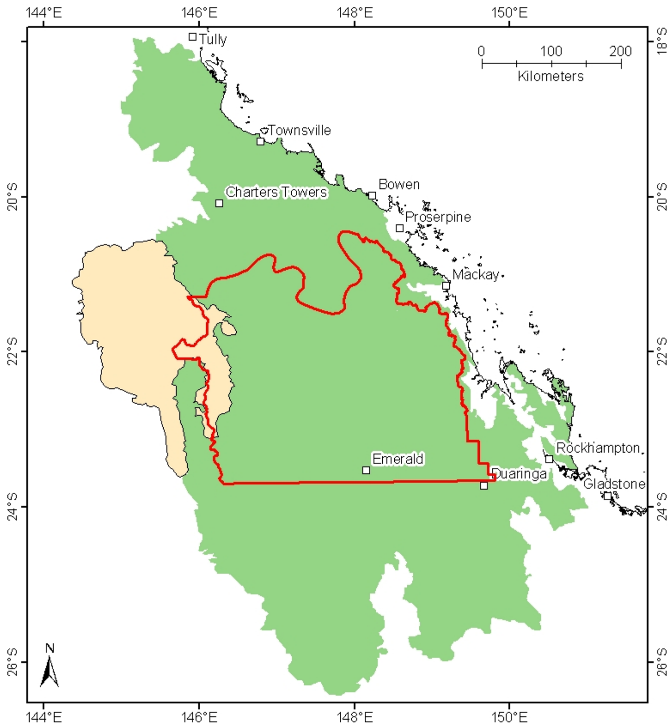


Aeromagnetics (Total Magnetic Intensity)



Groundwater Flow Systems

Physiographic Region 23 (36,788 km^2)



Land Division

Eastern Uplands

Land Province

Burdekin Uplands

Land Zone

Alice Tableland

Description

Perched sandy plain with interior drainage and higher lateritic rim; minor sandstone hills; linear drainage in west.

Lithology

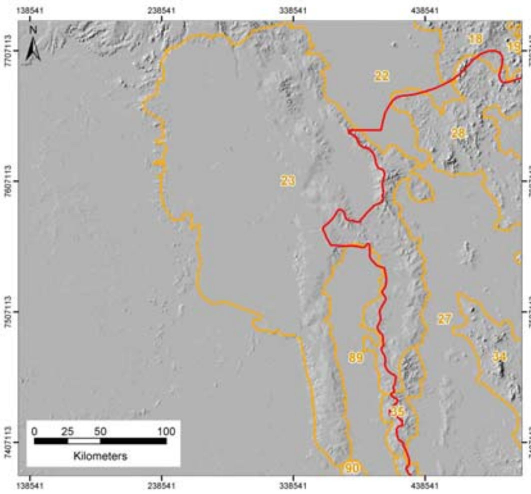
Predominantly Cainozoic sediments comprised of sand plains and channel and flood plain alluvium. Minor sandstone, siltstone, mudstone, conglomerates and lacustrine deposits are also evident.

Aeromagnetics

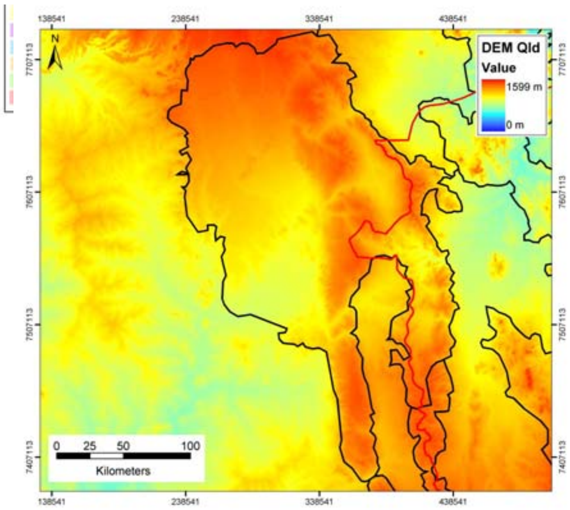
Only a small section of Region 23 falls within the study area. The aeromagnetic responses are characterised by relatively flat magnetic gradients reflecting the dominance of low susceptibility sedimentary units that comprise the Galilee Basin sequence. The positive long wavelength responses are probably sourced from regional structures located within the underlying basement. Some large ENE-WSW anomalies interpreted as large structural features are observed within the Galilee basin extending into the Drummond Basin.

Radiometrics

In the west are a series of south draining alluvial fans on radioelement depleted residual sand plains. The sand plains are dark blue in colour. The alluvial plains show a history of channel switching and evidence of older channels beneath are more subdued in colour and have very low K, and low Th and U. The channel system to the west is a more active than the system located in the centre of the physiographic region indicated by moderate Th and U in the active system. The sandstone hills are enriched in U and have moderate Th and low K when compare to the surrounding sand plains. The hill tops have a higher Th signature than the weathered slopes with a thicker soil cover. Alluvial sediments draining from the sandstone hills have higher Th corresponding to their sandstone derivative. The lacustrine sediments of Lake Buchanan are pink in colour from moderate K, Th and U. This reflects a possible granitic source and may be enhanced by the presence of potassic clays (e.g. illite) in the lake sediments.

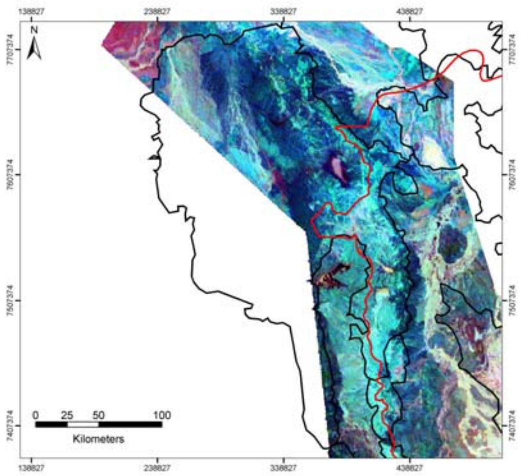


9 Sec DEM – hillshade

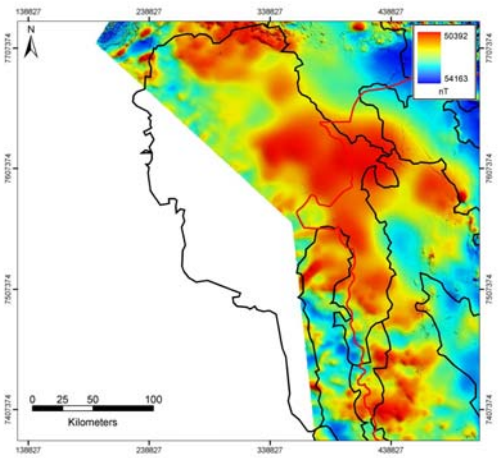


9 sec DEM

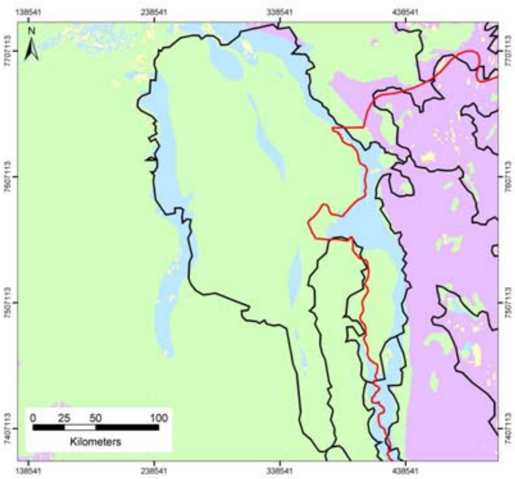
Landsat TM image not processed



Radiometrics

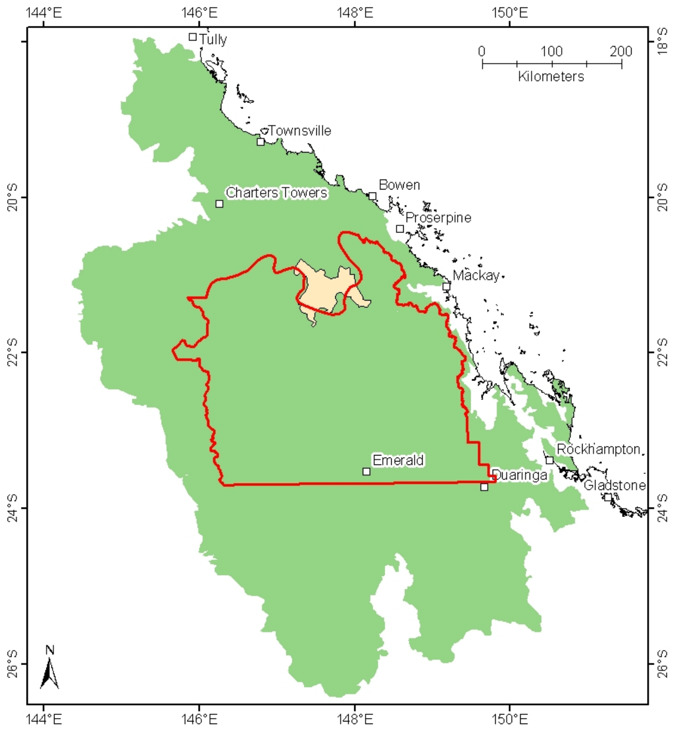


Aeromagnetics (Total Magnetic Intensity)



Groundwater Flow Systems

Physiographic Region 24 (4,042 km²)



Land Division

Eastern Uplands

Land Province

Burdekin Uplands Province

Land Zone

Bulgonunna Tableland

Description

Undulating tableland; higher centre and sloping margins on volcanic rocks with peripheral mantle of lateritic clayey sand.

Lithology

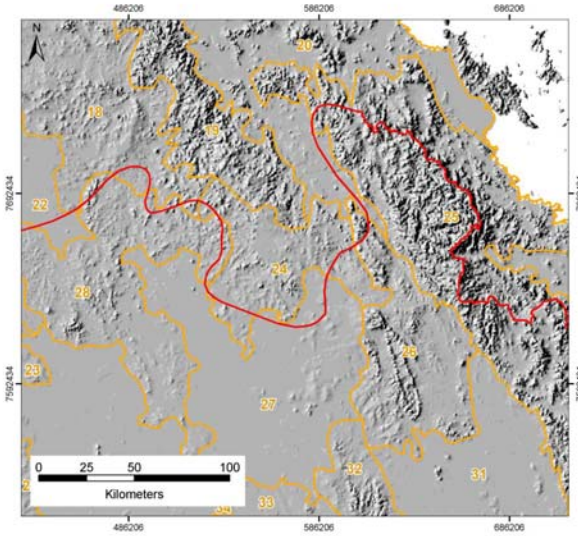
Late Carboniferous felsic extrusive volcanics on west. Undivided Tertiary sediments are in the centre of the region while Permian and Triassic lithic and clastic sediments and Tertiary mafic extrusives are present in the eastern part of the region.

Aeromagnetics

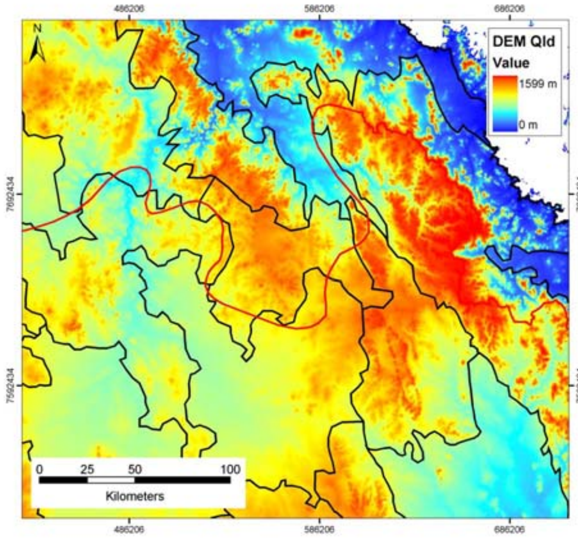
Only the southern part of Region 24 falls within the study boundary. This area is dominated by high frequency, high amplitude responses from the Carboniferous extrusives of the Bulgonunna Volcanics. The irregular distribution of magnetite within these rocks is represented by the variable magnetic response. Intrusions are also evident in this unit as small circular bodies with typically negative polarities. The quieter magnetic character in the west of the region represents the Bowen Basin sediments. These sediments are relatively non-magnetic, but have been extensively intruded by small plugs (of mainly negative polarities). These intrusions show relationships with NW-NNW trending linear magnetic anomalies interpreted as magnetic dykes. Thin, shallow to outcropping basaltic flows are found within the Bowen Basin, and are identified as areas of strong magnetic susceptibility with mainly negative remanence. These flows tend to mask the magnetic responses from the underlying geology.

Radiometrics

The radiometrics image of private company data so cannot be displayed in the west. The felsic volcanics in the west show as being high in K and U and moderate Th. The fresher volcanics are more yellow in colour from higher relative Th compared to the fresher bedrock. The undivided Tertiary sediments have green-blue hues relate to very low K and residual U and Th left within the soil profile after K is leached away. The dark blue areas in the Tertiary sediments are low in all 3 radioelements. Tertiary mafic extrusive rocks in east are red-black as it is depleted in all radioelements. Its colour may indicate that it has a deep weathering profile. Lithic sandstones in the east have moderate potassium, probably in the form of feldspars and micas, but is low in Th and U.



9 Sec DEM – hillshade



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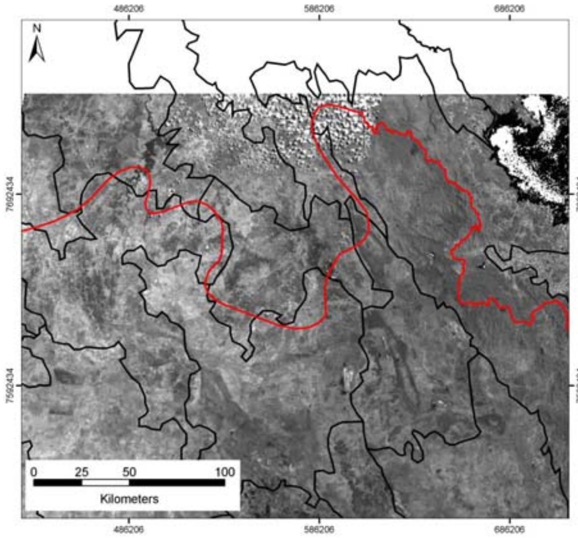
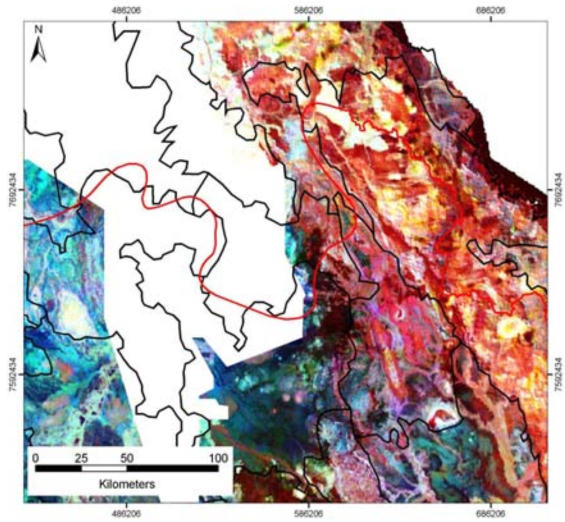
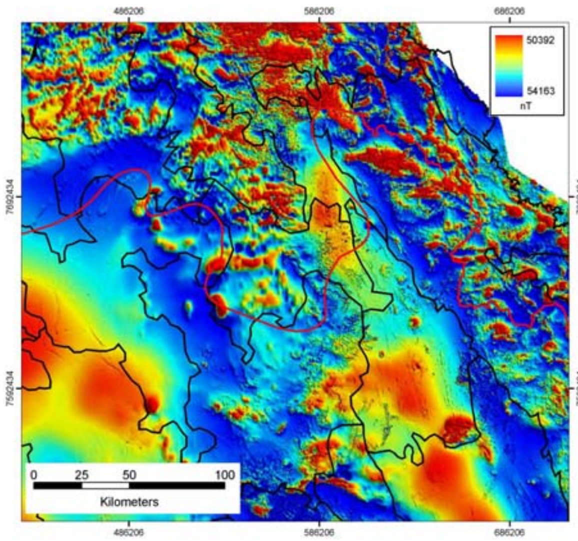


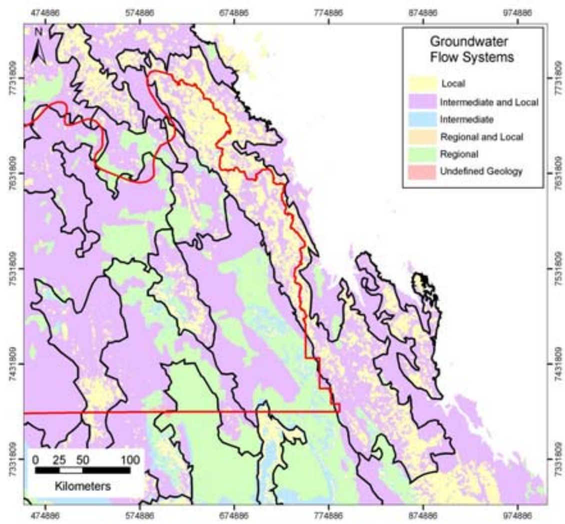
Landsat TM Band 8



Radiometrics

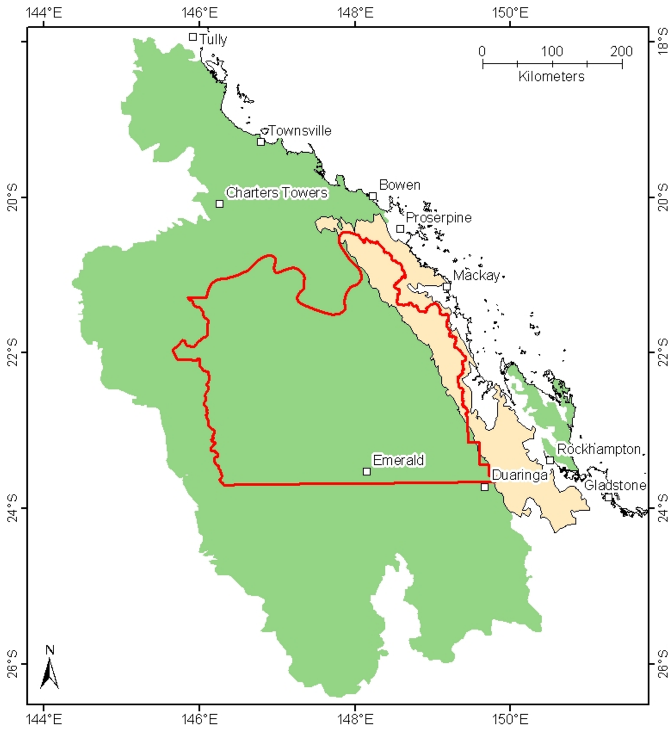


Aeromagnetics (Total Magnetic Intensity)



Groundwater Flow Systems

Physiographic Region 25 (28,585 km^2)



Land Division

Eastern Uplands

Land Province

Burdekin Uplands

Land Zone

Connors Ranges

Description

Rounded mountain ranges on predominately volcanic and volcaniclastic rocks building dissected E margin of uplands.

Lithology

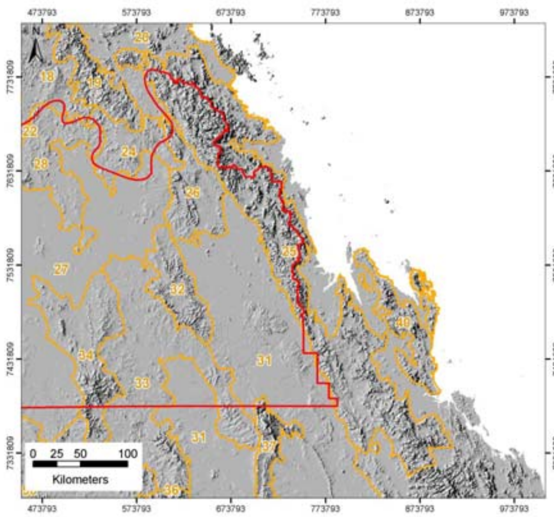
Complex and varied geological terrain. Felsic and intermediate intrusives, mafic extrusives, volcaniclastics and sedimentary rocks ranging in age from the Devonian to the Tertiary are present. Tertiary sand plains and alluvium are also present on the eastern side.

Aeromagnetics

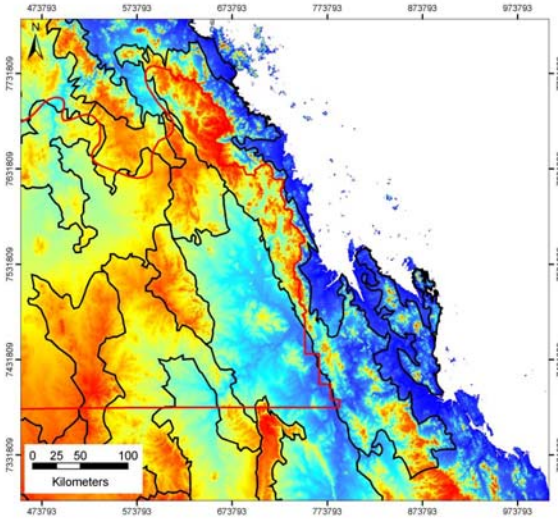
Physiographic region 25 covers most of the eastern margin of the study area. To the east, the physiographic correlates quite well with the tectonic margin of the Bowen Basin and the Connors Arch-Urannah intrusive complex, which forms magnetic basement in this area. This margin is inferred as the change in magnetic character between low magnetic gradients associated with the Bowen Basin to complex magnetic anomalies of the intrusive complex with a strong east-west fabric. Numerous large circular/elliptical intrusive bodies are interpreted within these igneous units. Areas of flatter magnetic gradients are interpreted as sedimentary material of low magnetic susceptibility. The Connors volcanics to the south-east shows some anomalous character in the magnetics.

Radiometrics

Felsic intrusives are characterised by a white-yellow reflectance and have high - very high concentrations of K, Th and U. The intermediate intrusives have moderate K and low K and Th are redder in colour than their felsic counterparts. Volcaniclastics in the east have moderate concentrations of K, Th and U.



9 Sec DEM – hillshade



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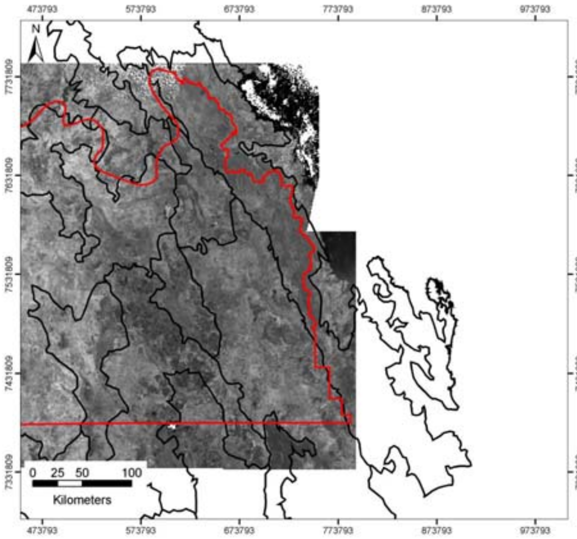

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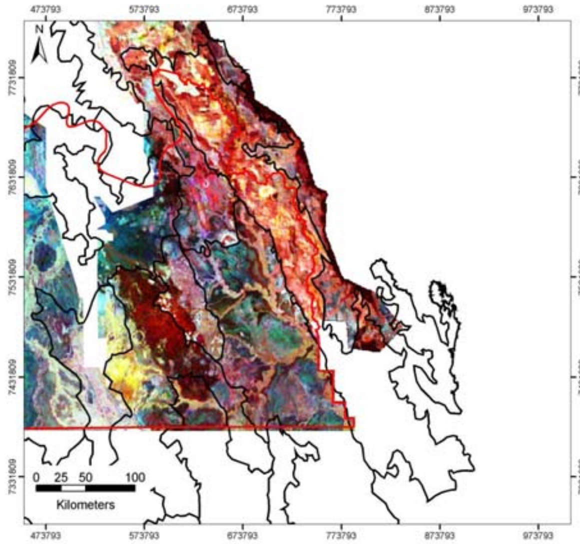
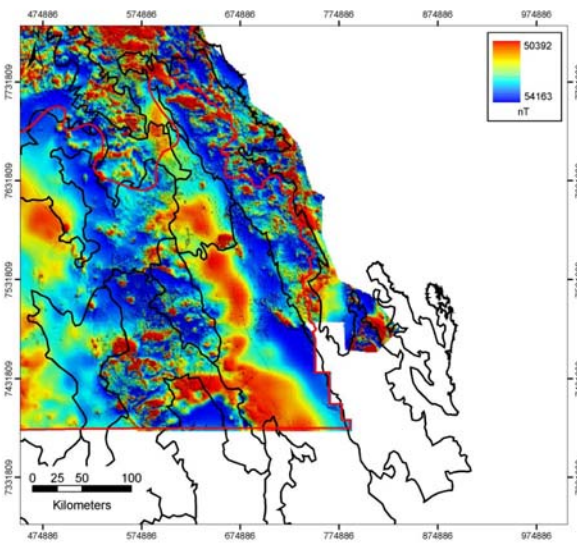
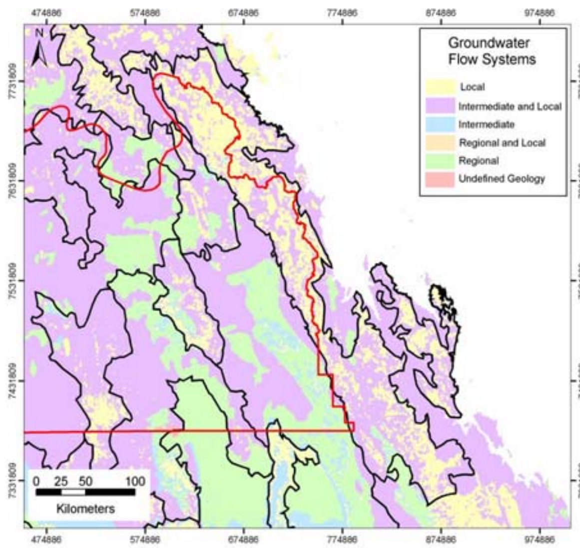


Radiometrics

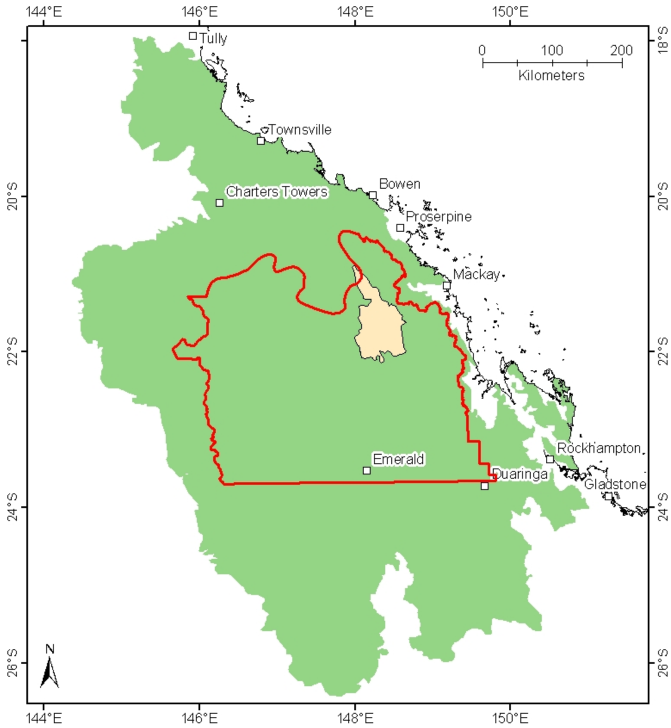


Aeromagnetics (Total Magnetic Intensity)



Groundwater Flow Systems

Physiographic Region 26 (5,106 km^2)



Land Division

Eastern Uplands

Land Province

Fitzroy Uplands Province

Land Zone

Carborough Ranges

Description

Sandstone and minor basalt plateaux to north; lower rolling country on sedimentary and volcanic rocks and sand plains.

Lithology

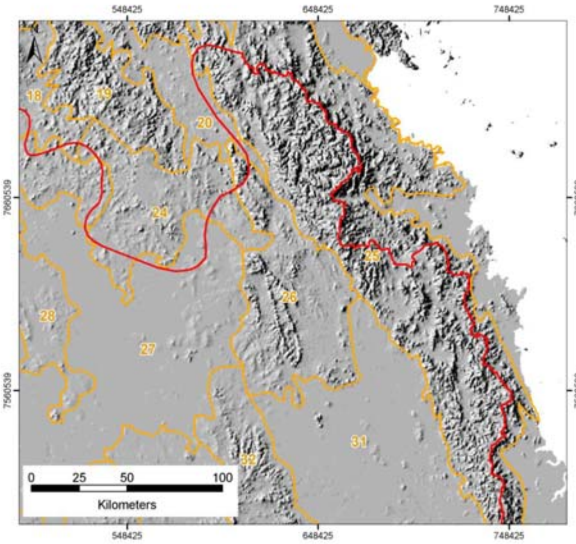
Dominated by Permian sandstones, and Triassic lithic, micaceous and quartzose sandstones. Cainozoic sand plains and Quaternary alluvium and Tertiary basalts are also common. Early Cretaceous felsic intrusives are located in the south.

Aeromagnetics

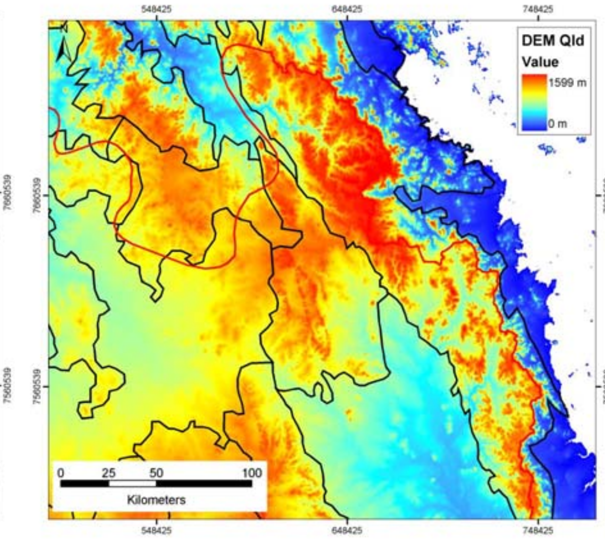
Physiographic region 26 is contained entirely within the Bowen Basin. Magnetic anomalies worth noting include the strong N-NW trending linear anomalies which are interpreted mainly as mafic dykes. There are some very large intrusions within this region, the largest being the Bundarra Granodiorite. This and other smaller intrusions within this area are characterised by negative to positive anomalies, alteration haloes (magnetite destruction) surrounded by radial dyke type intrusions showing weak to strong anomalies. The N-NW structural patterning becomes more pronounced near these intrusions. The high frequency, lobate, near surface responses observed on the margins of the physiographic region are Tertiary basalt flows. All of the mentioned features contrast sharply with the Cainozoic and basin sediments which exhibit generally low magnetic susceptibilities. Basement rocks at depth form the very broad wavelength responses either due to lithology or deep structure.

Radiometrics

A purple hue indicating low K, low-moderate Th and high U is associated with lithic sandstones, sand plains and some alluvial sediments. Higher U appears to be associated with the boundary of different geological units thus may indicate movement of fluids along these pathways. The tertiary sediments are dark green in colour and are low in all 3 radioelements. They are likely to be residual sands that are predominantly composed of quartz. The Tertiary basalts in the north east are deep red and are low in K, Th and U.



9 Sec DEM – hillshade



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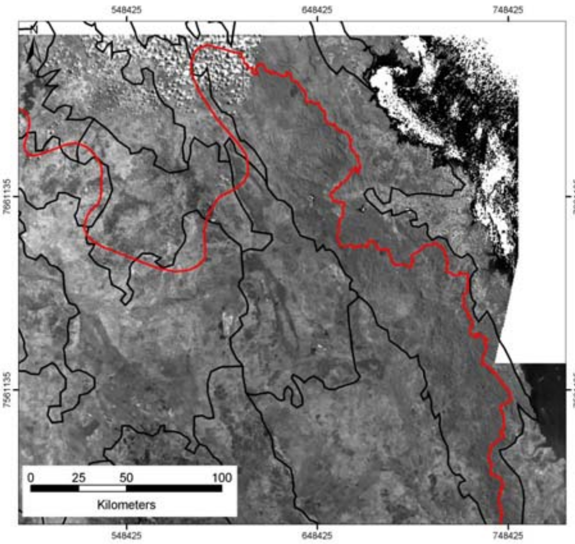
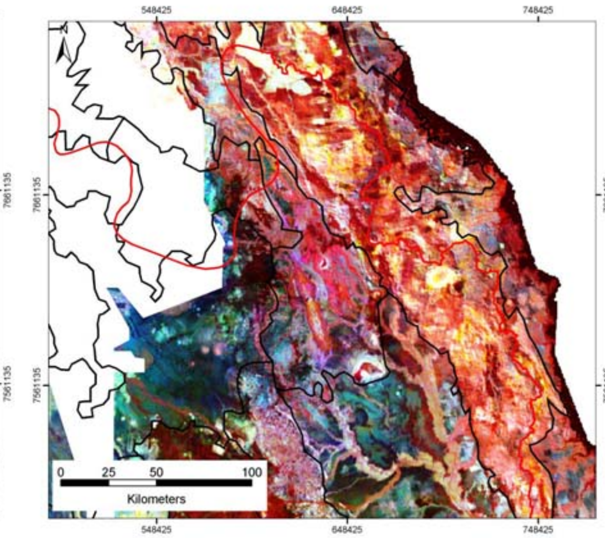
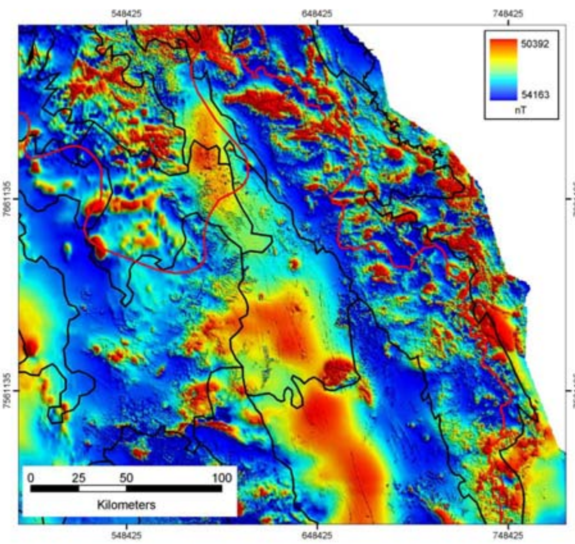


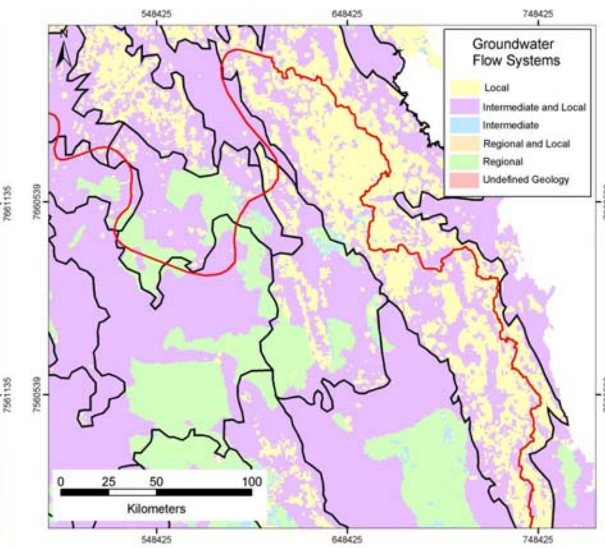
Landsat TM Band 8



Radiometrics

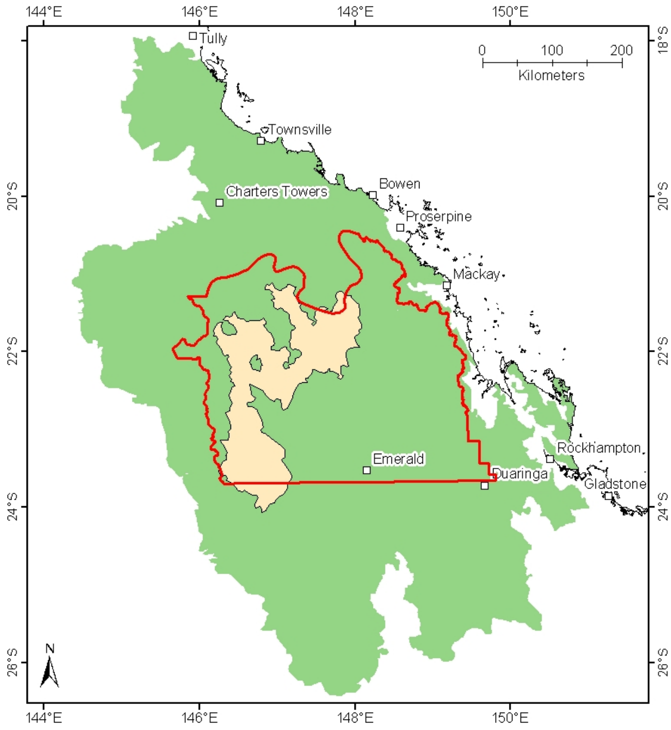


Aeromagnetics (Total Magnetic Intensity)



Groundwater Flow Systems

Physiographic Region 27 (2,614 km2)



Land Division

Eastern Uplands

Land Province

Fitzroy Uplands

Land Zone

Belyando Plains

Description

Clay plains and sandy plains; minor hills

Lithology

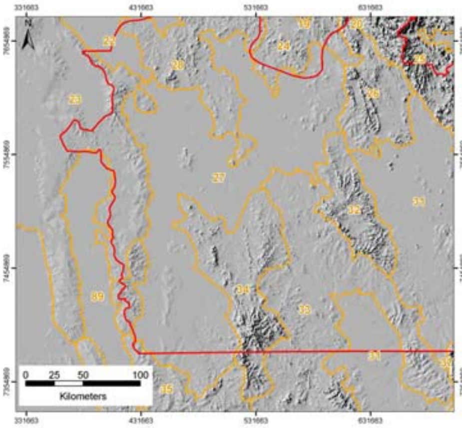
Cainozoic sand plains including some residual alluvium, gravels and clay and alluvial channel and plain systems. Minor Tertiary basalts and ferruginous duricrusts and Carboniferous - Permian clastic sediments.

Aeromagnetics

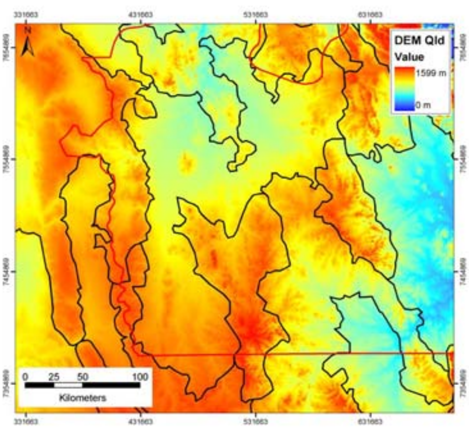
This physiographic region bears little relationship to the magnetic responses underlying geology. It covers four tectonically distinct zones, the Drummond Basin, some of the Galilee Basin, part of the Anakie Inlier and some of the Bowen Basin. The eastern part region is characterised by generally low magnetic gradients due to the presence of thick sedimentary units of low magnetic susceptibility overlying crystalline basement. This characterises the western Drummond and Galilee Basins and northern areas of this physiographic region. Some shallow to outcropping highly anomalous Tertiary basalts are also identified. The eastern part of the region includes a small part of the northern Bowen Basin and is characterised by responses from extensive basalt flows overlying relatively non-magnetic Permian basin sediments. The region is characterised by extensive Cainozoic cover which is relatively no-magnetic, but does cover a significant amount of bedrock geology. The aeromagnetics reveal numerous intrusions at variable depths observed as circular/elliptical anomalies exhibiting both positive and negative remanence of variable magnetic intensity. Distinctive contact aureoles may be observed as zones of low magnetic gradients around the intrusive margins. Positive to negative anomalies characterise numerous linear intrusive dykes observed as both east-west swarms and as northwest parallel trending features. The east-west trending dyke swarms are interpreted to be sourced from the underlying Anakie Metamorphics which forms basement within the central north – east area of the region, while the strong N-W parallel features are contained within the Bowen Basin area. Basalt flows are interpreted in the northeast and are characterised by short wavelength, high amplitude responses best observed in 1st and 2nd vertical derivative filtered images. The significant response from basalts tends to mask the responses from the underlying geology. Granite outcrop in the central part of the region is represented as positive anomalies with obvious NW structural control.

Radiometrics

North draining alluvial channels are characterised by moderate K, Th and U signatures. These overlie extensive sand plains which exhibit a texture showing palaeochannels and are predominantly low in K, Th and U. The angular maroon objects within the alluvial plains are low in K, Th and U and appear to be associated with local topographic highs. They may reflect sedimentary bedrock covered only by a thin veneer of flood plain sediments. To the north east the character of the tributaries entering the main channel changes to reflect their local sources. Those draining from the mafic intrusives and extrusives are lower in U and Th while the main channel is high in all 3 radioelements. White circles within this region relate to felsic extrusives and have very high K, Th and U.



9 Sec DEM – hillshade



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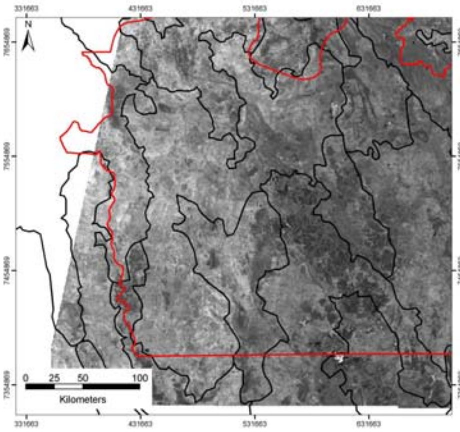
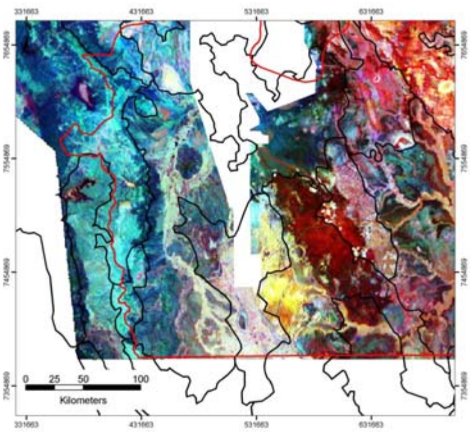
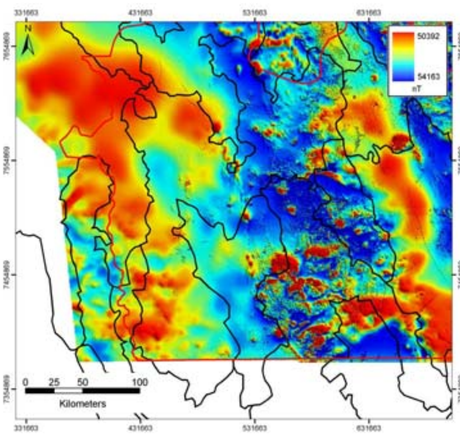


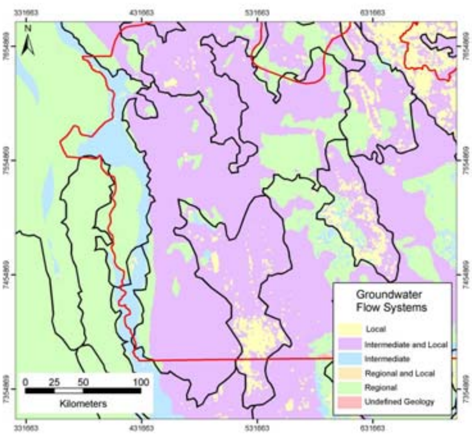
Landsat TM Band 8



Radiometrics

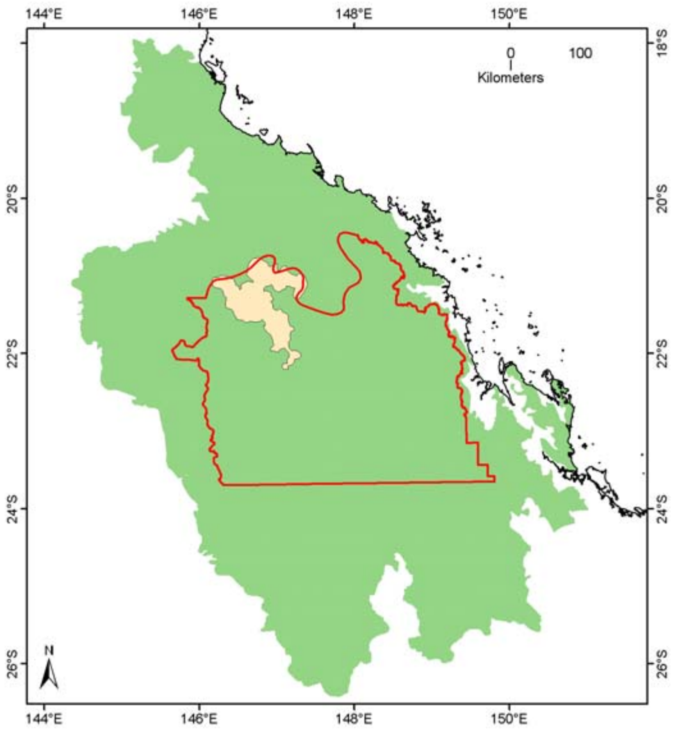


Aeromagnetics (Total Magnetic Intensity)



Groundwater Flow Systems

Physiographic Region 28 (7,814 km²)



Land Division

Eastern Uplands

Land Province

Fitzroy Uplands Province

Land Zone

Scartwater Hills

Description

Hills, ridges and vales on sandstone and minor metamorphic rocks; Tertiary sediments on rises and ferruginous duricrust to south.

Lithology

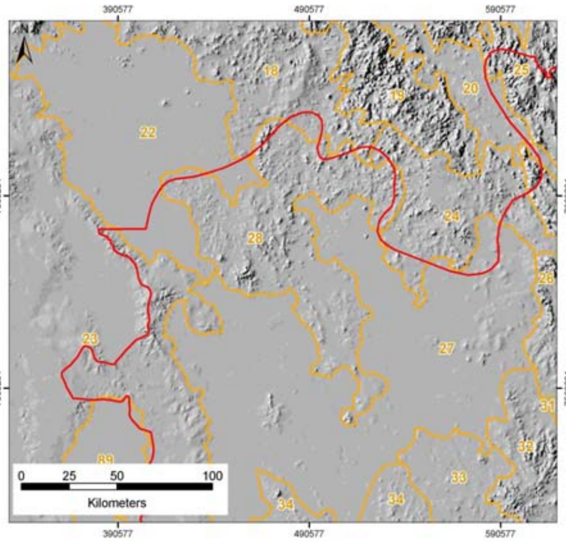
Carboniferous aged quartzose to feldspathic clastic sediments dominate with minor Neoproterozoic - Cambrian metasediments and Devonian - Carboniferous sandstones are also present. Undivided Tertiary sediments, alluvium and sand plains are also present with minor ferruginous duricrust exists in the south.

Aeromagnetics

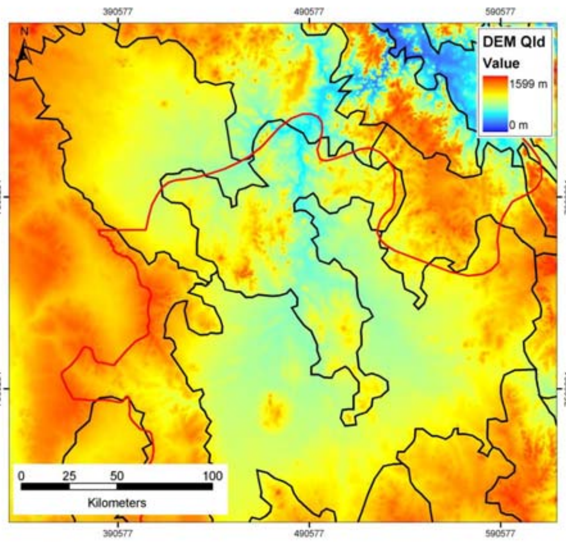
Physiographic region 28 covers two tectonically distinct zones, the Drummond Basin and the Anakie Inlier. The margins of this physiographic region generally correlate well with the mapped outcrops of Carboniferous Drummond basin sediments. These units exhibit generally low magnetic susceptibilities. Areas where the Anakie Metamorphics have been mapped exhibit strong a E-W structural fabric, and the margins with the Drummond basin could be inferred as distinctive anomalous edges. Intrusives may be observed as both large and small circular magnetic anomalies. Alteration haloes surrounding these intrusions are common with radial magnetic lineaments interpreted as dykes. The southern part of the region extends into the anomalous Retreat Granite.

Radiometrics

The metasediments containing siltstone, phyllite and schist and the feldspathic sandstones are high in K and U and moderate Th, hence have a bright radiometrics signature. Radioelement zonation is evident in some of the units relates to folding of different sedimentary units. On the northeast, alluvial sediments draining from the felsic extrusives are high in K and U while those sourcing sand plains are low in K, Th and U reflective of their source. Ferruginous duricrust in the south is low in K and high in Th and U, probably related to scavenging of the Th and U by the iron oxides.



9 Sec DEM – hillshade



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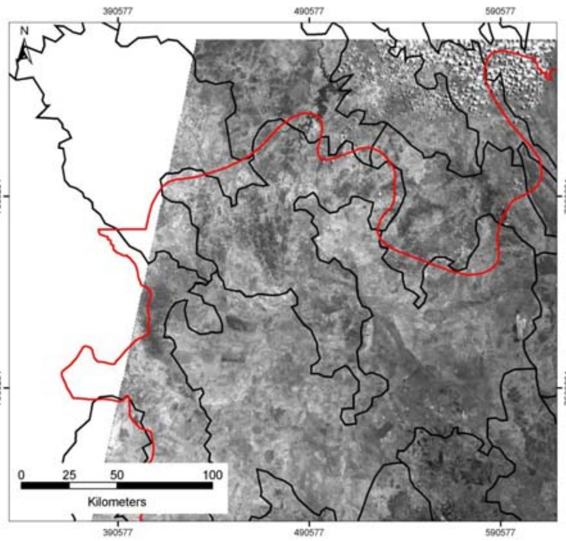
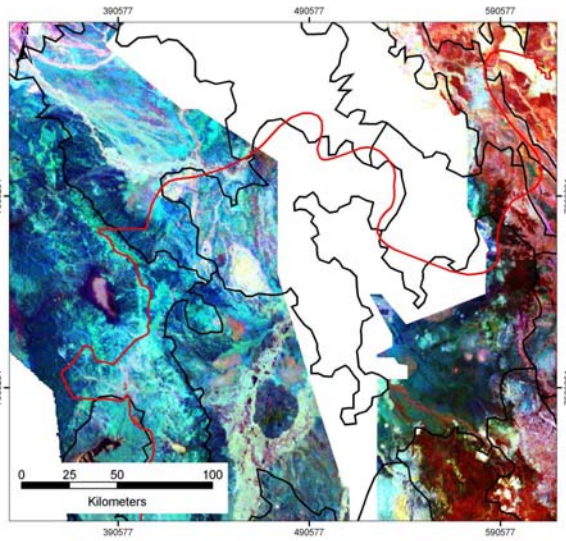
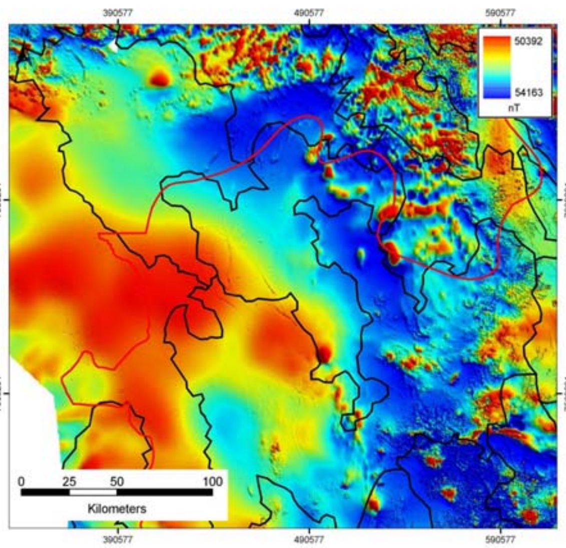


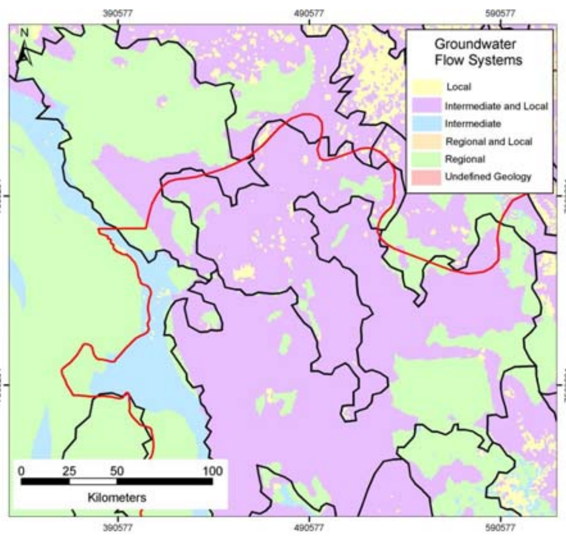
Landsat TM Band 8



Radiometrics

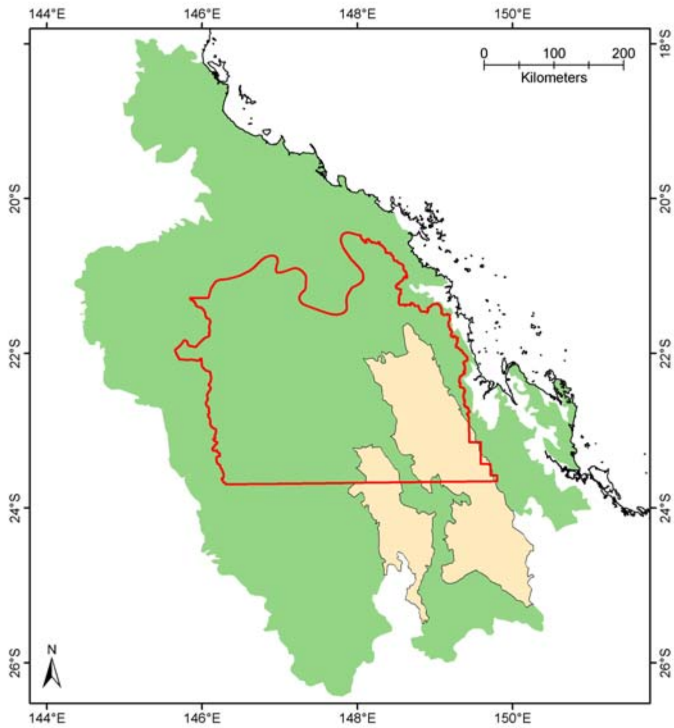


Aeromagnetics (Total Magnetic Intensity)



Groundwater Flow Systems

Physiographic Region 31(40,378 km²)



Land Division

Eastern Uplands

Land Province

Fitzroy Uplands Province

Land Zone

Mackenzie-Dawson Lowlands

Description

Alluvial plains, clay plains and sandy lowlands and basalt plains.

Lithology

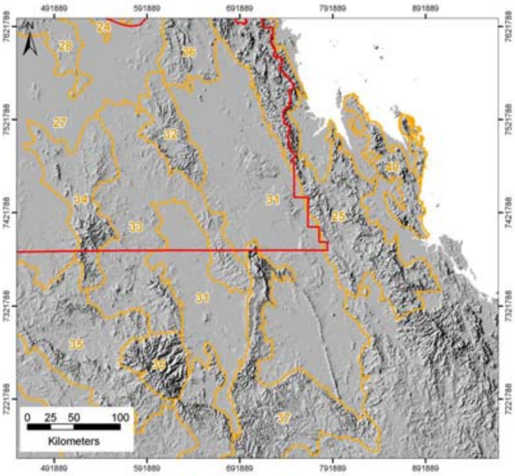
Region is dominated by undivided Tertiary sediments, sand plains and alluvium. Clastic sediments of the Permian aged Blackwater group are present in the east while Tertiary basalts are present in the west.

Aeromagnetics

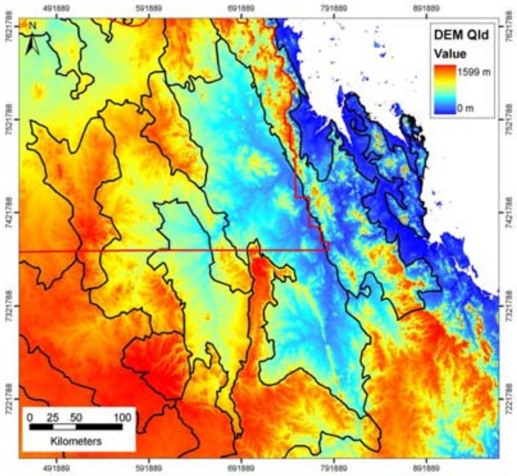
Physiographic region 31 covers most of the Central Bowen Basin and some of the Northern Bowen Basin with its eastern margin roughly co-incident with that of the interpreted basin margin, which is characterised as a distinct change in magnetic response from relatively flat gradients to highly anomalous mottled responses. This has been interpreted as a change from the Bowen Basin sediments to the intrusive basement rock in the east. There is also a distinct correlation between the western physiographic margin and a change in aeromagnetic response. This may reflect a distinct change in the underlying geology, possibly related to the strong NW structural trends observed as numerous magnetic lineaments throughout the basin. There is a very strong set of NW-NNW anomalous linear features in the eastern part of the region containing numerous small intrusions (negatively magnetised). These may be related to a fold thrust belt as suggested by Sliwa and Draper (2003), but validation is difficult due to extensive cover. There is also a very distinctive, structurally controlled anomaly that runs down the length of the basin. This structure has no surface expression, and appears to be intruded with highly magnetic mafic dyke material. The high frequency, short wavelength, negatively magnetised anomalies in the western area is interpreted as Tertiary basalts. These exhibit flow like structures and patterning, and are interpreted to be sitting on or near the surface. The broad wavelength anomalies observed within the region are attributed to deep N-NW trending structure.

Radiometrics

Only northern part of this region has radiometrics coverage. Deep red in north west indicating elevated K from associated Tertiary basalts. Alluvial channels vary in radioelement concentrations depending on the sediment source. Those from the Devonian granite have high to moderate K, and Th and are orange-yellow in colour. Pink-yellow coloured alluvium derived from Permian sediments have moderate K and Th and moderate - high U. Sediments from the basalts have low-moderate K and are deep red in colour. Sand plains, which are blue-green in colour is a result of the relative enrichment of Th are characterised by low-moderate U, moderate Th and low K.



9 Sec DEM – hillshade



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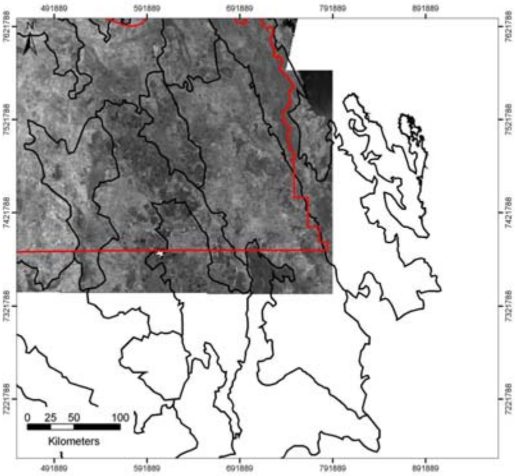
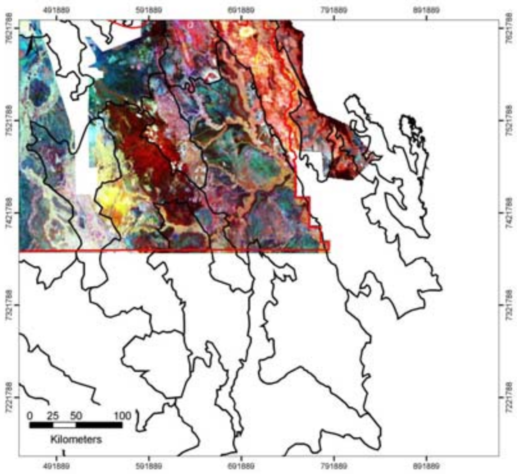
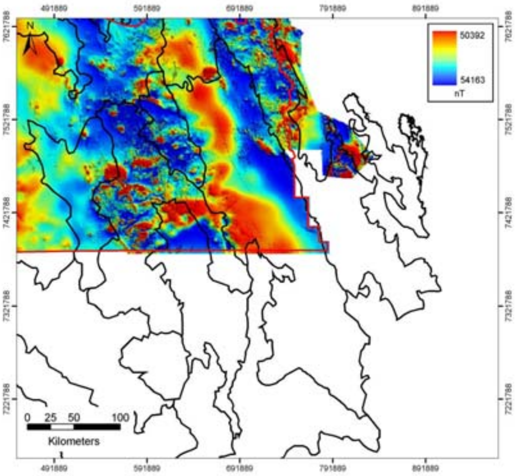


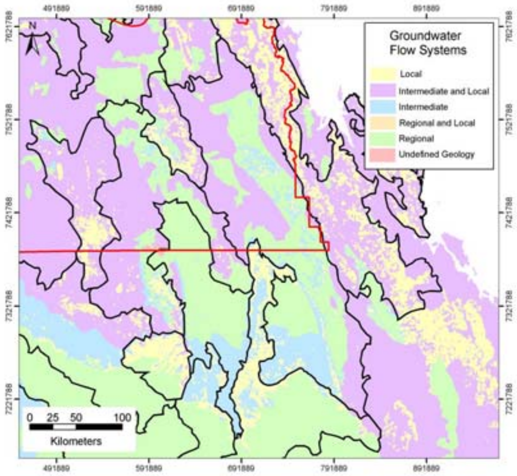
Landsat TM Band 8



Radiometrics

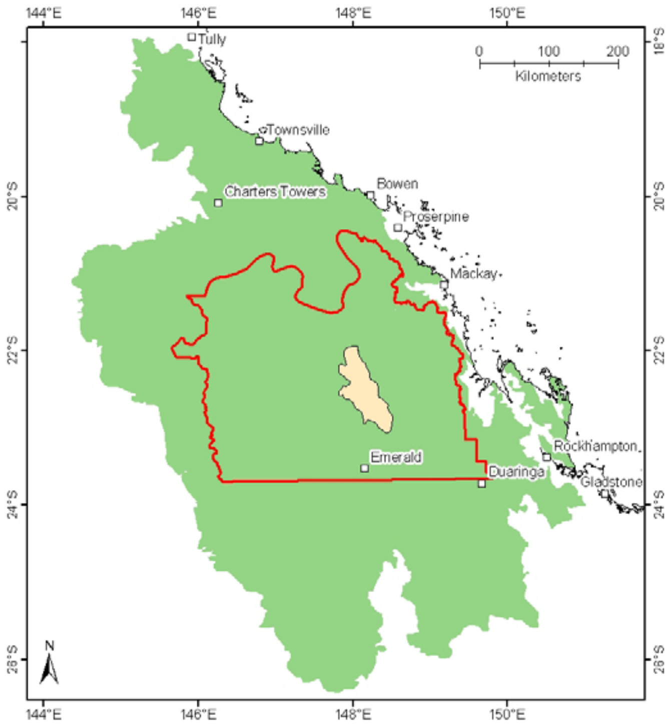


Aeromagnetics (Total Magnetic Intensity)



Groundwater Flow Systems

Physiographic Region 32 (4,152km²)



Land Division

Eastern Uplands Division

Land Province

Fitzroy Uplands Province

Land Zone

Cotherstone Plateau

Description

Dissected sandstone plateau to east; higher basalt hills to the west with drainage trending east.

Lithology:

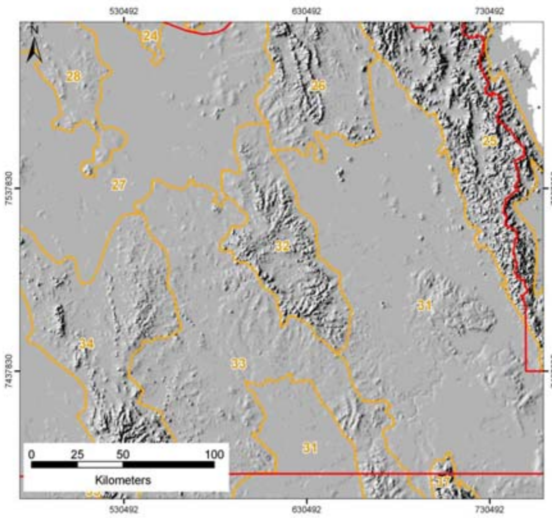
The area is dominated by clastic sedimentary units from the Permian Back Creek Group. Tertiary intermediate intrusives are associated with plugs, domes and flows within the Tertiary Basalt.

Aeromagnetics

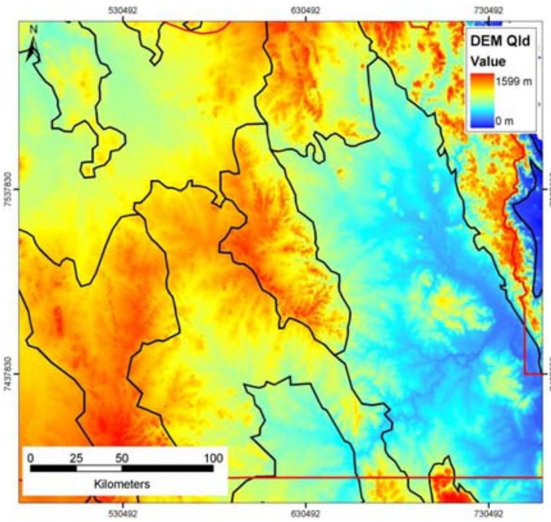
Region 32 is masked by high frequency responses from Tertiary basaltic overburden. These mostly negatively magnetised flows essentially mask the responses from the underlying geology. Some strong E-W trending anomalies are observed the north of this region, and are associated with what is interpreted as a series of circular intrusives of both positive and negative remanence. Smaller intrusives or plug type features may be interpreted within the basalts. Some structurally controlled anomalous flows are also observed to the north of this area.

Radiometrics

The deep red in west is associated with low to moderate K and low Th and U in Tertiary basalts. Alluvial channels draining east are deep red in colour reflecting their basaltic source rocks. The small bright white anomalies relate to plugs and domes of felsic intrusive rocks which are high in K, Th and U. The dappled effects of pinks-oranges in an eastern belt may be related to changing grainsize of the clastic sedimentary rocks. The sedimentary rock is characterised predominantly by moderate levels of all 3 radioelements. The clay and mudstones tend to have higher potassium while the sandstones are dominated by quartz and heavy minerals.



9 Sec DEM – hillshade



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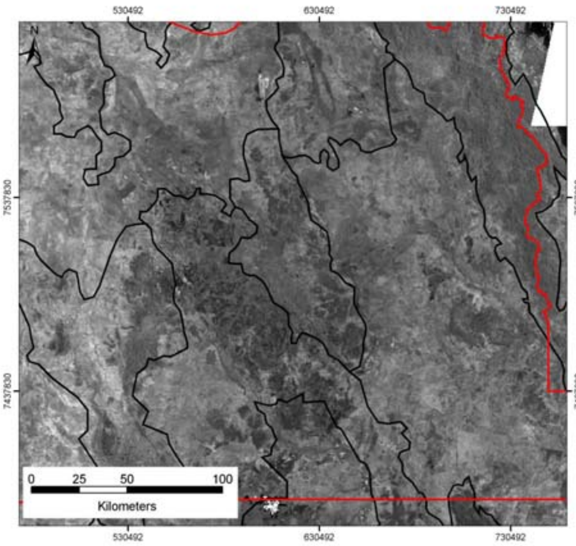

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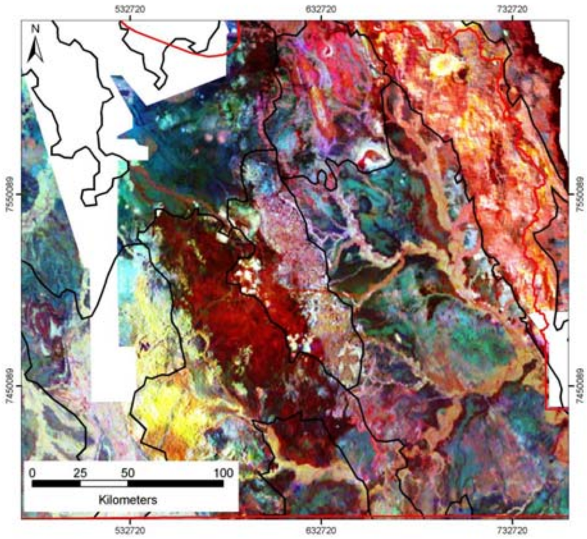
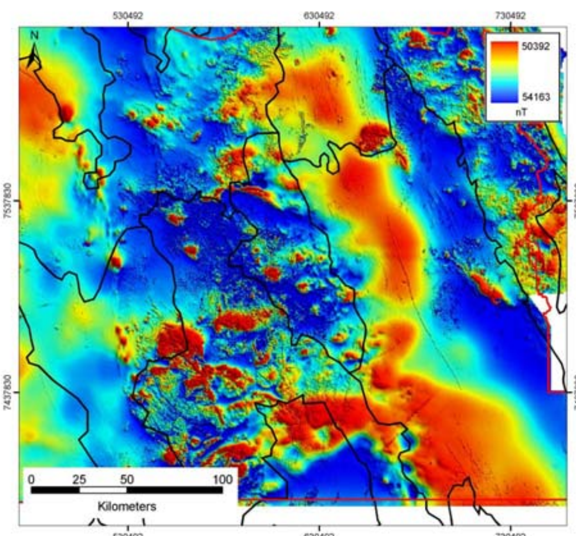
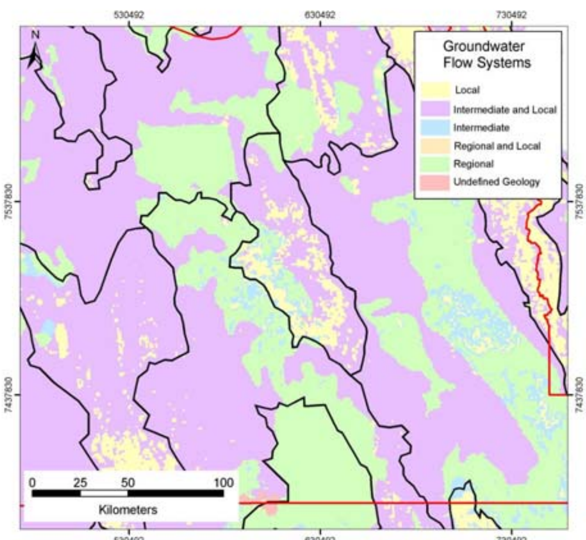


Radiometrics

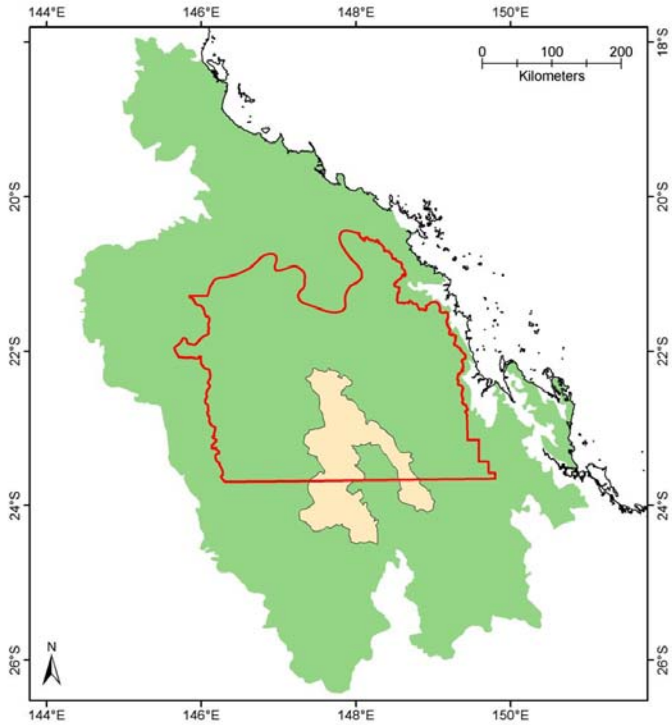


Aeromagnetics (Total Magnetic Intensity)



Groundwater Flow Systems

Physiographic Region 33 (20,589 km^2)



Land Division

Eastern Uplands

Land Province

Fitzroy Uplands Province

Land Zone

Springsure-Clermont Plateaux

Description

Moderately dissected low plateaux, mainly basalt; rolling country on minor sandstone, rolling granite hills and sand plains.

Lithology

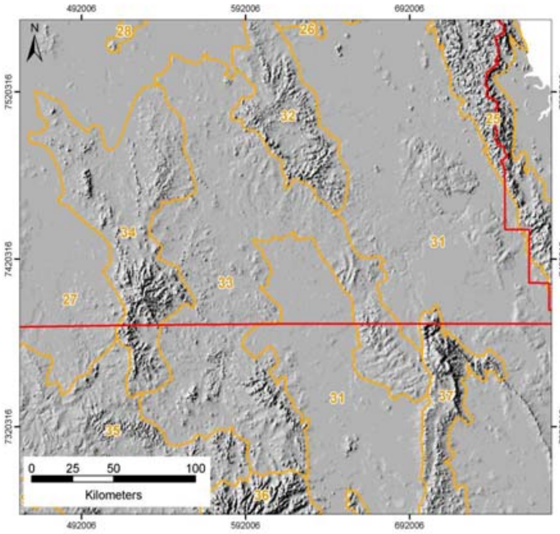
Dominated by Tertiary Basalt and Permian - Carboniferous sandstones and related clastic sediments. Devonian aged felsic intrusives occur in the west and minor Quaternary channel and alluvial plain deposits are also present.

Aeromagnetics

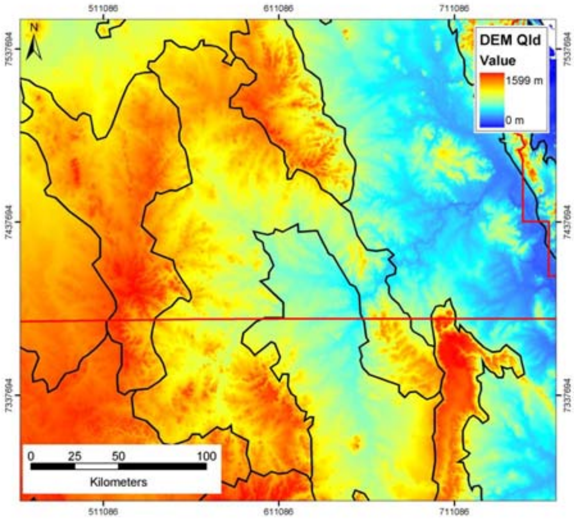
Most of physiographic region 33 is covered by extrusive Tertiary basalt. High frequency responses with strong negative susceptibilities dominate, and generally mask the underlying geological responses. The western part of the region is characterised by the highly anomalous Retreat Granite which forms part of the Anakie Inlier. This intrusive is characterised extensive lineament development and multi-phase intrusions. The margins of this unit correlate extremely well with geological mapping in the region. Magnetic responses again associated with near surface basaltic rocks dominate in the southern part of this region.

Radiometrics

Deep red areas are characteristic of the basalt terrain. The hue changes from deep to vibrant red depending on the degree of weathering. The more weathered the basalt has a deeper red indicating low K as much of the K has been leached out of the soil profile. Bright red is indicative of fresher basalt and moderate levels of K. Sandy plains in the eastern portion of the region are represented by greenish-blue hues from higher U and Th relative to K. The yellow-orange signature in the west is likely associated with felsdpars in the Retreat Granite. The yellow areas have high K, Th and low U and is probably fresher and in an area of more active erosion than its orange counterpart. To the southwest basalt is evident as varying shades of red. Green-blue hues directly south of the basalt is moderately enriched in Th and low in K and may indicate the presence of a duricrust forming on the weathered basalt. The alluvial channels and plains drain from the granite hence are also yellow in colour indicative of their source. The region in the east is dark green-blue hues are resultant from leaching away of K and relative enrichment of Th and U in heavy minerals like zircons and monazite.



9 Sec DEM – hillshade



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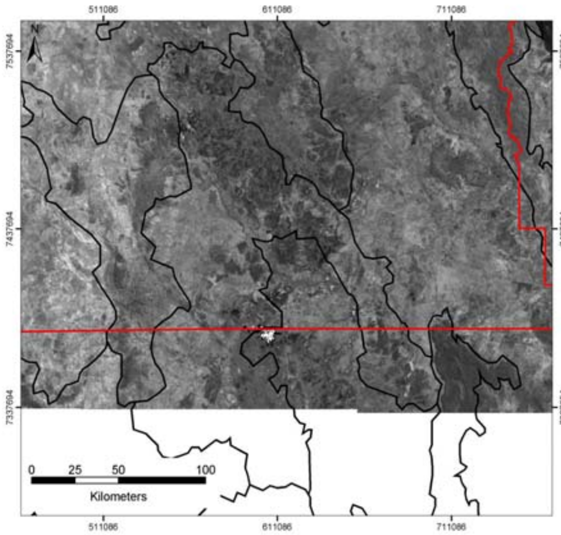
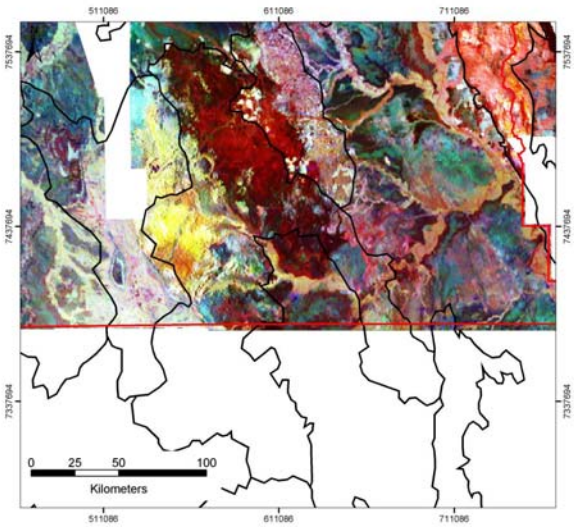
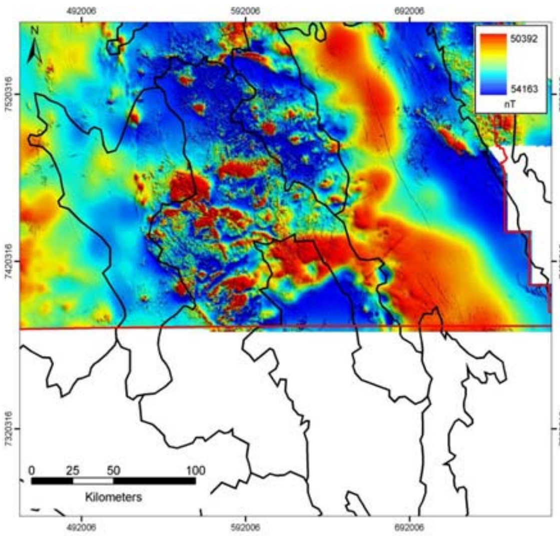


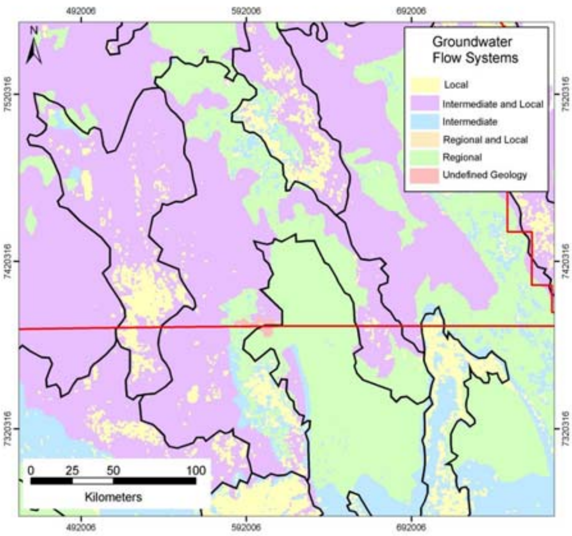
Landsat TM Band 8



Radiometrics

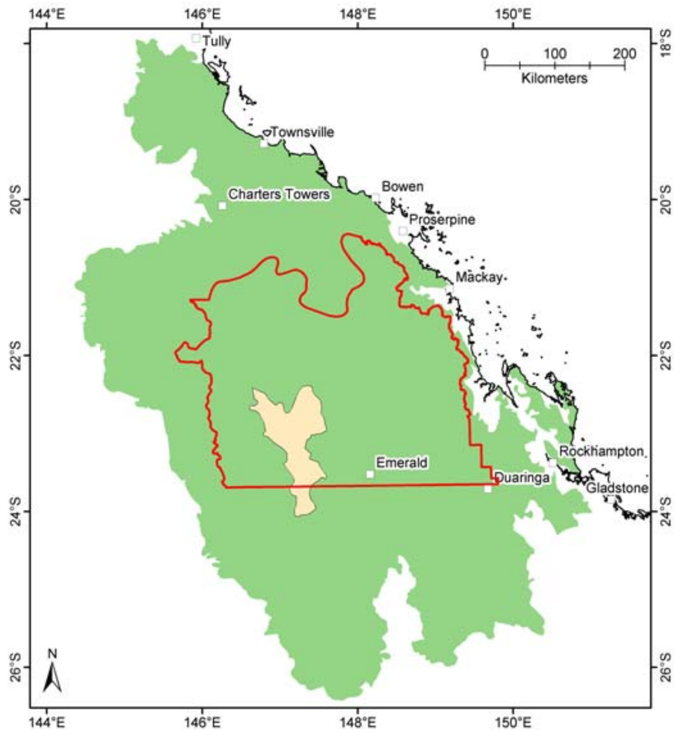


Aeromagnetics (Total Magnetic Intensity)



Groundwater Flow Systems

Physiographic Region 34 (8,290 km²)



Land Division

Eastern Uplands

Land Province

Fitzroy Uplands Province

Land Zone

Drummond Uplands

Description

Dissected ridges and vales on sandstone and minor metamorphic rocks.

Lithology

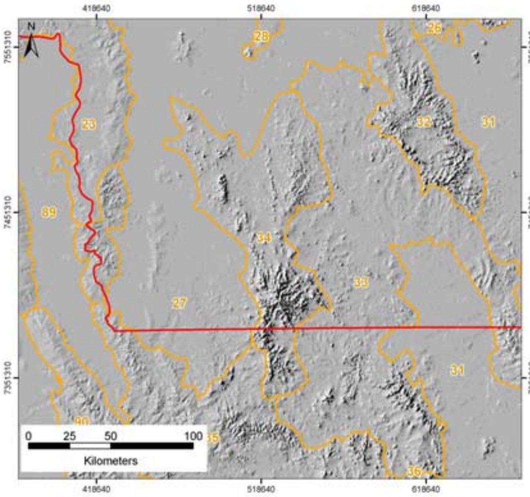
Dominated by Carboniferous feldspathic sandstone and related clastic sediments, and metasediments of the Neoproterozoic - Cambrian Anakie Metamorphic Group. Minor sand plains and volcanics are also present.

Aeromagnetics

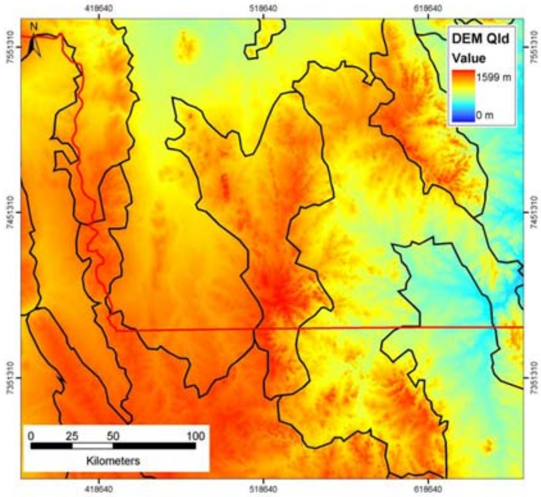
Physiographic region 34 covers both the Anakie Inlier and the Drummond Basin. The southeast physiographic margin shows a relationship the boundary between the anomalous responses of the Retreat Granite, and the smoothly varying, low magnetic gradient response from the Drummond Basin sediments. Numerous small intrusions are easily identified as small circular anomalies west of the Retreat Granite and within the Drummond basin sediments. Some anomalous inter-sedimentary features are also visible in the Drummond basin sediments and may represent fold or faulting of the weakly magnetic units. Some strongly magnetic roughly E-W trending linear dyke structures are interpreted in the northern part of the region. The NW section of the region is characterised by generally flat magnetic character which is inferred to correlate with the mapped metasediments of the Anakie Metamorphics.

Radiometrics

The southern portion of the region, covered by feldspathic sandstone has moderate - high K and U and moderate levels of Th. The variability within the sedimentary units can be differentiated as linear red (low-moderate Th, moderate K and U) and yellow (high K, Moderate Th and U) bands within a speckled pink to dull brown coloured unit. The dark green-red hues in the tear shaped structure relate to low K, Th and U in gravels and sands. The outer rim of the shape reflects a sedimentary unit with moderate K and moderate - high Th and U. The sandstone in the northeast has a different signature and has high Th and K. This may indicate that the sandstone is less clean and has more lithic components. Sand plains in northeast contain low K, moderate Th and high U rich and are bright green blue in appearance. Those in the northwest are duller in colour which reflects very low concentrations of K, and moderate Th and U. Siltstones and metasediments in the northeast contain moderate to high K and Th and low - moderate U.



9 Sec DEM – hillshade



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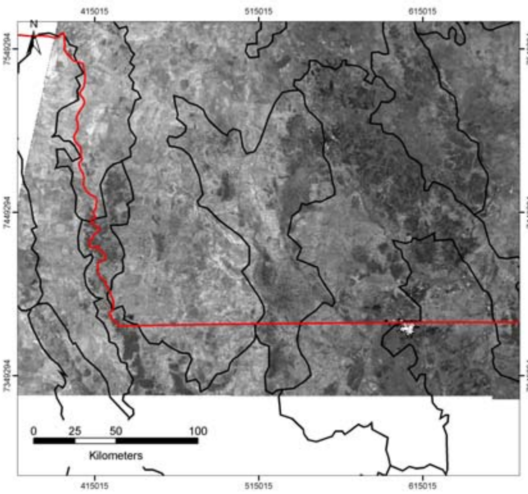
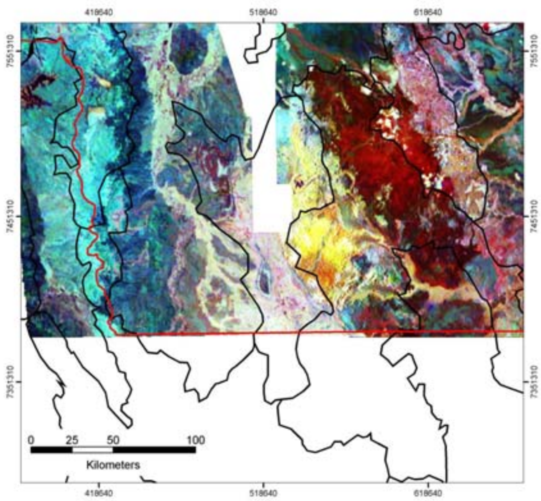
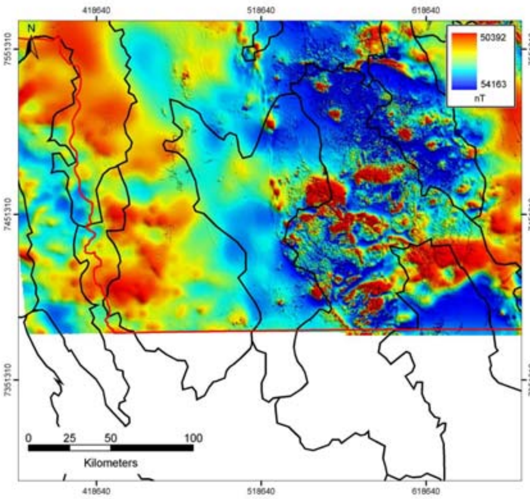


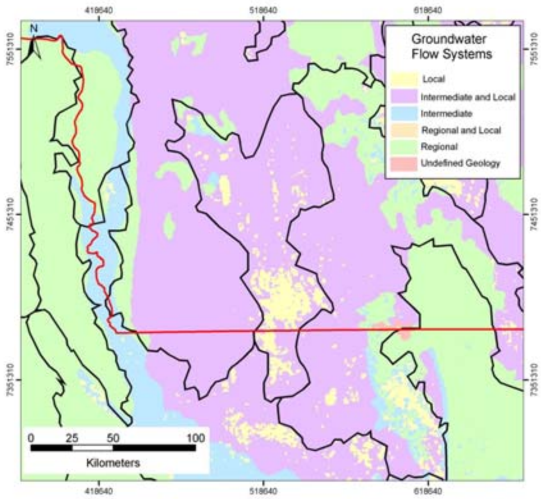
Landsat TM Band 8



Radiometrics

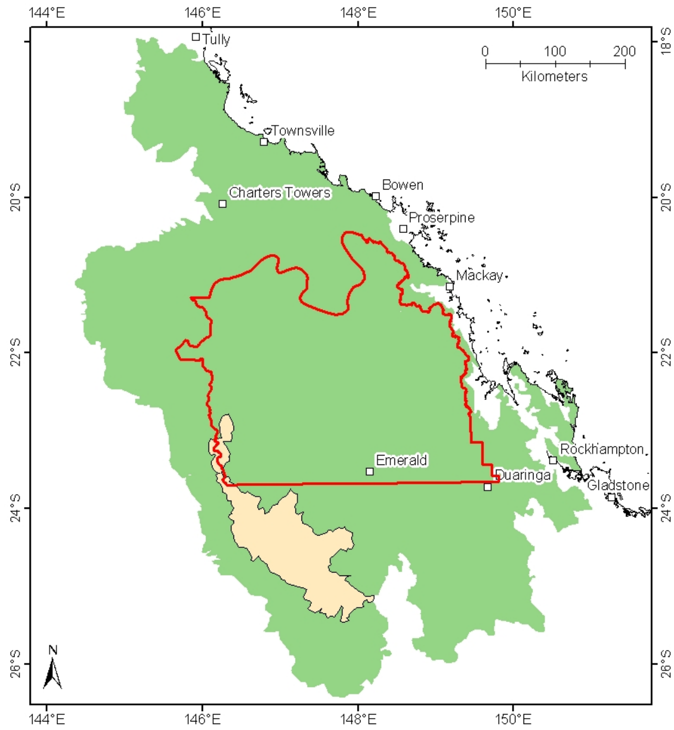


Aeromagnetics (Total Magnetic Intensity)



Groundwater Flow Systems

Physiographic Region 35 (17,756 km²)



Land Division

Eastern Uplands

Land Province

Fitzroy Uplands Province

Land Zone

Nagoa Scarplands

Description

Sandstone strike ridges, low rises and minor clay and sand vales.

Lithology

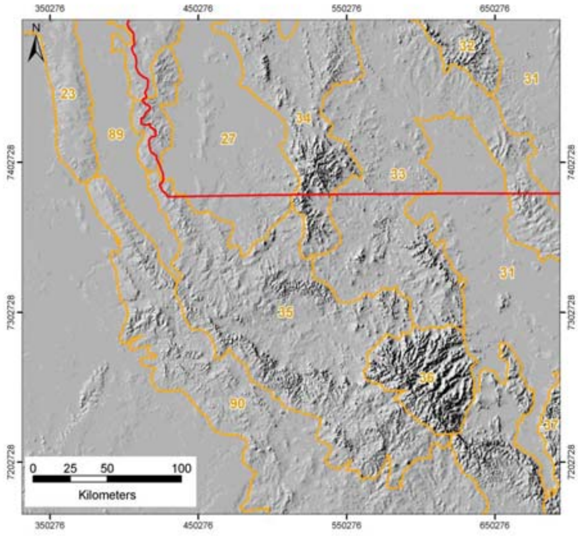
Triassic micaceous lithic to quartz rich sandstones, Early Jurassic and Permian sandstones and related siliciclastics with minor residual sand plains.

Aeromagnetics

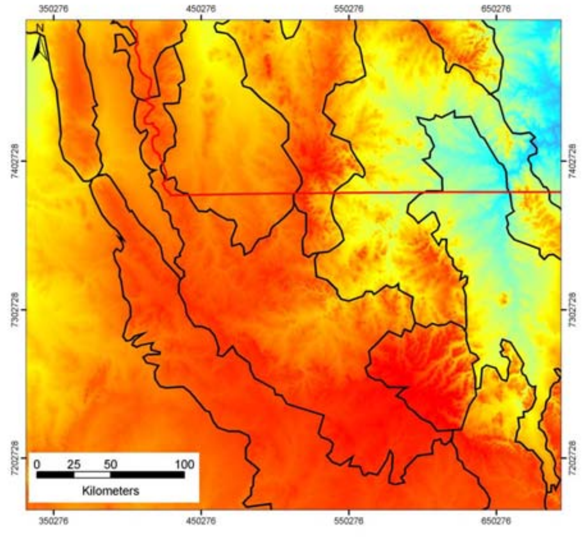
The aeromagnetics cover a small part of physiographic region 35 which is contained in the Galilee Basin. The area exhibits generally flat magnetic gradients where extremely long wavelength anomalies dominate reflecting a very deep causative source. A high frequency patterning pervades the response reflecting a shallower source of unknown character.

Radiometrics

Only northern tip has radiometrics coverage. Quartz rich sediments are characterised by green-blue hues relating to low K and moderate to high U and Th. The lithic sandstones have a pink colour and are higher K as they have greater mica and feldspar content.



9 Sec DEM – hillshade



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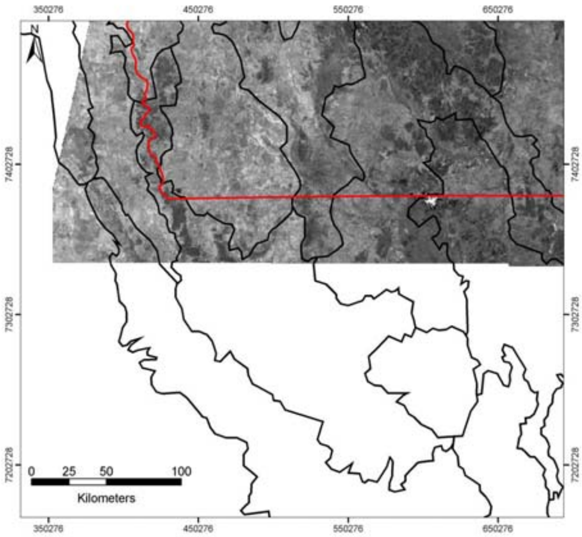
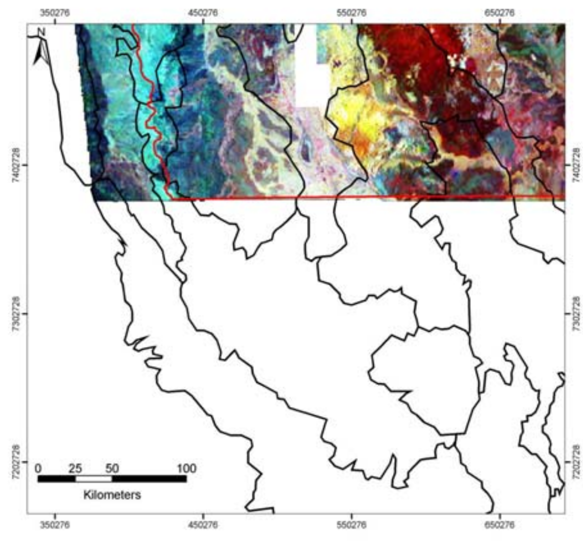
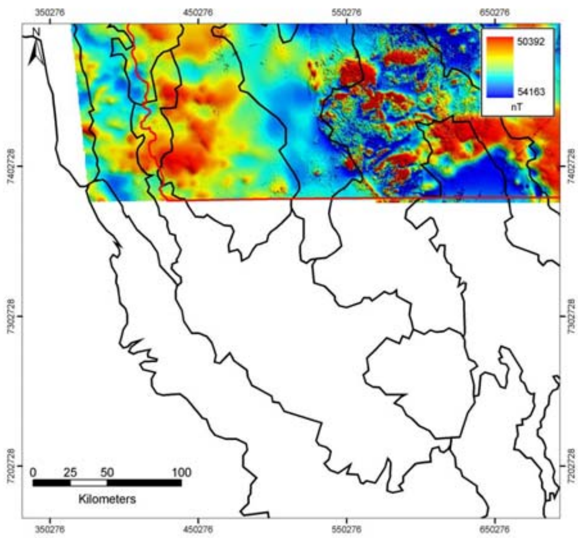


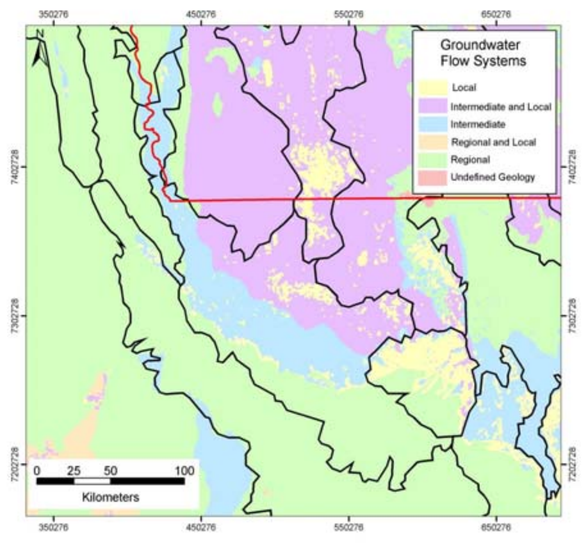
Landsat TM Band 8



Radiometrics

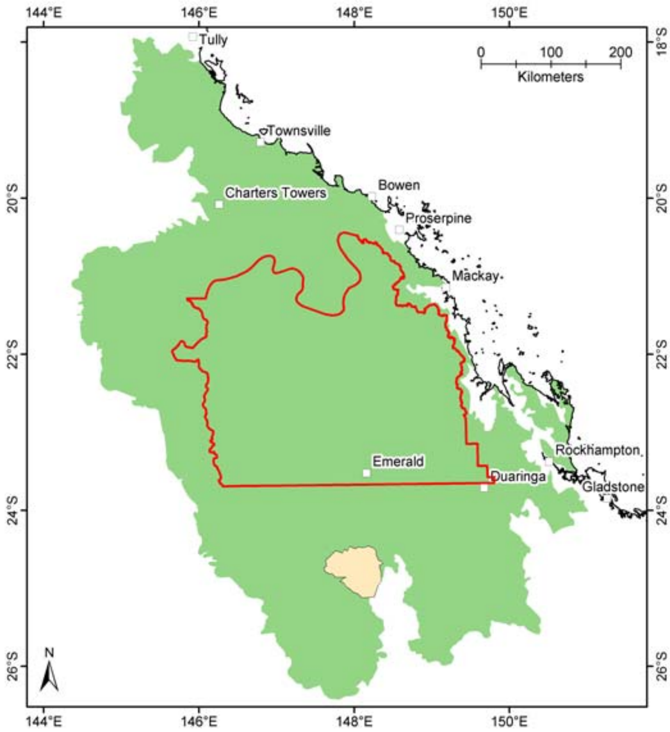


Aeromagnetics (Total Magnetic Intensity)



Groundwater Flow Systems

Physiographic Region 36 (3,731 km^2)



Land Division

Eastern Uplands

Land Province

Fitzroy Uplands Province

Land Zone

Buckland Plateau

Description

Dissected high plateau on basalt and sandstone.

Lithology

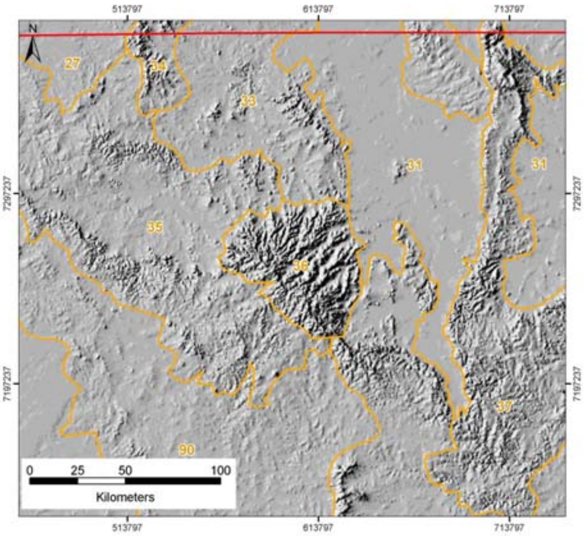
Predominantly Tertiary basalts with minor cretaceous micaceous lithic sandstones and Jurassic quartzose - labile sandstones and channel alluvium.

Aeromagnetics

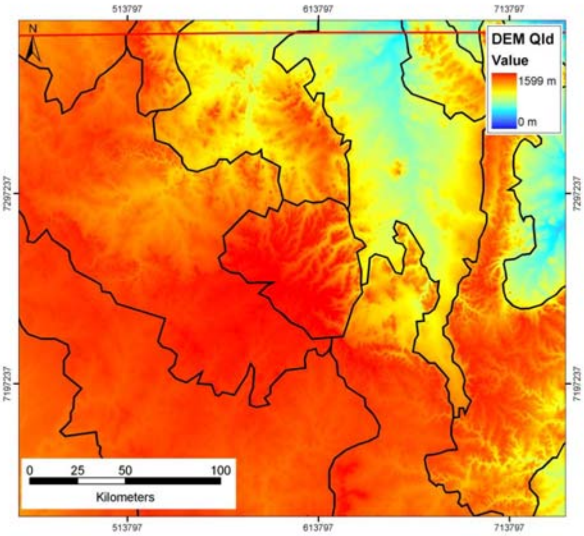
Outside of study area

Radiometrics

This region is out of the project area limits so no Radiometrics was processed.



9 Sec DEM – hillshade

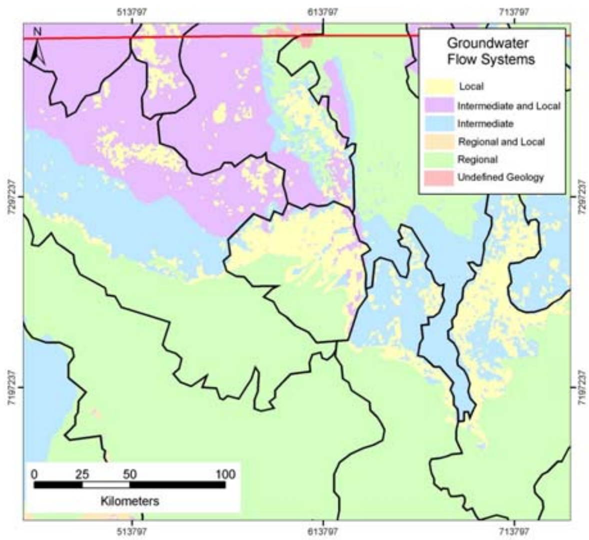


9 sec DEM

Landsat TM Band 8 not processed

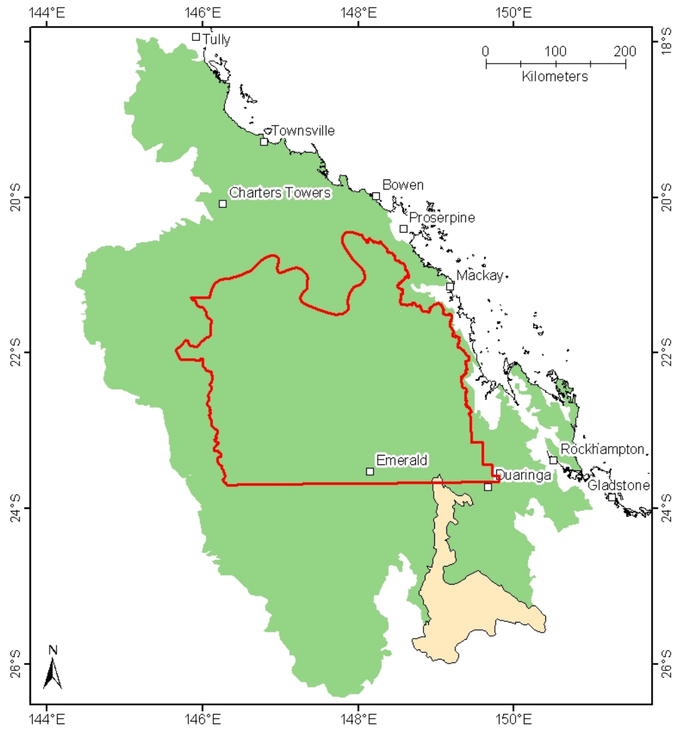
radiometrics are not available

No aeromagnetics available



Groundwater Flow Systems

Physiographic Region 37 (14,820 km^2)



Land Division

Eastern Uplands

Land Province

Fitzroy Uplands Province

Land Zone

Expedition Scarplands

Description

Rugged plateaux and ridges on sandstone.

Lithology

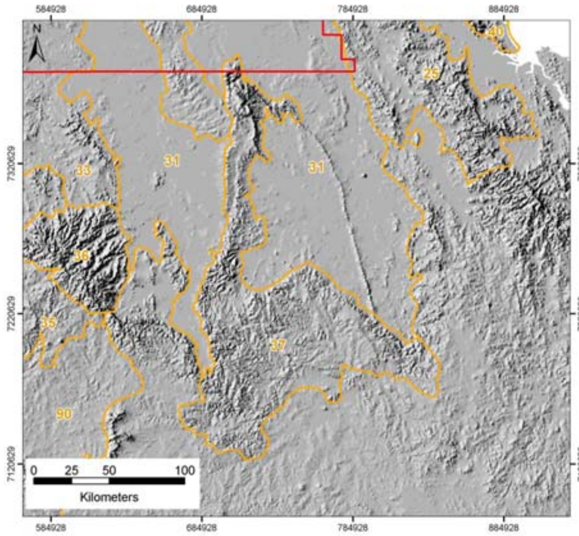
Dominated by Triassic quartz to feldspathic sandstones with minor Tertiary mafic extrusives present.

Aeromagnetics

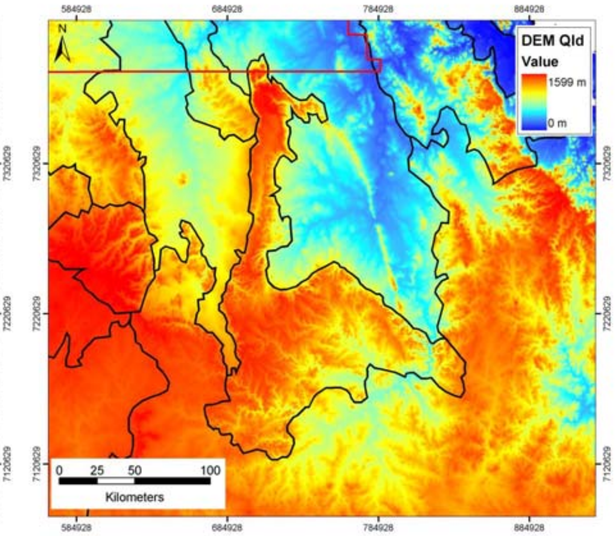
Outside of study area

Radiometrics

This region is out of the project area limits so no Radiometrics was processed.



9 Sec DEM – hillshade

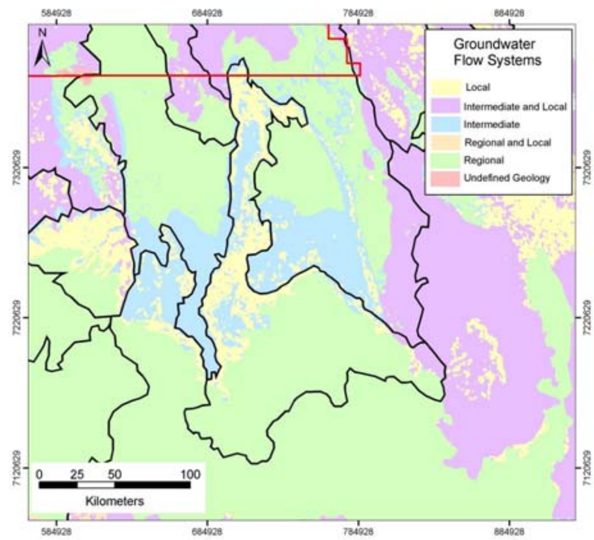


9 sec DEM

Landsat TM imagery not processed

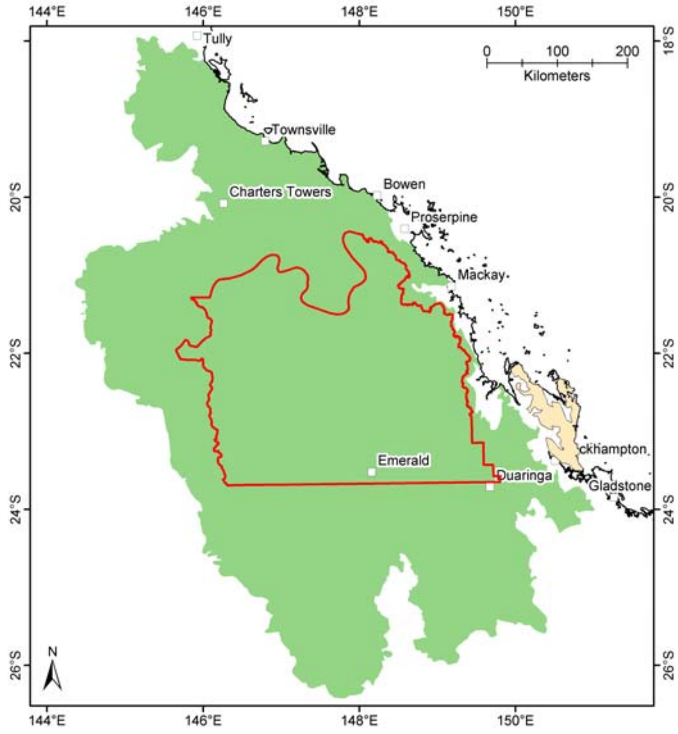
radiometrics are not available

No aeromagnetics available



Groundwater Flow Systems

Physiographic Region 40 (4,597 km²)



Land Division

Eastern Uplands

Land Province

New England-Moreton Uplands Province

Land Zone

Maryborough Lowland

Description

Lowlands on weak sedimentary rocks; partly dune covered, including Fraser Island.

Lithology

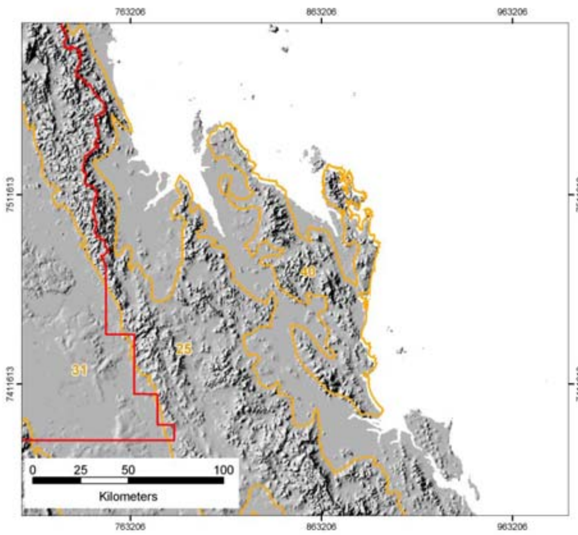
Permian - Cretaceous felsic intrusives, Carboniferous mudstones, siltstones and sandstones, Triassic volcaniclastics, minor Devonian - Carboniferous chert, interspersed with channel and floodplain alluvium and sand plains.

Aeromagnetics

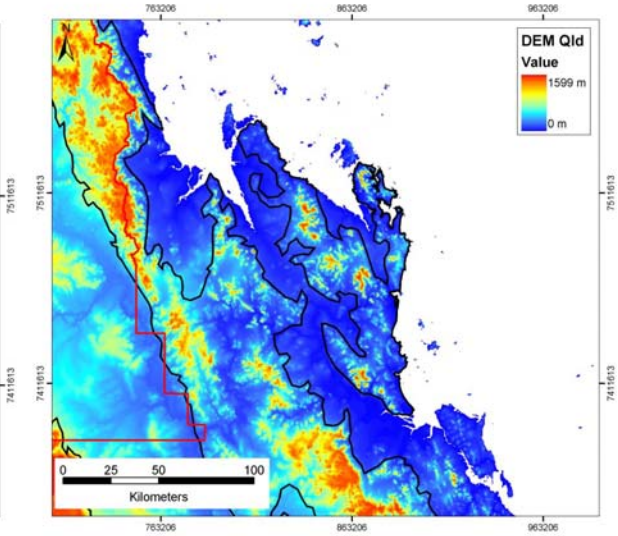
Outside of the study area

Radiometrics

This region is out of the project area limits so no Radiometrics was processed.



9 Sec DEM – hillshade

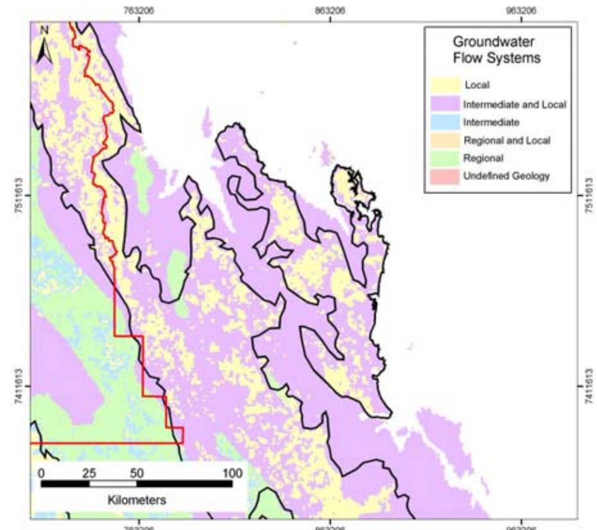


9 sec DEM

Landsat TM imagery not processed

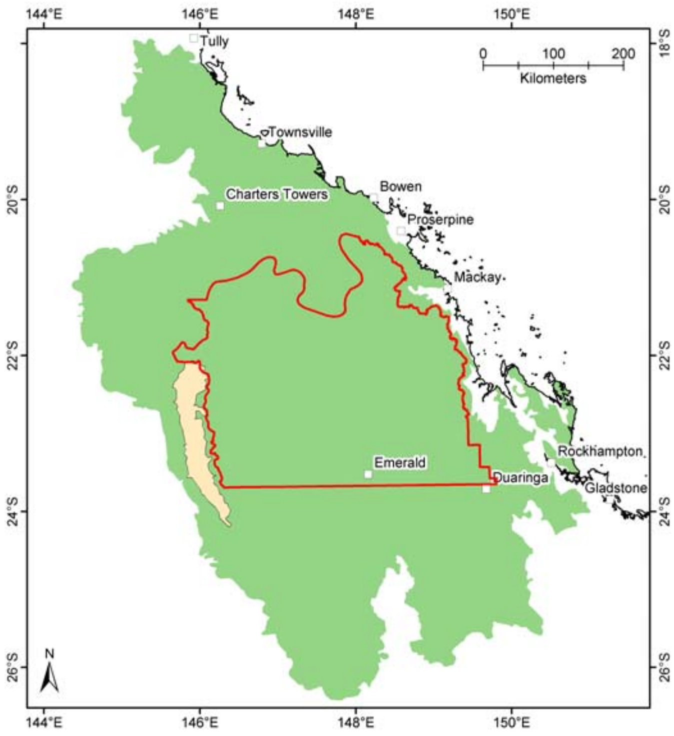
radiometrics are not available

No aeromagnetics available



Groundwater Flow Systems

Physiographic Region 89 (6, 229 km^2)



Land Division

Interior Lowlands Division

Land Province

Central Lowlands Province

Land Zone

Jericho Plain

Description

Predominantly sand plains with minor lake deposits in north; Plains drain mainly to the west.

Lithology

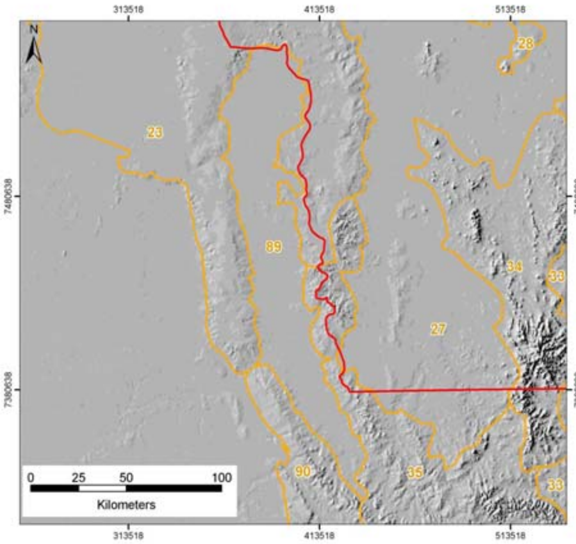
Largely Cainozoic sand plains with Quaternary lake deposit in the north relating to Lake Galilee. Also present are Quaternary alluvium associated with drainage lines and Triassic aged micaceous lithic sandstones which is present mostly in the far south.

Aeromagnetics

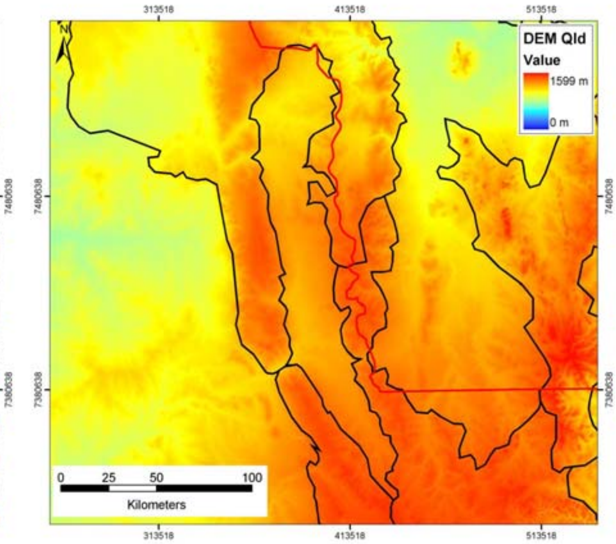
Outside of study area

Radiometrics

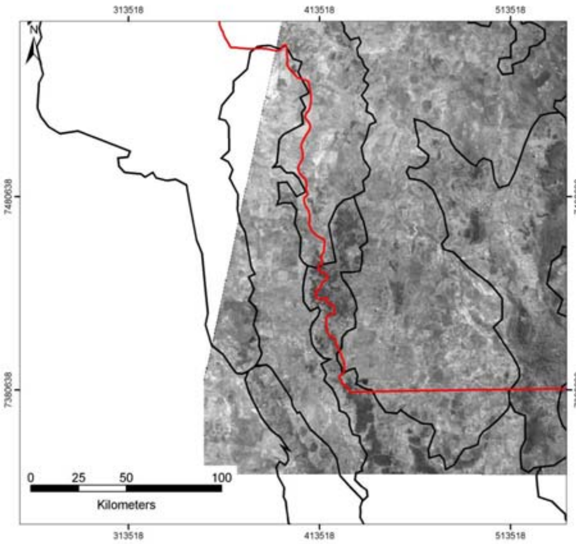
Sand plains have a mottled pattern of green-blue to dark blue with varying, but predominantly moderate concentrations of K, Th and moderate - high concentrations of U. There is an abrupt change in radiometrics character in the west with very low K, U and moderate Th. This change does not appear to be directly related to geology, nor relief but is clearly distinguishable by the dark blue-green colours on the image. The outcrops of sandstone can be identified being low in K, and moderate - high in Th and U. Lake Galilee is low in all 3 radioelements.



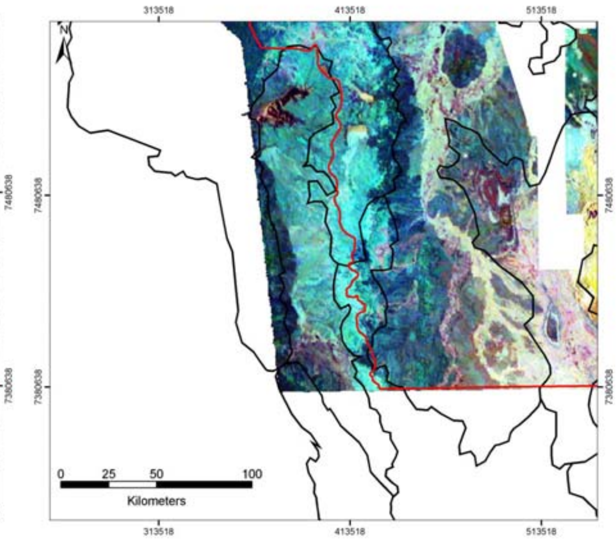
9 Sec DEM – hillshade



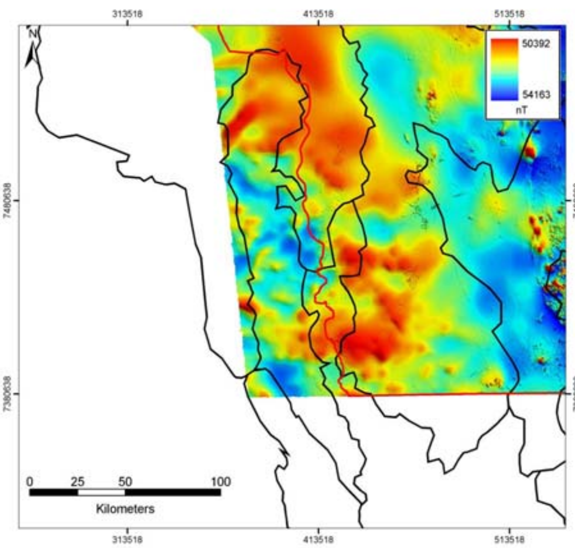
9 sec DEM



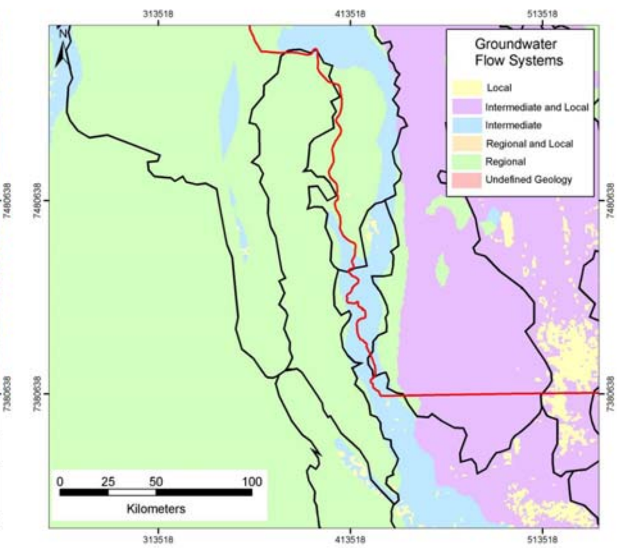
Landsat TM Band 8



Radiometrics

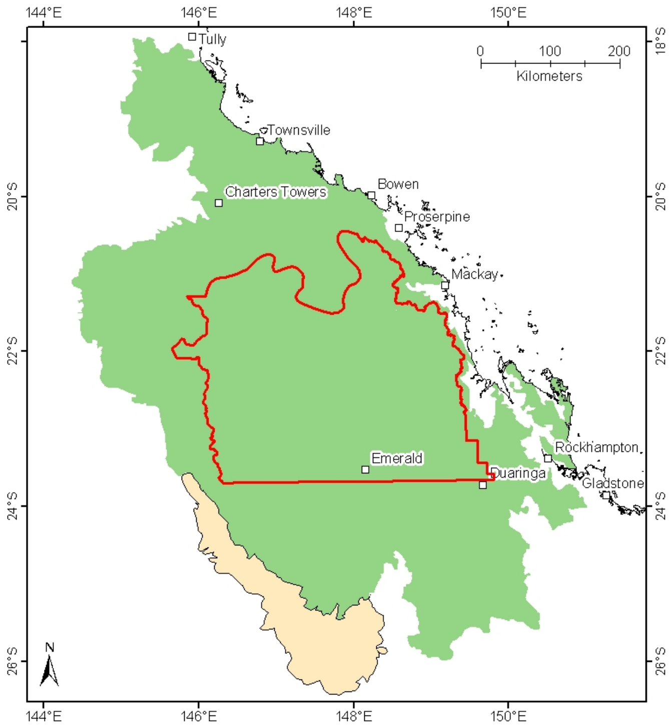


Aeromagnetics (Total Magnetic Intensity)



Groundwater Flow Systems

Physiographic Region 90 (22,583 km^2)



Land Division

Interior Lowlands Division

Land Province

Central Lowlands Province

Land Zone

Maranoa Lowlands

Description

Sandstone strike ridges, low sandstone hills and minor sand plains.

Lithology

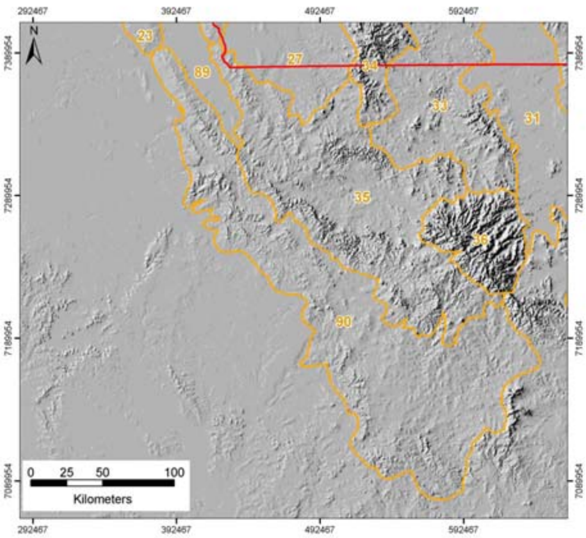
Dominated by Jurassic- Early Cretaceous sandstone. Limited cretaceous sand plains and Early Cretaceous mudstones and siltstones are located in the north with very minor occurrences of ferruginous duricrust in the south-west.

Aeromagnetics

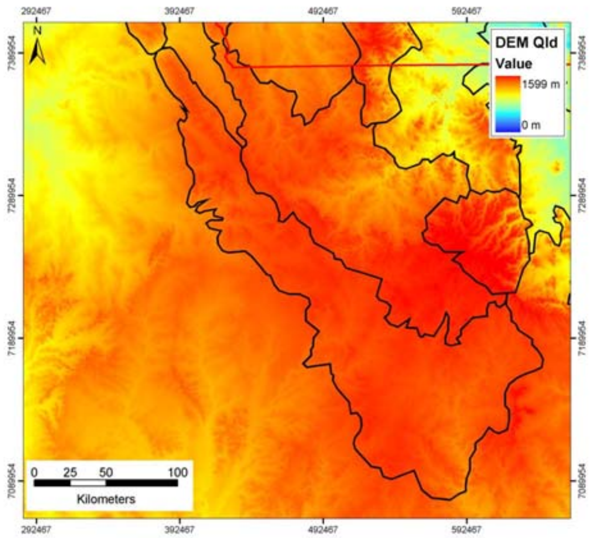
Outside of study area

Radiometrics

This region is out of the project area limits so no Radiometrics was processed.



9 Sec DEM – hillshade

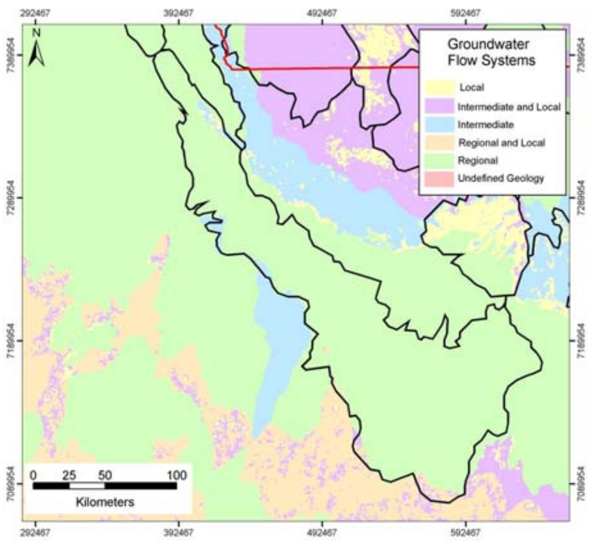


9 sec DEM

Landsat TM imagery not processed

radiometrics are not available

No aeromagnetics available



Groundwater Flow Systems

8. REGOLITH THICKNESS

8.1 Introduction

An understanding of regolith thickness, and particularly its 3D distribution, has useful application in NRM (groundwater potential, GFS, salinity risk assessment) and mineral exploration. There is very little information available within the Burdekin-Fitzroy study region relating to the regolith units, thickness of regolith, degree of bedrock weathering and bedrock type. As previously discussed, regolith in the context of this study is the Cainozoic materials overlying in most situations Palaeozoic bedrock. This chapter will outline how geophysical methods may be used to map regolith thickness over the study area, and also present a demonstrations of regolith thickness modelling using borehole data.

8.2 Use of Geophysics - Regolith Thickness

Magnetics

There are no documented studies where geophysical methods have been used to determine the thickness of the regolith in the Burdekin-Fitzroy catchments. Aeromagnetics in particular may not be overly useful to resolve the thickness of cover in the sedimentary basins due to a lack of magnetic contrast between the regolith materials and underlying bedrock. The resolution of the regional aeromagnetic datasets also precludes their use for accurate estimates of the thickness in areas of shallow regolith. In areas where regolith overlies true magnetic basement, aeromagnetic data may be useful to estimate cover thickness provided the data is of high enough resolution. The general rule of thumb is that the minimum resolvable depth to basement is half the line spacing for the survey (e.g. for 400m line spacing the minimum depth of investigation is 200m). Another significant problem using “depth to magnetic basement” methods is the presence of extensive near surface to outcropping basaltic flows which dominate the response. Differentiation of the individual components of the regolith is also difficult using ground magnetic methods. The regolith materials may in some places may be weakly magnetic, but this response is generally masked by the responses from other highly magnetic geological units such as basaltic flows and magnetic intrusive rocks. This is a common problem in regolith studies, and it emphasises that the magnetic method is not overly useful for determining regolith thickness. There may be some exceptions in the study area however, if:

a. the regolith materials overly true magnetic basement the depth to this interface may be calculated giving an estimation of the thickness of the overburden.

b. the regolith overlies a mafic sill or buried flow, the depth to this interface may be calculated giving an estimation of its depth, hence the thickness of the material above.

c. the regolith overlies an intrusion that is resolved magnetically, then the depth to the top of this intrusion could be calculated.

All of the above points assume that the data is of sufficient resolution to provide reliable estimates of depth, that no other magnetic sources are contributing to the anomaly being used for the depth estimate and that the anomaly being used is sourced from the actual basement-regolith interface (in the case of a). Depth to basement calculations based on point sources must be treated with caution due to the problems of non-uniqueness (ambiguity) and there is up to 20% inherent error associated with the calculations themselves. The problem of ambiguity will always be a factor, therefore the magnetic method is problematic for depth of regolith estimation.

Figure 69 is an example of how to use ground acquired magnetic profile data to calculate the depth to the top of a magnetic sill in the Bowen Basin by Stanley (1985). The technique applies empirical calculations on the individual anomalies to estimate depth the top of the causative magnetic unit. These estimates give an indication of the depth of the overlying material in this case. Note how the amplitude and frequency of the magnetic responses attenuate with depth. This is a highly idealised example. One needs to account for variability of rock composition (i.e. magnetite distribution) and the effect of other magnetic sources (Stanley, 1985). Refer to Stanley (1985) for a full summary of this method.

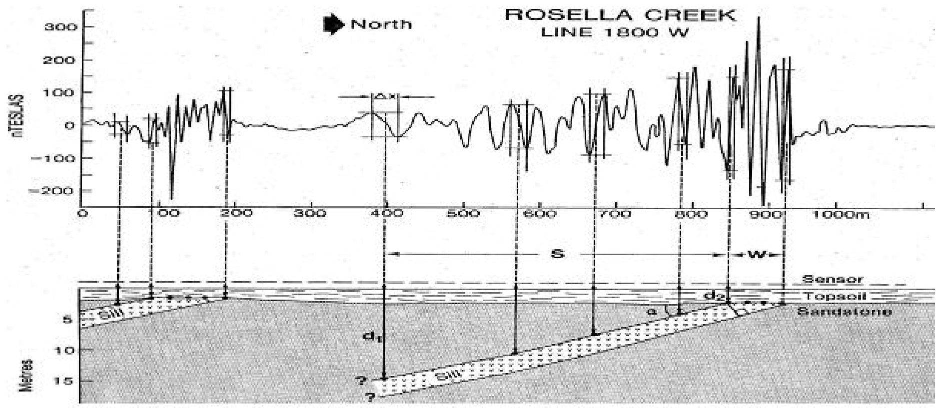


Figure 69. Example of using a magnetic sill to estimate depth of cover (from Stanley, 1985).

In the case of the study area, regolith rarely overlies true magnetic basement, therefore the use of traditional depth to basement magnetic methods is not applicable in most areas due to the lack of magnetic contrast between the base of the regolith and fresh bedrock. Regolith development in much of the study area is over thick sedimentary basin rocks which are essentially non-magnetic. These basins are significantly deeper than the Cainozoic cover which is considered to be the lower limit of the hydrological basement in the Burdekin.

There are some areas where the Cainozoic sediments are directly overlying magnetic basement rocks (e.g. parts of the Anakie Metamorphics) In these areas, empirical calculations may be performed on magnetic profile data to determine depth to basement or bedrock (i.e. from an intrusion).

Gamma Ray Spectrometry

The airborne spectrometric data may be used to identify regolith materials within the study area, but the use of this method to determine approximate thicknesses of these materials is predictive. Radiometric surveys will at most map the spectrometric properties of the top 30cm of the surface geology in ideal situations. Combining airborne spectrometry and digital elevation models in the Burdekin-Fitzroy catchments may not necessarily produce reliable estimates of regolith thickness due to the suspected complex nature of the underlying bedrock. Surface regolith attributes within both catchments are believed not to reflect the complex nature of the bedrock, which was a significant erosional landscape during the early Tertiary. Depositional regimes since this time have been heavily influenced by subsequent volcanism that has significantly altered the drainage systems over the Cainozoic period.

Gravity

The gravity station data over the study area is variable, but may have use in some areas for determining regolith thickness. There are areas within the Bowen Basin where the station coverage is very closely spaced. Most of the station coverage outside of these areas is at much wider spacing and is not useful for approximations of the thickness of the Cainozoic cover.

Seismic

Most of the seismic data within the study area is not very useful for determining the thickness of the Cainozoic cover.

8.3 Use of Boreholes – Regolith Thickness

This section will present a basic conceptual model of the thickness of regolith materials within the Central Bowen Basin using stratigraphic and lithological information from bore hole logs. The area to be modelled covers the same area as the Central Bowen Basin airborne survey, and will be considered a demonstration area (Figure 70).

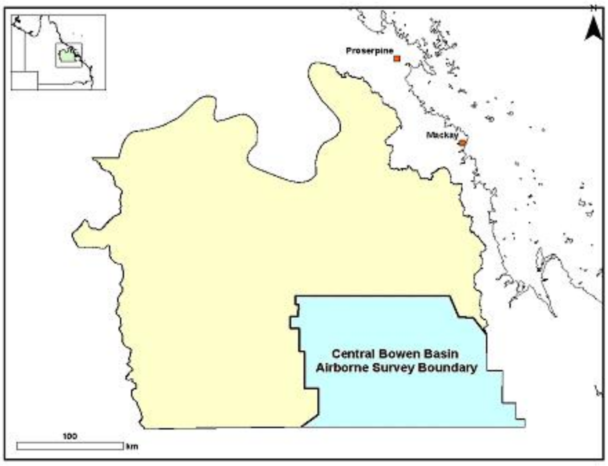


Figure 70. Central Bowen Basin airborne survey area.

Regolith for the purpose of this study will be defined as all geological materials of Cainozoic age in the Central Bowen Basin. This classification separates the Cainozoic materials from the underlying basement which is mainly of Permian –Triassic age. This boundary forms an unconformity which was an active erosional surface at the beginning of the Tertiary. This unconformity is not always clearly identifiable in the bore-hole logs due to poor lithological descriptions. The Cainozoic sediments within the Central Bowen Basin are composed of consolidated to unconsolidated material to fresh to completely weathered basalts which are often inter-bedded with sedimentary packages. Extensive clay horizons are common. The classification for regolith also includes any thin *in situ* soil cover and alluvium. Alluvium is mostly re-transported sand, boulders and gravel of fluvial origin. Weathering profiles on the Palaeozoic basement is considered part of the regolith.

There are few previous investigations into the thickness of the Cainozoic sediments in the Central Bowen Basin area. Previous studies have been performed by private coal mining companies to assess groundwater conditions and the distribution of basalt over prospective areas. Much of the focus on groundwater in this context is contained within the Permian porous sediments of the Bowen Basin, generally at prospect scale. Some studies do investigate the properties of the Cainozoic sediments themselves but generally focus on the distribution and thickness of the Tertiary basalts.

This study will attempt to model the thickness of the Cainozoic sediments. This has been performed using descriptions from bore hole logs rather than geophysical information due to:

- The difficulty in differentiating the Cainozoic sediments from the underlying bedrock in aeromagnetic data. Both of these units have weak magnetic susceptibilities and therefore have a lack of magnetic contrast. Automated depth to magnetic basement routines cannot be used in this area. The true magnetic basement is in fact probably igneous rock at the base of the sedimentary Bowen Basin sequence (up to 4000m).

- Radiometric data contain responses from the surface geology (top 30cm) only. The method is only useful for mapping the surface geology

- Seismic data in the area are not very useful for shallow investigations. Depth to fresh bedrock is difficult to distinguish in the seismic profiles.

- Gravity data not useful for type of investigation.

Method

Without the use of geophysical data the regolith depth model has been constructed using only the bore hole data. Over 1200 groundwater borehole locations were extracted from the NR&M groundwater database (Figure 71). Where available the following information was also extracted for the borehole locations.

- Stratigraphic descriptions
- Lithological descriptions
- Aquifer information.

The stratigraphic, lithological and aquifer information were examined carefully for each borehole to determine the following.

- The depth to the base of the Cainozoic cover, or the Tertiary unconformity. This was calculated as a depth from the top of the borehole (top=0 meters)

- The thickness and depth of any basaltic units within the bore hole (where present).

Boreholes that had no lithological or stratigraphic descriptions were discarded. Boreholes without stratigraphic information that could not be reliably interpreted from the lithological descriptions were also discarded. This resulted in 426 boreholes that could be used for the model. The reduction from 1200 to 426 boreholes clearly demonstrates of how unreliable a majority of the borehole descriptions are for regolith thickness modelling. Of the remaining 426 holes, only 203 intersected bedrock at the base of the Tertiary. Due to time constraints only these 203 intersections were used in the model. Future work should consider using these additional holes as minimum depth to basement constraints.

Once bore holes to be used in the model were identified they were imported into ESRI ARCMAP v8. The borehole locations were then overlaid onto the 80m DEM acquired from the Central Bowen Basin airborne survey in 2003. Collar elevations for these boreholes were then rectified to the DEM using ESRI spatial analyst. The depth to bedrock intersections were then corrected against the rectified collar elevations. The result is a set of bedrock intersections correctly located in 3 dimensions (z component referenced to height above means sea level).

The next step was to create a surface using the depth to bedrock intersections. This was performed by gridding the data points and intersections using GEOSOFT Montaj v5.1.8. For this model a Triangular Irregular Network (TIN) gridding method was used. Contours for the gridded intersections were also produced.

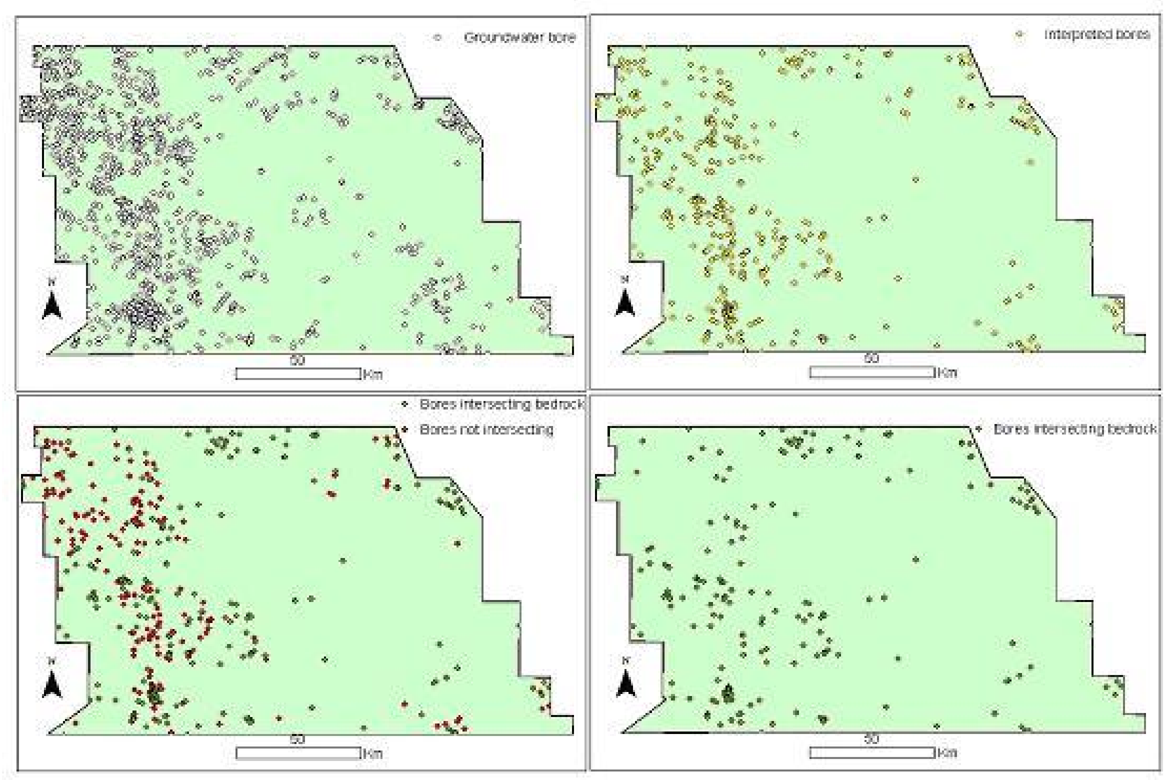


Figure 71. Location of groundwater bores in the Central Bowen Basin. (a) All bores (b) Interpreted bores (c) Bores that intersect or don't intersect bedrock (d) Bores that intersect bedrock.

8.4 Results

The results are shown below both as a contour map (Figure 72) and a 3D block model (Figure 73). The bedrock interface is viewed as a topographic surface. The locations of the bores are indicated (Figure 71).

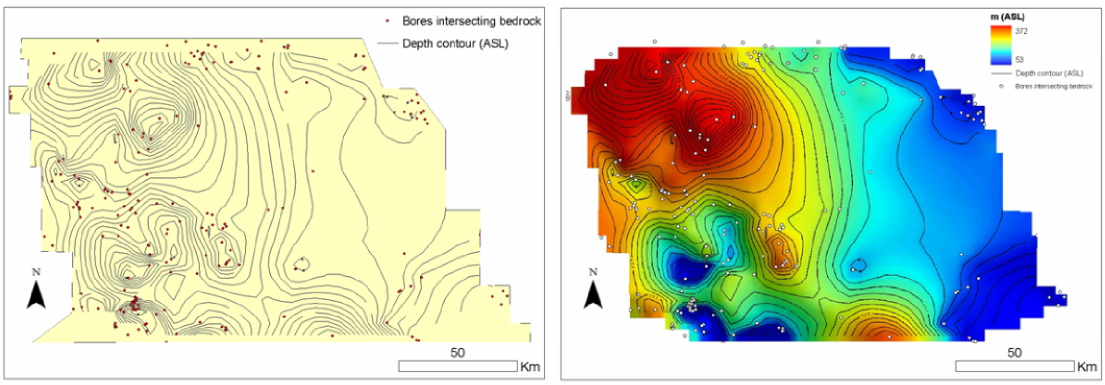


Figure 72. Regolith thickness from groundwater bore holes. (a) Contoured preliminary depth to bedrock model for the Central Bowen Basin (b) TIN gridded and contoured (contours are in meters ASL, 10m intervals).

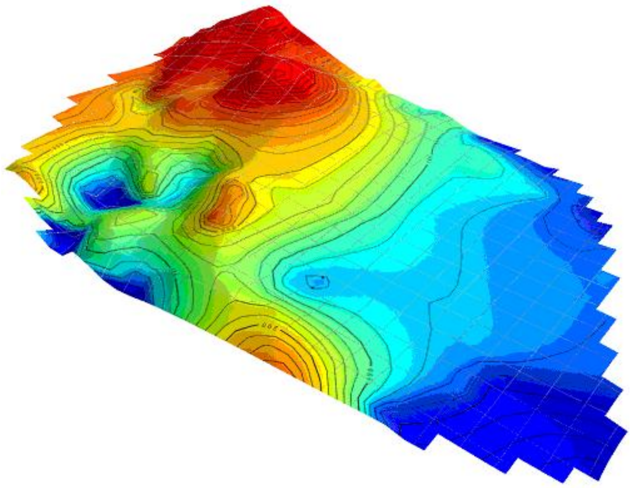


Figure 73. Preliminary depth to bedrock model for the Central Bowen Basin (Contours are in meters ASL, 10m intervals, VE x100).

8.5 Discussion

This model is preliminary and could be significantly improved with additional information (i.e. drill hole data). The remaining interpreted boreholes that did not intersect bedrock should be used to further constrain the model.

Interpolation of the bedrock surface between boreholes should be treated as approximate until further steps are taken to constrain the model. Confidence in the interpolated surface diminishes with distance from any given drill hole intersection (data point). The model could be constrained by implementing the following

- No interpolation between points that are above the height of the DEM. These points are outcrop or where the basement depth is 0.

- If former drainage lines on the Tertiary surface could be inferred. specialised gridding methods could be employed to account for these features creating a more realistic model

The examination of the bore hole logs revealed some interesting observations regarding the Cainozoic cover in the Central Bowen Basin. The base of the Tertiary is characterised by a silt and clay base which may be over 20m thick in places. The Tertiary itself is composed of a range of lithologies. The basaltic units are inter-bedded with many of these sediments. Additional improvement to such this model would be a layered model incorporating some of these observations. Weathering profiles on the bedrock surface need to also been considered. Such a model may be classified according to the following criteria: Regolith, Saprolite and Bedrock.

8.6 Conclusions and Recommendations

- Aeromagnetic data were generally not useful for determining regolith thickness over the Burdekin-Fitzroy region.

- All the existing bore holes in the region should be re classified to estimate the depth to fresh bedrock in an attempt to model the depth to fresh bedrock where applicable. Such a model would significantly improve the current understanding of the thickness of the Cainozoic cover. These observations should be correlated with any regolith thickness maps in existence.

- To update current solid geology maps to provide a full basement interpretation over the study region.

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