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# CEO comment

**Neil Williams** – CEO Geoscience Australia

This issue of *AusGeo News* features several articles based on presentations by our scientists at the recent International Uranium Conference in Darwin hosted by the Australian Institute of Mining and Metallurgy. I am pleased to report that Geoscience Australia's presentations, which included a review of uranium mineral systems modelling, new maps of uranium igneous rocks and 3D models of uranium systems, drew positive comments and significant interest from industry.

One of these articles outlines how the recently released Radiometric Map of Australia is facilitating rapid assessment of uranium prospectivity from the national scale through to the local scale. It can also be enhanced and integrated with other datasets for targeting areas of potential uranium mineralisation. Another article describes the revised conceptual framework for a fresh assessment of Australia's uranium mineral potential as well as key exploration criteria of practical value.

There is also an update on Geoscience Australia's Offshore and Onshore Energy Security Programs which provide pre-competitive information to support mineral and energy resource exploration. Geoscience Australia has recently received the first batch of processed data from the Southern Margins 2D seismic survey (see *AusGeo News 94*). It is anticipated that a data package covering the region, which includes new and reprocessed data, should be available by the end of 2009. The update also reports on the release of data from the recently completed Pine Creek Orogen airborne electromagnetic survey and the deep crustal seismic traverse across the south-western Georgina Basin. Both these surveys were done in collaboration with the Northern Territory Geological Survey.

This issue also reports on the latest version of the Bathymetry and Topography Grid of Australia which draws together the most recent bathymetric datasets for the Australian region. The grid includes data from the Southwest Margin and the Remote Eastern Frontiers surveys which revealed a number of new seafloor features including small volcanic mountains and canyons.

In this issue you will also read about our contribution to research into nutrient cycling processes and their possible impact on water quality in Darwin Harbour. The Harbour is a largely unmodified estuary in the wet tropics of northern Australia.

Brief reports on the Broken Hill Managed Aquifer Recharge Project and the contribution by a Geoscience Australia scientist to a field exercise conducted in Kazakhstan by the Comprehensive Nuclear Test Ban Treaty Organisation are also included. The former will map and characterise the groundwater aquifer systems near Menindee Lakes in western New South Wales and identify suitable targets to develop a managed aquifer recharge borefield.

In product news, recent releases include updated digital gridded radiometric datasets, which are part of the Radiometric Map of Australia, and new maps covering the spectacular MacDonnell Ranges, west of Alice Springs, in Australia's Red Centre.

As usual we always appreciate your feedback and encourage you to use the online rating mechanism with each article.

Neil Williams

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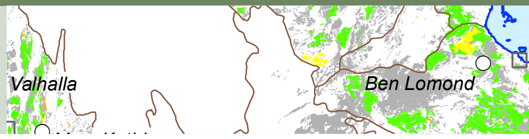
# New views of Australia's uranium mineral systems

## *Recent releases will assist uranium explorers in area selection*



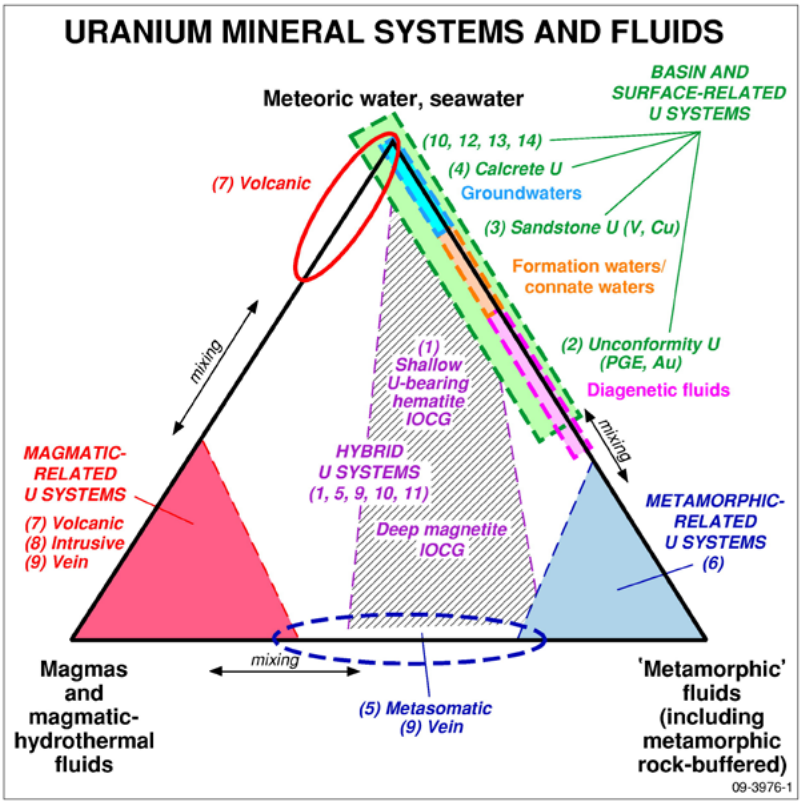

*Roger G. Skirrow*

Geoscience Australia's Onshore Energy Security Program is delivering pre-competitive data to boost investment in exploration for onshore energy resources such as petroleum, uranium, thorium and geothermal energy. As part of this Program, Geoscience Australia has recently released two reports and a series of maps which will support uranium explorers in area selection at the continental and regional scales.

## Uranium mineral systems

Australia holds the world's largest identified resources of uranium recoverable at low cost, with uranium mining constituting an important and growing part of the nation's mineral export industry.

The key geological and geochemical processes controlling where and how uranium mineralisation occurs in Australia and globally are examined in *Uranium mineral systems: processes, exploration criteria and a new deposit framework* (Geoscience Australia Record 2009/20).




This report provides a revised conceptual framework for a fresh assessment of Australia's uranium mineral potential as well as key exploration criteria of practical value. It outlines generalised models for families of uranium mineral systems, with shared characteristics, based on an understanding of the fundamental processes in uranium mineral systems and descriptions of well-documented ore systems.

The new classification framework in *Uranium mineral systems* outlines three families of uranium mineral systems: magmatic-related, metamorphic-

**Figure 1.** Schema showing the three families of uranium mineralising systems and the three end-member fluid types. A continuum of deposit styles may exist between these end-members, represented by hybrid styles of uranium mineralisation such as iron oxide-copper-gold-uranium (IOCGU) deposits. Uranium deposit types from the IAEA Red Book classification are numbered in order of economic importance to Australia (McKay and Miezitis 2001): 1) breccia complex (IOCGU); 2) unconformity-related; 3) sandstone; 4) surficial (including calcrete); 5) metasomatite; 6) metamorphic; 7) volcanic; 8) intrusive; 9) vein; 10) quartz-pebble conglomerate; 11) collapse breccia pipe; 12) phosphorite; 13) lignite; 14) black shale.

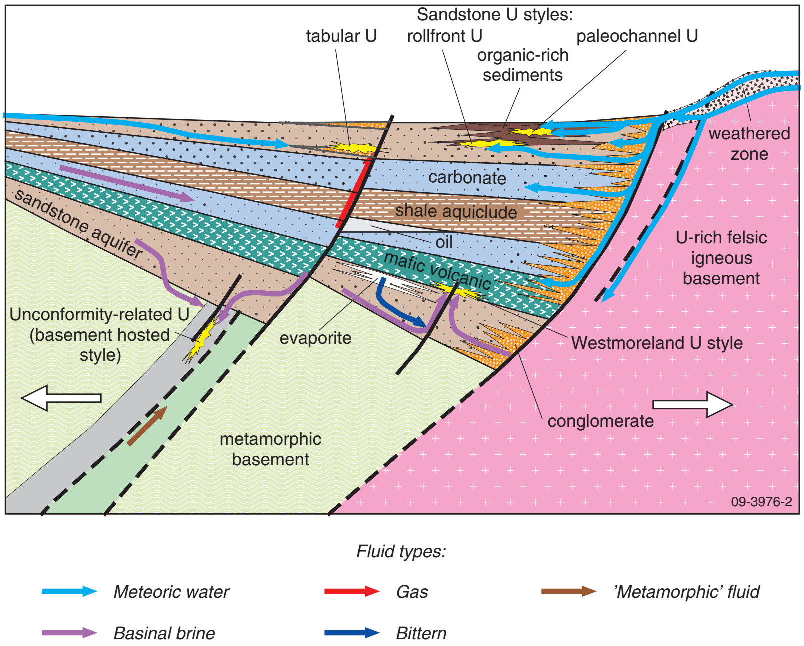



**Figure 2.** Basin-related uranium mineral systems, for a hypothetical basin, during extension or sag phase.

related, and basin- and surface-related (figure 1). Each family is related to one of three fundamentally different types of crustal fluid (magmatic-hydrothermal, metamorphic and surface-derived, such as rain, seawater). The families of mineral systems contain a range of uranium deposit styles, most of which are familiar to exploration geoscientists. Basin-related mineral systems, for example, contain the variants of 'sandstone-hosted' deposits ('roll-front', 'tabular', 'paleochannel' etc), as well as the so-called 'Westmoreland' style and 'unconformity-related' styles (figure 2). This new process-based framework can accommodate the 14 deposit types in the well known classification of the International Atomic Energy Agency's biannual 'Red Book', which are based mainly on host rock type. The inter-relationships between deposit types are emphasised rather than the differences. Indeed, the tripartite framework explicitly includes hybrid deposit types, and predicts a continuum of deposit styles between end-member types. The giant Olympic Dam iron oxide-copper-gold-uranium (IOCGU) deposit, which holds the world's largest single resource of uranium, is viewed as a hybrid type of deposit. This is because its formation involved fluids of both deep-sourced origin (magmatic-hydrothermal and/or metamorphic rock-reacted fluids) and surface-derived origin. The latter fluid most probably leached uranium from felsic igneous host rocks.

"This report provides a revised conceptual framework for a fresh assessment of Australia's uranium mineral potential as well as key exploration criteria of practical value."

## Uranium content and potential of igneous rocks

Geoscience Australia is currently undertaking a range of studies of uranium mineral potential at national scale and in selected regions, applying the mineral systems-based approach outlined above in combination with empirical data. One of these studies is reported in the recently released *Uranium content of igneous rocks of Australia 1:5 000 000 maps: Explanatory notes and discussion* (Geoscience Australia Record 2009/17) which describes and discusses the data presented in an accompanying series of three 1:5 million scale maps of Australia. The maps use whole-rock geochemical data compiled from Geoscience Australia's OZCHEM database, supplemented by data from relevant state and territory geoscience agencies. Map 1 shows the uranium concentrations of igneous rock samples plotted on igneous rock polygons from Geoscience Australia's new 1:1 million scale *Surface Geology of Australia* dataset. Map 2 shows the average uranium content of each surface geology polygon, which is calculated from geochemical data points occurring within each polygon. Map 3 uses a similar methodology, but shows average uranium contents for solid geology polygons. This map is expected to be particularly useful in assessing those large areas of the continent where igneous rocks are concealed beneath a cover of sediment or regolith.

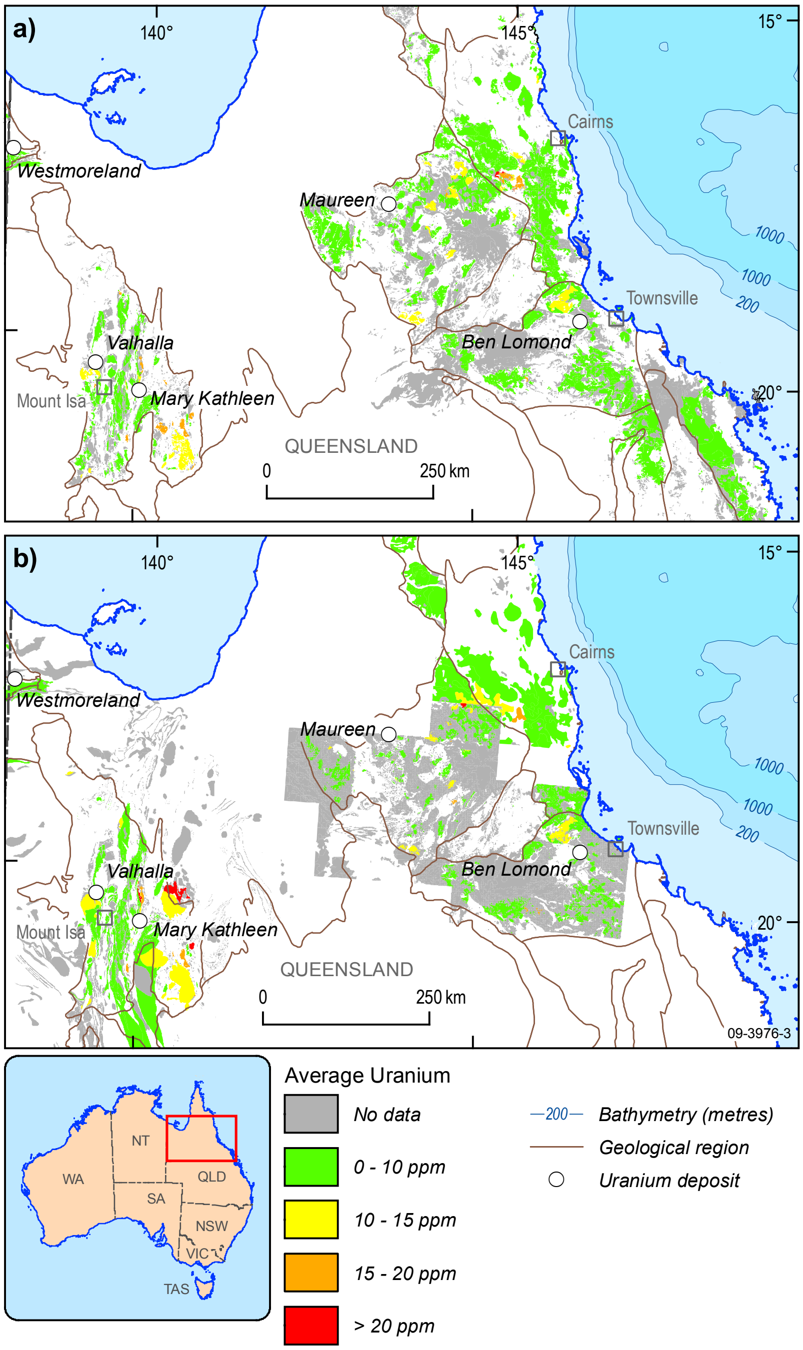



**Figure 3.** Average uranium content of igneous rocks from northern Queensland. The top image shows the average uranium content of igneous rocks occurring at the surface. The bottom image shows the average uranium content of igneous rocks extracted from solid geology, providing constraints on the distribution of uranium-rich igneous rocks under cover. The compilations show high levels of uranium associated with felsic igneous rocks in the area around Mount Isa and eastern north Queensland.

As outlined in *Uranium content of igneous rocks of Australia*, Geoscience Australia is applying an understanding of how uranium is concentrated during magmatic processes, combined with the empirical geochemical data, to help identify areas with high potential for magmatic-related uranium mineralisation (including magmatic-hydrothermal systems). Australia appears to lack major resources of magmatic-related uranium mineralisation, despite the abundance of uranium-rich igneous rocks. Some of the largest uranium deposits globally, such as the giant Rössing deposit in Namibia, are associated directly with magmatic processes. Consequently this type of deposit has been targeted for study. Preliminary assessment of the uranium potential of north Queensland, the focus of another recent Onshore Energy Security Program activity, has identified a number of areas with a favourable combination of characteristics for magmatic-related uranium mineralisation. Follow-up fieldwork is planned to ground-truth the initial results. Similar assessments elsewhere in Australia will be undertaken to build a continental-scale map depicting the potential for magmatic-related uranium mineralisation.

## Uranium mineral occurrences update

Geoscience Australia's MINLOC database holds basic information on mineral occurrences in Australia, including uranium. This database has recently been updated with more than 300 newly documented uranium occurrences with significant additions for Western Australia and the Northern Territory. These data, along with other national datasets, such as the *1:1 million Surface Geology of Australia* and the recently-released *Radiometric Map of Australia*, are fundamental to uranium exploration efforts and to Geoscience Australia's assessments of uranium potential.

## Basin-related uranium systems

Globally, some of the largest resources of uranium are hosted by sandstones and other clastic units in basins of Tertiary or Mesozoic age, for example, in Kazakhstan. Increased production from a number of giant deposits has recently elevated Kazakhstan to the world's second largest producer after Canada and ahead of Australia. Although Australia has several significant deposits of this type, including the recently discovered Four Mile deposit in South Australia, no giant deposits have yet been discovered despite apparently favourable characteristics in a number of basins.

Consequently, Geoscience Australia is generating 3D models of selected basins with high potential, including 3D maps of those geological, geochemical and hydrological components that are considered to be critical in the formation of basin-related uranium mineralisation. As a result, structural architecture and spatial variations in the oxidation-reduction potential of the sedimentary rocks and basin fluids are being mapped in 3D. Insights on the location of possible mineralisation are being gained from numerical modelling of fluid flow and ore-forming chemical reactions. It is planned to report regularly on the results over the next 12 months through the Geoscience Australia website (see Related websites/articles).

### For more information

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McKay AD & Miezitis Y. 2001. Australia's uranium resources, geology and development of deposits. AGSO-Geoscience Australia. Available at: www.ga.gov.au/image_cache/GA9508.pdf

### Related articles/websites

Geoscience Australia's Uranium Systems Project
www.ga.gov.au/minerals/research/national/uranium/index.jsp

Uranium mineral systems: processes, exploration criteria, and a new deposit framework (Geoscience Australia Record 2009/20)
www.ga.gov.au/products/servlet/controller?event=GEOCAT_DETAILS&catno=69124

Uranium content of igneous rocks of Australia (Geoscience Australia Record 2009/17)
www.ga.gov.au/products/servlet/controller?event=GEOCAT_DETAILS&catno=68762

Surface Geology of Australia 1:1 000 000 scale
www.ga.gov.au/minerals/research/national/nat_maps/nat_geol_maps.jsp

Radiometric Map of Australia
www.ga.gov.au/minerals/research/national/radiometric/

MINLOC database (mineral occurrences in Australia)
www.australianminesatlas.gov.au/?site=atlas&tool=search

*AusGeo News 89*: Association of large sandstone uranium deposits with hydrocarbons
www.ga.gov.au/ausgeonews/ausgeonews200803/uranium.jsp

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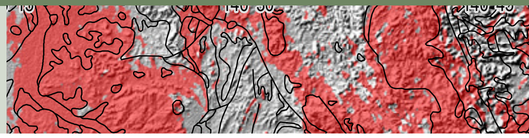
# Radiometric Map of Australia provides new insights into uranium prospectivity

## *New map facilitates rapid assessment*



*John Wilford, Lisa Worrall and Brian Minty*

The new radioelement map of Australia facilitates rapid assessment of uranium prospectivity from national through to local scales. The map shows the distribution of potassium (per cent K), uranium (parts per million (ppm) equivalent U) and thorium (parts per million (ppm) equivalent Th) over 80 per cent of the Australian landmass. It has been calibrated using the recent Australia-Wide Airborne Geophysical Survey (AWAGS) to adjust all the public-domain airborne radiometric surveys in Australia to the International Atomic Energy Agency's (IAEA) Global Radioelement Datum (*AusGeo News 93*).

The new datum provides a baseline for all current and future airborne gamma-ray spectrometric surveys in Australia and, for the first time, enables quantitative assessment of the distribution of potassium, equivalent thorium and equivalent uranium in exposed bedrock and regolith. Uranium concentrations derived from airborne measurements can now be analysed and compared across landscapes with different or similar geological and geomorphological histories. This article briefly describes the concentration of uranium in rocks and regolith, and demonstrates how the new radioelement map of Australia can be enhanced and integrated with other datasets for targeting areas of potential uranium mineralisation.

## Uranium at the surface

Airborne gamma-ray spectrometry measures gamma-rays from potassium, thorium and uranium that emanate from the uppermost 30 to 40 centimetres of soil and rock in the crust. Variations in the concentrations of these radioelements largely relate to changes in the mineralogy and geochemistry of rock and regolith materials (for example soils, saprolite, alluvial and colluvial sediments). Potassium abundance is measured directly as gamma-rays emitted when potassium ($^{40}K$) decays to Argon ($^{40}Ar$). Uranium and thorium abundances are derived indirectly by measuring gamma-ray emissions associated with the daughter radionuclides bismuth ($^{214}Bi$) and thallium ($^{208}Tl$), respectively.

Uranium is the least abundant of the three radioelements in the Earth's continental crust with a concentration estimated to be in the range of 1 to 4 ppm (Rogers and Adams 1978). The abundance of uranium increases during the fractionation of igneous rocks so that acid igneous and volcanic rocks, for example, have higher uranium averages than their mafic and ultramafic equivalents. In Australia, the airborne-measured average concentration of uranium in exposed regolith and bedrock (to a depth of around 30 centimetres) based on the new radioelement data is 1.1 ppm.

Uranium occurs in two main valence states: $U^{4+}$ and $U^{6+}$. The oxidised form $U^{6+}$ is most common in near-surface conditions and forms complexes with oxygen to create a uranyl ion ($UO_2^{2+}$). Uranyl ions are mobile and typically form soluble complexes with the anions $NO^3$, F-, OH-, $CO_3^{2}$- , $SO_4^{2}$- and $PO^{3-}$. The solubility of uranium is favoured by oxidising conditions and acid groundwaters (see *Uranium mineral systems: processes, exploration criteria and a new deposit framework*). Under reducing conditions, the $U^{+4}$ form is contained in insoluble minerals. Weathering and alteration associated with hydrothermal systems can preferentially concentrate uranium compared to thorium. Thorium has a single valence ($4^+$) in near-surface environments and so its mobility does not alter under changing redox conditions. Importantly, thorium, unlike

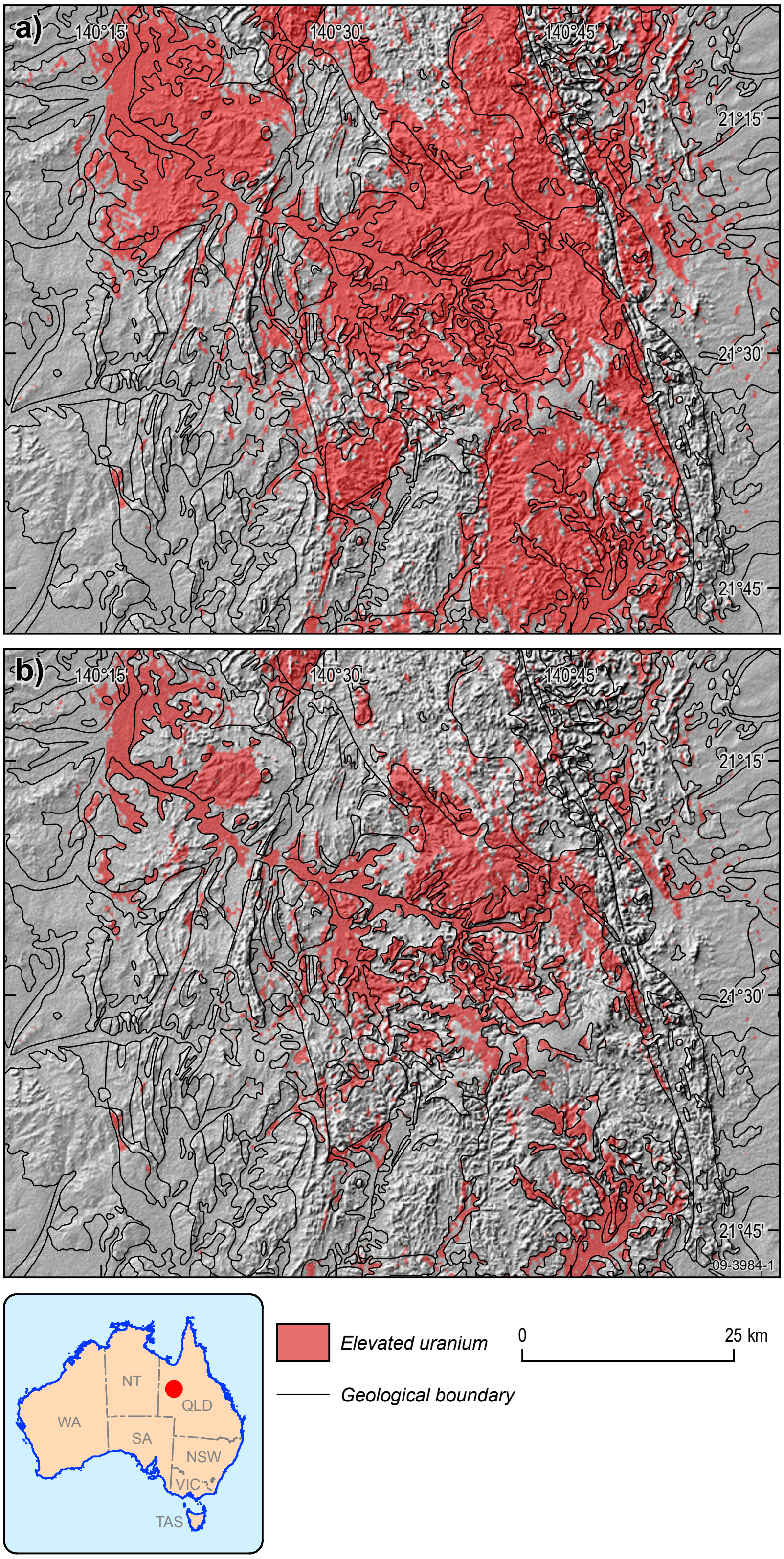



**Figure 1. (a)** Elevated uranium values relative to background values calculated for crystalline rocks, sedimentary rocks and unconsolidated regolith materials in the southern Mount Isa region. **(b)** Elevated uranium values relative to background values calculated for individual geological units in the southern Mount Isa region.

potassium and uranium, is not usually affected to the same degree by weathering and alteration processes. This enables the use of ratios of K/Th and U/Th ratios as a proxy for detecting areas of mineralisation (Shives et al 1997; Dickson and Scott 1997).

In the regolith, uranium and thorium are associated with more stable weathering products including clay minerals, iron and aluminium oxyhydroxides and resistate minerals (such as monazite and zircon). The presence of organic matter and specific bacteria (for example, sulphate-reducing bacteria) can also influence the distribution of uranium in the regolith. High thorium/uranium ratio values in the weathering profile compared to the underlying bedrock can indicate preferential mobilisation and leaching of uranium, and may indicate nearby sources of secondary uranium mineralisation.

## Exploration for secondary uranium deposits

Establishing appropriate uranium background values is a prerequisite to identifying uranium anomalies associated with mineralisation or secondary enrichment processes. Background values of uranium for any given area will change depending on the geology, regolith, geomorphic setting and history, hydrology and climate.

The background uranium values for individual rock or regolith units can be calculated by integrating analysis of uranium data and geological data.

This analysis has been carried out using uranium data from the new *Radiometric Map of Australia* and the new digital *1:1 million Surface Geology Map of Australia* (*AusGeo News 93*). Background uranium averages were calculated for three geological groups; crystalline rocks, sedimentary rocks and unconsolidated regolith materials (such as, alluvial and colluvial sediments). Above-average uranium values for these three groups are shown for an area south of Mt Isa in figure 1(a). Background uranium averages were also determined for individual geological units and elevated uranium values derived from this calculation for the same area are shown in figure 1(b).

Ratios of the radioelements can provide further constraints for identifying potential uranium deposits. Wyborn et al (1994) showed that alteration zones associated with Coronation Hill-style mineralisation have slightly elevated uranium but are strongly depleted in thorium compared to the surrounding rocks which have high levels of both uranium and thorium. A ratio of $U^2/Th$ proved effective in highlighting uranium mineralisation in the area.

The $U^2/Th$ ratio is also effective in separating the primary uranium, associated with uranium-bearing granites, from secondary uranium associated with paleochannel calcrete (such as at Yeelirrie in Western Australia; see figure 2). High $U^2/Th$ ratio values are associated with many uranium deposits in Australia and can be used to highlight new areas of potential mineralisation. These ratio values, and other enhancement techniques using airborne imagery, need to be interpreted in the context of the local geological and regolith setting. For example, some rocks have inherently low thorium compared with uranium and are not associated with mineralisation processes. Nevertheless, normalising techniques using geological units and radioelement ratios provide a rapid approach for locating potential uranium mineralisation which can then be followed up by on-ground validation and assessment.

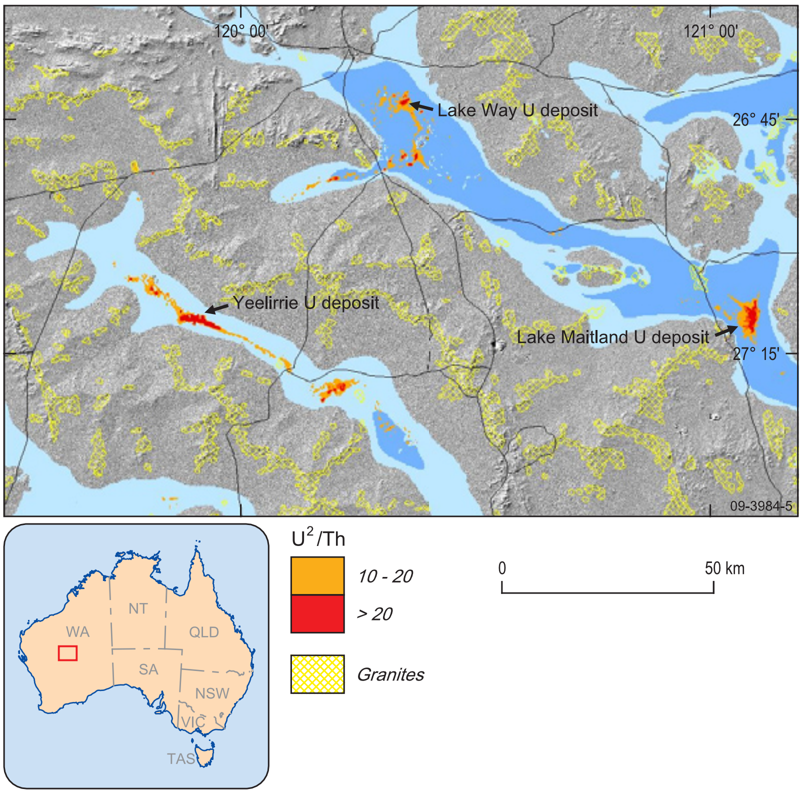



**Figure 2.** Uranium/thorium ratio ($U^2/Th$) for the Yeelirrie deposit in Western Australia with paleochannels highlighted in light blue.

## Potential limitations and false anomalies

Airborne spectrometry measures surface radioelement concentrations to a depth of approximately 40 centimetres. Uranium mineralisation which is deeper than 40 centimetres will not be detected by airborne spectrometers. Spectrometric mapping of uranium also assumes equilibrium in the $^{238}U$ decay chain. Disequilibrium can occur where daughter products above the measured Bismuth ($^{214}Bi$) in the decay chain are either enriched or removed, thereby giving either an over- or under-estimate of uranium. For example, uranium anomalies can be caused by the accumulation of radium ($^{226}Ra$) in ground waters. Dickson (1995) showed that disequilibrium effects in soils were not large. Soil disequilibrium together with generally low count rates are significant factors that contribute to the noise in uranium channel data.

Uranium concentrations derived from gamma-ray spectrometry are normally expressed in units of 'equivalent' parts per million (ppm eU) as a reminder that these estimates are based on the assumption of equilibrium in their respective decay series. False uranium anomalies can result from disequilibrium processes and it is essential that anomalies identified using airborne data are verified by soil and bedrock geochemistry. Correlation of airborne radioelement values with soil and rock geochemistry (figure 3) is currently being investigated as a means of better understanding issues around disequilibrium, scale and accuracy of the spectrometric method.

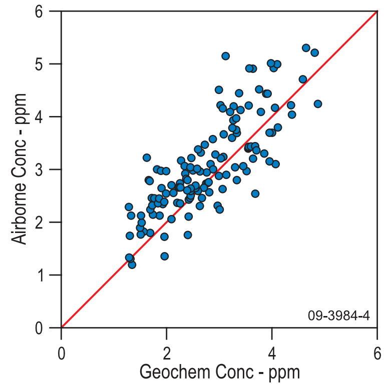



**Figure 3.** Correlation between soil and airborne measured uranium. The samples analysed were collected as part of the Riverina geochemical survey (de Caritat et al 2007).

## Exploring the data

The information above, as well as additional spatial information pertaining to uranium in the Australian environment, will be made available through the 'Uranium Prospector' on the Geoscience Australia website (see link below). Uranium Prospector is a virtual globe using the NASA World Wind application which allows the user to display, visualise and interpret a suite of information related to uranium. Some of the themes include; location of known uranium deposits, uranium occurrences, normalised uranium and ratio distributions using lithological units, uranium channel data, airborne first vertical derivatives magnetics, and the $U^2$/Th ratio image.

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### *Related websites/articles*

*AusGeo News 92*: New Radiometric Map of Australia

www.ga.gov.au/ausgeonews/ausgeonews200812/radiometrics.jsp

*AusGeo News 93*: New digital geological map of Australia

www.ga.gov.au/ausgeonews/ausgeonews200903/geological.jsp

Radiometric Map of Australia datasets

www.ga.gov.au/minerals/research/national/radiometric/index.jsp

Uranium mineral systems: processes, exploration criteria, and a new deposit framework (Geoscience Australia Record 2009/20)

www.ga.gov.au/products/servlet/controller?event=GEOCAT_DETAILS&catno=69124

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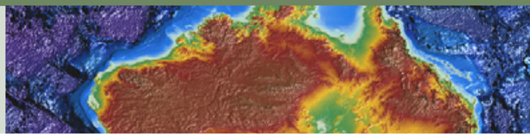
# High resolution coverage of Australia's sea floor



## *New bathymetry and topography grid released*

*Tanya Whiteway*

Geoscience Australia, as the national co-custodian of bathymetric data for Australia with the Royal Australian Navy, has been acquiring and collating bathymetric survey data for the Australian marine jurisdiction since 1963 (Webster and Petkovic 2005). In 2000, Geoscience Australia used this data to create a one kilometre (0.01 decimal degree: dd) grid for the Australian territorial waters and beyond. A revised 250 metre (0.0025dd) version of the grid was produced in 2005 to meet client requests. Since the release of the 2005 version, data from continuing surveys and field studies have contributed to the collation of a number of new high-resolution datasets along the Australian continental shelf margin.

The new 250 metre (0.0025dd) 2009 Bathymetry and Topography Grid of Australia draws together the most recent bathymetric datasets for the Australian region (figure 1). The area covered in this grid (9°S - 45°S, 108°E - 160°E) represents the full Australian Exclusive Economic Zone including waters adjacent to the continent of Australia, Macquarie Island surrounds, and the Australian Territories of Norfolk Island, Christmas Island, and Cocos (Keeling) Islands. This coverage does not include Australia's offshore jurisdiction from the Territory of Heard and McDonald Islands or the Australian Antarctic Territory.

## Data Sources

The datasets used to create the 2009 version of the grid varied greatly in resolution, source and data type. They included:

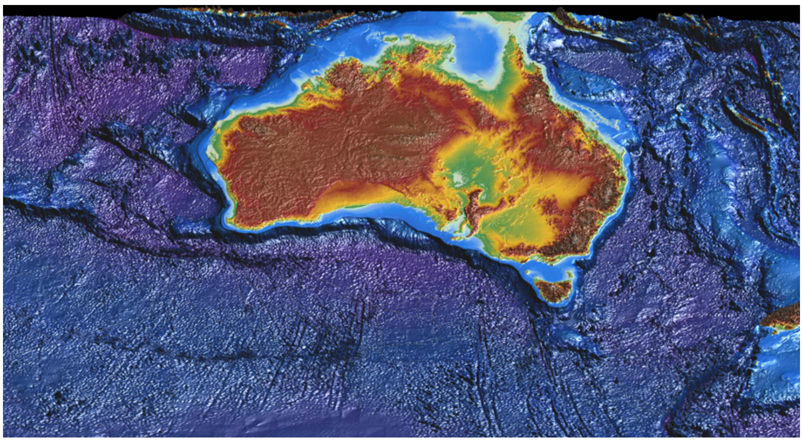


**Figure 1.** False-colour image showing a 3D view of the Australian Bathymetry and Topography Grid, June 2009.

- Multibeam Swath sonar bathymetry
- Fairsheets (Hydrographic Office, Royal Australian Navy)
- Laser Airborne Depth Sounder (LADS) data (only those LADS datasets that had previously been converted to a suitable datum were used in this grid)
- Deep ocean data (where high resolution data were not available) based on the ETOPO1 or ETOPOv2g data supplied by the National Geophysical Data Center, US Department of Commerce (NGDC)
- Australian Digital Elevation Model (DEM) supplied by Geoscience Australia and the Australian National University
- New Zealand DEM based on the 250 metre DEM data supplied by Geographx, New Zealand
- Indonesian and Papua New Guinean DEMs based on the SRTM DEM supplied by the CGIAR Consortium.

## New high resolution datasets

A range of new high resolution datasets were used in the compilation of the 2009 version of the grid. Data from recent surveys including the Southwest Margins Marine Reconnaissance (Foster et al 2009) and the Remote Eastern Frontier Basins Reconnaissance (Heap et al 2008) covered areas along the continental margin and revealed a number of new seafloor features including small volcanic mountains (figure 2a) and canyons (figure 2b).

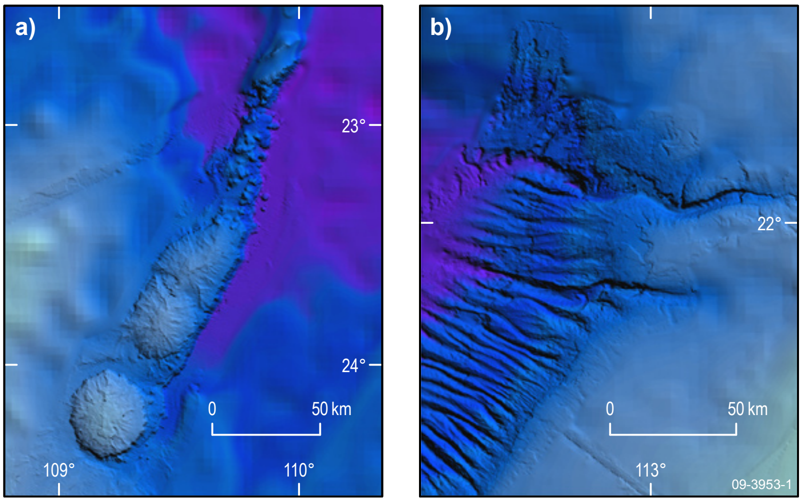



**Figure 2.** False-colour bathymetry images showing: (a) underwater volcanic mountains and (b) submarine canyons off Western Australia, discovered during the Southwest Margin Marine Reconnaissance Survey, October 2008 to January 2009.

New bathymetric grid compilations for Cocos (Keeling) Islands, Christmas Island and Lord Howe Island (Mleczko 2008), as well as the Gulf of Papua (Daniell 2008) are also included in this version. These datasets include the most recent and best available input data providing improved sea floor topography for these areas. This will particularly reduce the effects of invalid cliff edges caused by the lack of data and over-interpolation of data which occurred in the 2005 version of the grid.

The inclusion of higher resolution topographic grids for Australia, New Zealand and Indonesia has improved continuity between the land and bathymetric data, resulting in improved accuracy of the ocean-land interface.

The 250 metre New Zealand Digital Elevation Model (DEM) was sourced from Geographx (Geographx 2008), and for Indonesia, the 90 metre SRTM DEM (Jarvis et al 2008) was included. These datasets were resampled to 250 metre (0.0025dd) grid and added to the final product.

In 2008, Geoscience Australia completed a revised version of the 9 second DEM for Australia using ANUDEM version 5.2.2. This 9 second DEM was used in the production of the 2009 version of the grid. All other input grids were aligned to the cell location of this grid to maintain a single cell configuration throughout the processing. This also ensured the final bathymetry product could be used in conjunction with the 9 second DEM product with no cell offset.

## Global bathymetry and background datasets

As well as high resolution local datasets, global scale datasets are also an important component of the Australian bathymetry grid. The resolution and accuracy of global bathymetric datasets has been constantly improving over the last ten years. The latest global relief datasets, in particular ETOPO2v2g (Smith and Sandwell 1997) and ETOPO1 (Amante and Eakins 2008) are now down to 2 arc-minute and 1 arc-minute resolution respectively. In these datasets, the bathymetric component of the data is based primarily on satellite altimetry measurements tied to ocean soundings. These grids lack much of the detailed data sourced in local and regional surveys, but provided excellent background data sources for the development of the higher resolution grid for Australian waters.

In the 2009 grid, lower resolution ETOPO2 and ETOPO1 data has been used to fill those off-shelf areas (approximately -200 metres or deeper) where higher resolution survey datasets (such as swath, fairsheets and LADS) were not available. The result in off-shelf areas is a combination grid of high resolution data where it is available and lower resolution ETOPO data elsewhere. There is also a visual difference between the ETOPO dataset in the 2005 grid compared with the 2009 grid. In the 2005 version, the ETOPO data was resampled to a 0.0025dd cell size using an interpolation process which smoothed the data and added apparent detail. In the 2009 grid, the ETOPO data was resampled to 0.0025dd using a bilinear process to minimise interpolation. As a result the ETOPO data in the 2009 grid appears coarser and seems to have less detail although it is truer to its original source (Whiteway 2009).

For on-shelf areas (approximately -200 metres or shallower) surveys completed over the last few years have greatly improved the overall accuracy and resolution of the data. In some cases there were notable discrepancies between the survey data and ETOPO datasets. These were where the difference in resolution and accuracy caused anomalous valleys or ridges as the higher resolution survey data cut through the lower resolution ETOPO data. These differences also resulted in edge effects where the edges of the different datasets did not meet at the same height. In such cases, an interpolation process was used to smooth the data artefacts.

## New processing methods

The programs and processes used to create the 2009 Bathymetry and Topography Grid are described in Whiteway (2009). The major processing steps included:

- Initial raw data editing for fairsheets, gridding and mosaicing using Intrepid™ software.
- Review of gridded data, mosaicing and the creation of the lineage shapefile in ArcGIS.
- Interpolation of replacement data to fill data gaps, and data review in ER Mapper.

A number of the processes used in the creation of the 2009 grid are new techniques applied specifically to improve the land-sea confluence and the joins between high and low resolution datasets.

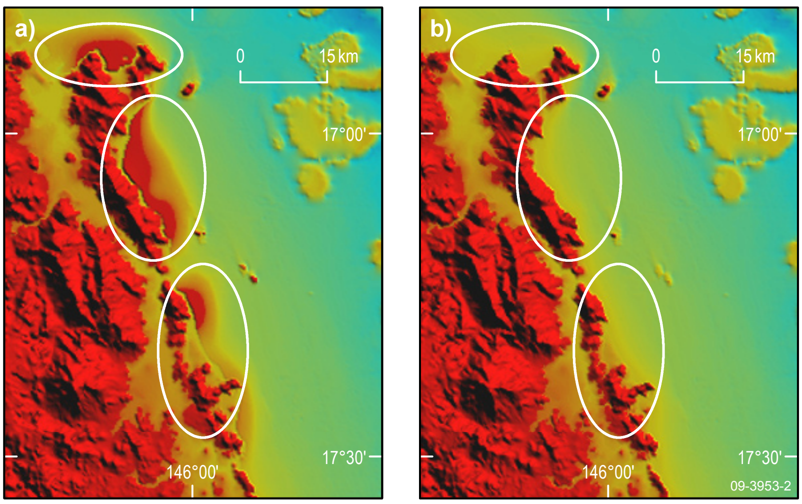



**Figure 3.** False-colour images showing the reduction to the interpolation artefacts between the continental shelf and land areas using the improved interpolation process. Comparison of the 2005 version of the grid (a) and the 2009 version (b) with variations highlighted by circled areas.

In an effort to reduce the interpolation effects seen in the 2005 bathymetric grid where land occurred in areas of ocean (figure 3a), the new Australian 9 Second DEM was used in the processing phase. The 9 Second DEM was set to 0 metres across the grid and this setting was then used in the interpolation process to fill the gaps between survey datasets covering the shelf and the land. Setting the land elevation to 0 metres meant that the interpolation process resulted in a smooth gradient to the coastline, reducing the areas where land occurs in the ocean (figure 3b).

The 9 Second DEM was also used in the final process, draping it over the existing data to ensure the topography matched the DEM. The combination of these processes ensures that cliffs above the waterline remain, however, it should be noted that underwater cliffs only exist in areas where the survey data meets (or is close to) the land edge. In other coastal areas, a smooth gradient will occur between survey data and the 0 metre coastline.

In the 2009 grid, a new process was also applied to allow the production of a lineage shapefile showing the overall input data type for each of the grid cells. The process involved gridding similar resolution datasets in the same process, and mosaicing them with other datasets that had been gridded together. This differed from previous grids where all datasets were gridded together. For this reason, there are smoothing artefacts around sections of data that were mosaiced, similar to those seen when all datasets are interpolated together. In the 2009 grid, however, they appear sharper in some areas, as the boundary change distance has been minimised to avoid smoothing through other higher accuracy datasets.

A range of errors were identified in the 2005 grid, including irregular ship track lines, swath spikes, ETOPO gravity anomaly highs and fairsheet digitising errors. Generally these errors are products of the raw data, causing high and low anomalies, lines of erroneous data and large-scale interpolation artefacts. When identified these errors were removed through editing the output grid. However, the prolific errors seen in the single beam data meant that this entire dataset was removed prior to interpolation.

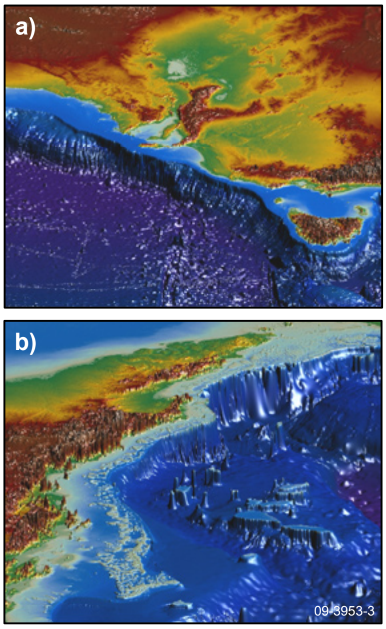



**Figure 4.** False-colour images showing 3D views of (a) Tasmania and Spencer Gulf and (b) a section of Queensland and the Great Barrier Reef.

## Final products

The final 250 metre (0.0025dd) 2009 Bathymetric and Topographic Grid has been produced in two main formats: ESRI™ grid and ER Mapper™ (ers), and additionally as an ascii bil file. There are also two vector files. A lineage shapefile that can be used to identify the general source data for each cell in the grid, and a 500 metre contour shapefile produced in ArcMap™. The data can be ordered on DVD from the Geoscience Australia Sales Centre.

The 2009 bathymetry grid provides excellent regional context (figure 4), and the greater volume of high accuracy data on the continental shelf provides an improving local context. The production of an Australian region bathymetric grid, however, should be seen as a process of review and re-compilation to fully exploit the latest methods for managing and gridding new data.

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### *To purchase a copy*

**visit** www.ga.gov.au/products/servlet/controller?event=GEOCAT_DETAILS&catno=67703

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*AusGeo News 93*:
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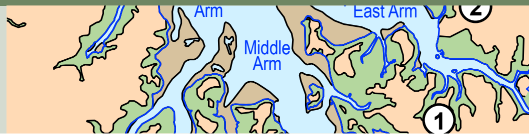
ISSUE 95 Sept 2009

# The role of sediments in nutrient cycling in the tidal creeks of Darwin Harbour




## *Research project aims to assess ecosystem health*

*Jodie Smith and Ralf R. Haese*

Darwin Harbour is a largely unmodified estuary in the wet tropics of northern Australia and the water quality varies greatly with tides, season and location. Darwin Harbour is surrounded by extensive intertidal mudflats and mangroves fringe at least two-thirds of the foreshore (figure 1).

Numerous water quality studies have been conducted in Darwin Harbour by the Northern Territory Department of Natural Resources, Environment, The Arts and Sport (NRETAS) over the past 20 years. These have determined the contribution of diffuse sources, such as urban and rural runoff, as well as point sources such as treated sewage effluent, to total catchment loads (see related websites).

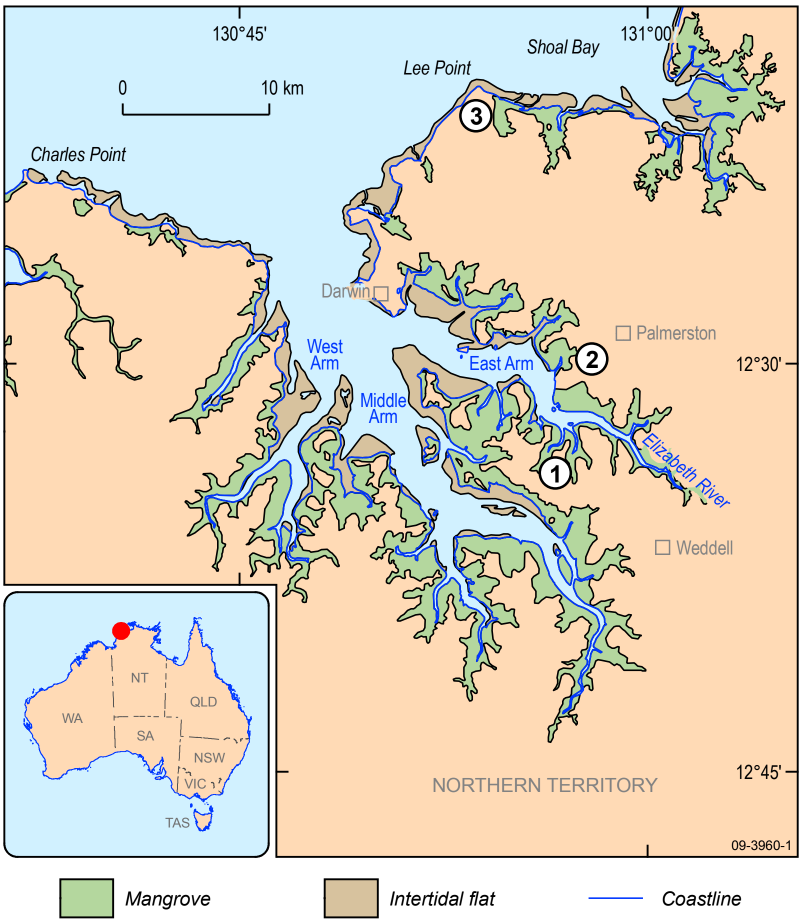



**Figure 1.** Map of Darwin Harbour showing the extent of intertidal mudflat areas and mangroves, and (1) the reference creek; (2) Myrmidon Creek; and (3) Buffalo Creek.

Impacts on water quality in the harbour from urbanisation have already been reported (Water Monitoring Branch 2005) and it has been found that treated sewage effluent is the main contributor to total nutrient loads (Skinner et al 2009).

On a whole-of-harbour scale, diffuse runoff and point-source sewage discharges are relatively minor compared to the overall nutrient status of the harbour. However, research suggests that the effects may be significant at local scale, that is, within tidal creeks where point source nutrients are discharged (Fortune and Maly 2009). A need for further research has been identified to assist in understanding how nutrients from sewage effluent are assimilated in the receiving tidal creeks (Skinner et al 2009).

To ensure that water quality objectives are maintained, and that community values associated with the Harbour are protected, NRETAS is developing a Water Quality Protection Plan for Darwin Harbour. A recent detailed report on the development of the Plan (Fortune and Maly 2009) included a summary of previous water quality studies, the development of water quality objectives, pollution load assessment and targets and priority research being undertaken to support the Plan. The report also identified a number of key elements, including nutrient cycling and algal interactions, as well as priority zones for future research efforts.

Consequently, a number of research projects have been initiated to provide insights into key water quality processes in Darwin Harbour and inform water quality model parameters (Fortune and Maly 2009). One of these projects aims to assess the effect of sewage inputs on the ecosystem health in Darwin Harbour. The project involves collaboration between NRETAS, Geoscience Australia, Griffith University (Queensland), CSIRO and Charles Darwin University (Darwin). It was funded through the Tropical Rivers and Coastal Knowledge (TRaCK) research hub which was established under the Commonwealth Environment Research Facilities Program.

## Study of nutrient transformation and retention processes

Field studies examining nutrient cycling were conducted in three tidal creeks which each receive different amounts of sewage discharge. The field sites are within the identified priority zones for the harbour. Surveys during the wet and dry season were undertaken to differentiate land runoff effects from sewage inputs. The project focused on the extensive intertidal mudflat sediments which have received little attention in previous nutrient studies, despite occupying a substantial area within the harbour (figure 1). In addition, intertidal mudflats play an important role in regulating primary productivity (that is, algal growth) by storing and recycling nutrients and therefore act as a potential buffer against increased nutrient loads. However, it is not clear whether nutrient transformation processes within the extensive intertidal mudflat areas will retain the additional nutrient discharge. This project is designed to advance the scientific knowledge beyond the traditional water quality monitoring programs and to develop a greater understanding of the longer term impacts and implications for ecological health from increased nutrient loads.

Scientists from Geoscience Australia studied nutrient transformation and retention processes in the sediments. The key factors quantified were:

- release of nutrients from sediments (‘benthic nutrient fluxes’)
- sediment nutrient pools
- the capacity of sediments to convert bioavailable nitrogen into dinitrogen gas (‘denitrification’)
- the capacity of sediments to retain phosphorus
- breakdown (‘respiration’) and growth (‘photosynthesis’) of microalgae.

Partners from Griffith University (Queensland) and CSIRO focussed on the biological aspects of the project and gathered information on:

- the extent of the sewage signal on microphytobenthos, benthic infauna and phytoplankton
- the interactions between turbidity and nutrients with respect to phytoplankton and microphytobenthic production
- the effectiveness of benthic bioindicators in tracing sewage in the food web.

## Darwin Harbour water quality

River flow into Darwin Harbour reflects the highly seasonal rainfall pattern, with maximum flows between January and March each year. The rivers have naturally low concentrations of nutrients and sediment because of the low relief and infertile soils of the highly weathered catchment. Darwin Harbour is macrotidal, with a maximum tidal range of 7.8 metres. The large tidal movement produces strong currents up to two metres per second which cause resuspension of fine sediments and lead to a naturally turbid system and a general perception of poor ecosystem health (McKinnon et al 2006). However, nutrient concentrations are low in the main body of the harbour (0.05-2.0 milligrams per litre of nitrogen and 0.01-0.04 milligrams per litre of phosphorus) with slight seasonal variations due to river runoff during the wet (Water Monitoring Branch 2005).

The majority of nutrients that enter the harbour are imported from the ocean and are typically in the particulate or organic form (Burford et al 2008). These nutrients are not considered to be bioavailable, that is, able to be used by biological organisms. Nutrients also enter the harbour from the surrounding catchment and are derived from both diffuse sources, such as urban and rural runoff, as well as point sources such as treated sewage effluent. The impacts of urbanisation on water quality in the harbour have already been reported with nitrogen and phosphorus loads from the catchment 1.7 and 5.9 times higher than pre-urbanisation loads (McKinnon et al 2006). Treated sewage effluent contributes 71 per cent of total phosphorus and 31 per cent of total nitrogen of the annual catchment load (Skinner et al 2009) and these nutrients are typically bioavailable. The sewage effluent is typically discharged into tidal creeks on the fringes of the harbour. There is evidence of localised impacts on the water and sediment in tidal creeks receiving sewage effluent, including anoxic water conditions, elevated chlorophyll concentrations and higher sediment nutrient concentrations (Padovan, 2003). However, most of the harbour remains in a healthy state with some areas such as West Arm considered relatively pristine (Water Monitoring Branch 2005).

There is potential for more severe impacts on coastal water quality and overall ecological health in the future due to increasing population and land development. The harbour is adjacent to the cities of Darwin and Palmerston (figure 1). Darwin is the fastest growing capital city in Australia with the population expected to double by 2050. Skinner et al (2009) have predicted the impact of future population growth and development on nutrient loads entering Darwin Harbour. While previous studies have identified the contribution of sewage effluent to catchment nutrient loads, they do not address the fate of nutrients and their ecological consequences once they enter the harbour.

## Geomorphology, hydrodynamics and sewage loads

The tidal creeks studied as part of the TRaCK project were the unnamed reference creek and Myrmidon Creek in East Arm of Darwin Harbour and Buffalo Creek in Shoal Bay (figure 1). The reference creek, on the western side of East Arm, is considered to be near-pristine with no known impact from urbanisation or land development. Myrmidon Creek, on the eastern side of East Arm, is adjacent to Palmerston. Both creeks display relatively simple geometry, with predominantly straight channels, widening downstream, and extensive intertidal mudflats along the length of the creeks. As a result, both creeks are well flushed during each tidal cycle.

Throughout the dry season, Myrmidon Creek and the reference creek typically have high salinity (greater than 37), are well oxygenated and have low nutrient concentrations. During the wet season, freshwater inputs to East Arm from the Elizabeth River are pushed into the creeks during high tide, lowering the salinity and slightly increasing nitrogen concentrations.

Buffalo Creek consists of a long, narrow channel with a few large meander bends at the downstream end. A large intertidal sand bar across the mouth inhibits tidal movement to a significant degree. Upstream the channel becomes even narrower and meanders through dense, overhanging mangroves. The majority of the creek has straight-sided banks but there are sections of intertidal mudflats on the meander bends and parts of the main channel.

Treated sewage effluent is discharged from sewage treatment plants into the mangroves fringing Myrmidon and Buffalo Creeks. These are licensed under the *Water Act* and administered by NRETAS (Water Monitoring Branch 2005). The Palmerston sewage treatment plant discharges into Myrmidon Creek. The discharge point is approximately 850 metres from the mouth of the creek. At this point the creek is approximately 100 metres wide and six metres deep at high tide. There is a distinct green sewage plume which enters the creek at the discharge point (figure 2a). The plume, typically restricted to the surface layer, is low in dissolved oxygen and enriched in nutrients, suspended matter and chlorophyll-a. The plume gradually disperses during the ebb tide and is rapidly diluted and mixed, becoming undetectable within a few hours (figure 3a).

The Leanyer Sanderson sewage treatment plant, the largest in Darwin, discharges into Buffalo Creek. The sewage outfall is at the upstream end of the creek, approximately 5000 metres from the mouth, where the creek is very narrow. Buffalo Creek experiences episodic hypereutrophic events with very high algal concentrations in the water column and sediment (figure 2b). Anoxic conditions occur in Buffalo Creek and the very low dissolved oxygen concentrations suggest significant respiration is occurring as a result of organic carbon and nutrient inputs, and this is likely to have major effects on the ecosystem functioning of this creek. The impacts of the sewage discharge are detectable along the entire length of the creek, with high nutrient concentrations and low dissolved oxygen concentrations measured even at the downstream end of the creek (figure 3b). Dissolved oxygen and nutrient concentrations vary with tidal levels and there is a general improvement in water quality conditions during high tide. The impacts of the continual inflow of nutrient-rich sewage discharge at the constricted upstream end of the creek is exacerbated by minimal mixing and poor flushing, particularly during neap tidal conditions (when tides attain the least height).

While there is a clear distinction in the level of impact from sewage outfalls on water quality between the three tidal creeks, there is also a significant difference in nutrient cycling within the intertidal mudflats that is relevant to this project. A water quality model for Darwin Harbour has been developed (Fortune & Maly 2009). The concentration of nitrogen and phosphorus in the harbour, as a result of catchment runoff and sewage treatment plant discharge has been simulated to estimate the total maximum pollutant loads to achieve water quality objectives. Refinement of the model will continue as monitoring data is collected and specific research addresses critical parameter inputs. The results presented here address some of the key parameters associated with nutrient cycling in the sediments and will make an important contribution to


**Figure 2.** (a) Myrmidon Creek sewage plume (photo courtesy of Emily Saeck, Griffith University). (b) Hypereutrophic event in Buffalo Creek (photo courtesy of Jodie Smith, Geoscience Australia).

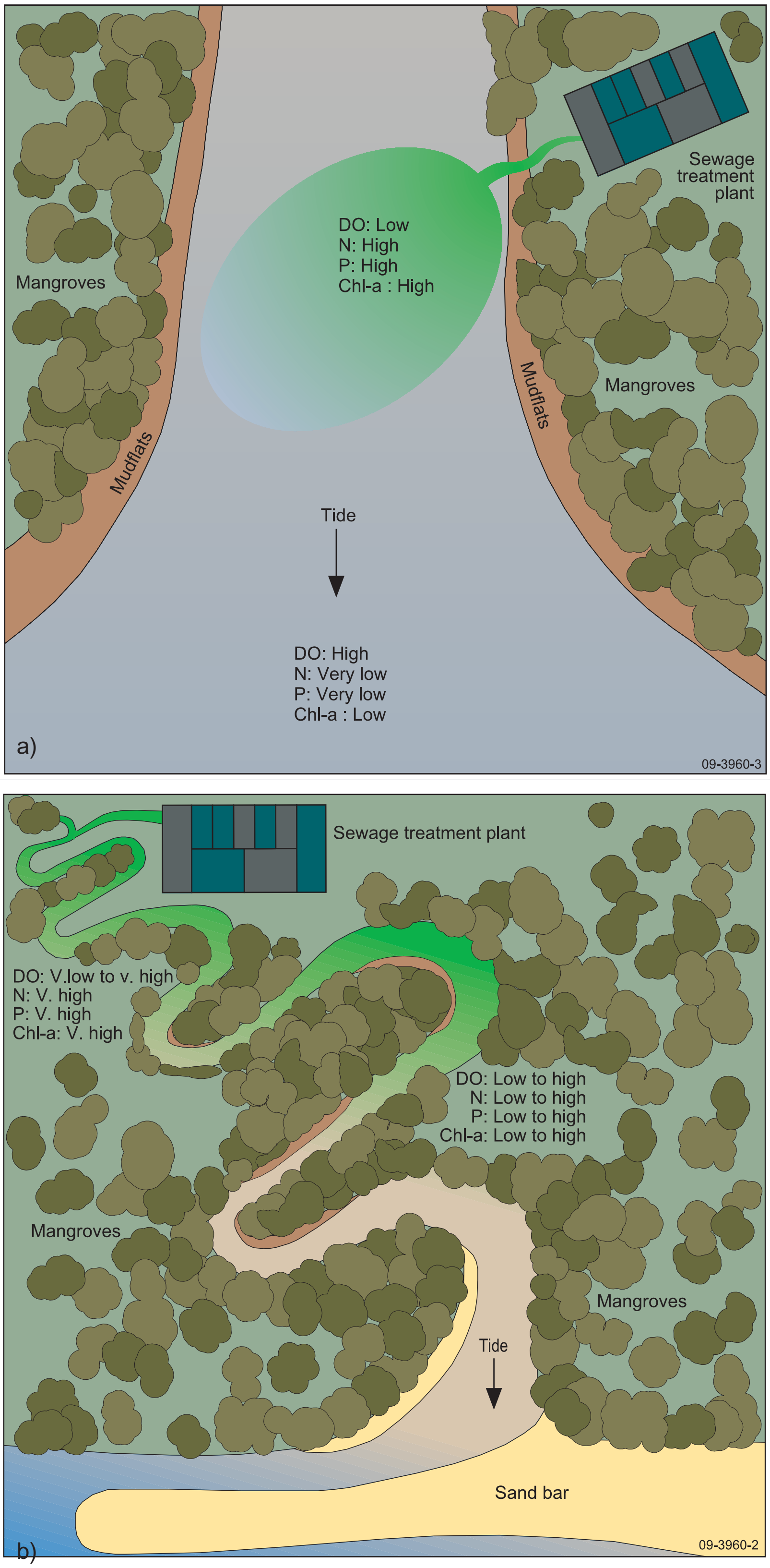



**Figure 3 (a) and (b).** Conceptual diagrams of Myrmidon and Buffalo Creeks showing geomorphology, sewage discharge points and nutrient and oxygen conditions.

refining the water quality model for Darwin Harbour.

## Nutrient cycling in the intertidal mudflat sediments

The intertidal mudflat sediments are highly heterogenous and heavily bioturbated by crustaceans, polychaete worms and other infauna. This results in a large natural variability in nutrient cycling processes within each sampling site. However, there were marked differences in a range of nutrient cycling processes in Buffalo Creek compared to Myrmidon Creek and the reference creek which were far greater than any natural variability.

Benthic nutrient fluxes (the release of nutrients from the sediments to the overlying water column) were up to 100 times higher in Buffalo Creek compared to Myrmidon Creek and the reference creek. Additionally, porewater nutrient pools indicate the sediments in Buffalo Creek contain a large source of dissolved nutrients. This is significant because it indicates the sediments would continue to release nutrients to the water column for a long period even if sewage discharges were ceased. There were no marked differences in benthic nutrient fluxes between Myrmidon Creek and the reference creek or between the wet and dry seasons, despite additional nutrient inputs during the wet.

Denitrification is a process which occurs in sediments whereby inorganic nitrogen is converted into dinitrogen gas. Denitrification was measured in the sediments as an indication of the efficiency of nitrogen removal from the system. It provides a useful indicator of ecosystem health. In Myrmidon Creek and the reference creek, denitrification efficiency was very high (80 to 90 per cent) indicating that most nitrogen is released from the sediments back into the atmosphere. Conversely, denitrification efficiency in Buffalo Creek was low and the majority of nitrogen is released back into the water column (as ammonium and nitrate) where it is bioavailable.

The degree to which the sediments have retained additional phosphorus from sewage inputs was assessed by determining the different phosphorus fractions in the sediments. Initial results indicate that concentrations of phosphorus in surface sediment are up to three times higher in Buffalo Creek compared to Myrmidon Creek and the reference creek. More importantly, over 50 per cent of the phosphorus in Buffalo Creek is in the exchangeable and redox-sensitive fraction. This fraction is a bioavailable source for phytoplankton and microbenthic algae growth. Moreover, there is potentially a risk of phosphorus release into the overlying water column under anoxic conditions, which are known to occur in Buffalo Creek.

The low benthic nutrient fluxes and high denitrification efficiencies measured in the intertidal sediments of Myrmidon Creek and the reference creek provide a clear indication that the ecological health of these two creeks is intact, despite additional nutrient sources from wet season runoff and sewage outfalls. The geomorphology and hydrodynamics of Myrmidon Creek allow for a short residence time with efficient flushing and rapid export of sewage discharges. This research indicates that the effect of sewage inputs in Myrmidon Creek is only temporary and localised, with the effects principally measured in the water column rather than sediment processes.

On the other hand, residence times in Buffalo Creek are longer, particularly upstream where the sewage outfall is located. A larger nutrient load, low denitrification efficiency and poor tidal flushing have resulted in large sediment nutrient pools and poor ecosystem health in Buffalo Creek.

## Conclusions

The effects of treated sewage effluent on ecosystem health in Darwin Harbour are localised. In Buffalo Creek, a range of nutrient cycling processes is impacted by high nutrient loads from sewage effluent. In Myrmidon Creek, the impacts are temporary and limited to the water column. This project provides an understanding of the predominant nutrient cycling processes and the fate of nutrients in the intertidal mudflats of affected areas. It provides information about the assimilatory capacity of the ecosystem to cope with increasing pollution loads.

This knowledge will contribute to the development of a conceptual model showing the effect of nutrient and sediment loads on the health of mudflats and mangroves and identify a suite of potential bio-indicators for assessing ecosystem health. This research will provide valuable input into the development of an optimal monitoring program for Darwin Harbour. The research on the impact of biogeochemical

“This project provides an understanding of the predominant nutrient cycling processes and the fate of nutrients in the intertidal mudflats of affected areas.”

processes in intertidal mudflats will provide key information needed to validate a mathematical model simulating and predicting water quality in Darwin Harbour.

The outcomes of this research will enable water managers to make better informed decisions when considering issues such as sewage treatment options when planning expanded urban development. There will also be more effective targeting of future investments to maintain or improve water quality or to upgrade sewage treatment.

## Acknowledgements

We wish to thank the Project Leader Dr Michele Burford (Griffith University) and Dr Andrew Revill (CSIRO) for their advice throughout the project and support in the field. We wish to thank Julia Fortune, Tony Boland, Matt Majid and staff from the Department of Natural Resources, Environment, The Arts and Sport for providing important local information, as well as boats and other field support, and Charles Darwin University for providing laboratory space and facilities. TRaCK receives major funding for its research through the Australian Government's Commonwealth Environment Research Facilities initiative, the Australian Government's Raising National Water Standards Program, Land and Water Australia, the Fisheries Research and Development Corporation and the Queensland Government's Smart State Innovation Fund.

### *For more information*

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Tropical Rivers and Coastal Knowledge (TRaCK) research hub

www.track.gov.au

Aquatic Health Unit, Department of Natural Resources, Environment, The Arts and Sport

www.nt.gov.au/nreta/water/aquatic/index.html

Water Quality Protection Plan for the Darwin Harbour

www.nt.gov.au/nreta/water/quality/wqpp.html

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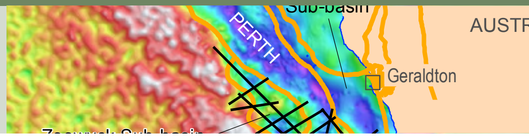
# Energy Security Programs update




## Southwest Margin surveys

After recently completing the Southwest Margin offshore geophysical acquisition surveys along Western Australia's continental margin (*AusGeo News 94*), Geoscience Australia is analysing the processed data.

The Southwest Margins 2D seismic survey acquired approximately 7300 kilometres of commercial 2D seismic reflection data as well as more than 10 000 line kilometres of gravity and magnetic data.

The seismic reflection data has been divided into four logical areas for processing: Mentelle Basin, Wallaby Plateau and Zeewyck and Houtman sub-basins (Perth and Southern Carnarvon basins: figure 1). The seismic field data are being processed, with priority given to completion of the Mentelle Basin and Wallaby Plateau data.

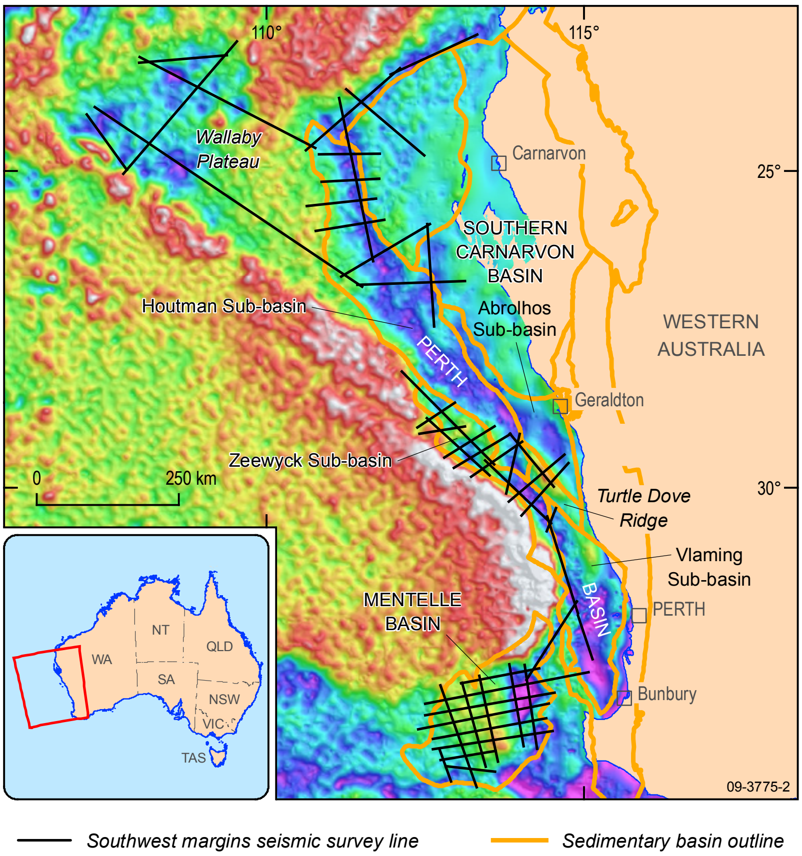



**Figure 1.** Seismic lines acquired during the Southwest Margin 2D seismic survey by the MV *Duke*. The background image is Bouguer-corrected satellite gravity data.

Mentelle Basin seismic sections have recently been received by Geoscience Australia and are currently being checked for product quality. The Wallaby Plateau data is expected shortly, with the data for the Zeewyck and Houtman sub-basins expected within several months. When all the processed data has been received, Geoscience Australia will prepare a seismic data package consisting of the newly acquired data and any reprocessed data covering the Southwest Margin region. This data package should be available towards the end of 2009.

The processed gravity and magnetic line data acquired during the seismic survey have just been returned from processing and are being checked for product quality. Geoscience Australia will shortly begin merging these data into the existing potential field grids to produce updated magnetic and gravity data grids of the region. These will also be available towards the end of 2009.

The new bathymetry data acquired during the Southwest Margin marine reconnaissance survey has been edited, checked for quality and integrated into the new bathymetric maps *energy security programs update*

covering the region. All of the samples collected for geochemical analysis have now been processed and analysed and results are being verified and will be reported after interpretation is finalised.

## Pine Creek airborne electromagnetic survey

Geoscience Australia, in collaboration with the Northern Territory Geological Survey (NTGS), recently acquired approximately 30 000 line kilometres of airborne electromagnetic (AEM) data over the Pine Creek Orogen. The survey was primarily funded through Geoscience Australia's Onshore Energy Security Program. Infill flying within the AEM survey area was funded by the National Water Commission and exploration companies. Data from the Woolner Granite AEM survey area was released in July, while planned release dates for the Rum Jungle and Kombolgie AEM survey areas are September and November respectively (figure 2).

The AEM acquisition was aimed at encouraging exploration by providing a regional geophysical and geological context for areas prospective for uranium mineralisation. Several known unconformity-style uranium deposits in the survey region (such as Ranger, Jabiluka, and Koongarra) are hosted by early Palaeoproterozoic Pine Creek Orogen meta-sediments. Near these deposits the meta-sediments are unconformably overlain by late Palaeoproterozoic sandstones of the Kombolgie Subgroup. The AEM data will characterise the conductivity of the early Palaeoproterozoic basement rocks, and in particular, respond to graphitic schists, a known host for uranium mineralisation. The data may also map the subsurface unconformity with the overlying sandstones which is a target for exploration because mineralisation is inferred to occur adjacent to structures above or below this feature.

AEM survey coverage was extended into areas of laterally extensive regolith and Mesozoic and Cambrian sediment cover with a limited history of exploration. Results in these areas will indicate whether AEM data can penetrate the younger cover and map the underlying highly-prospective Proterozoic bedrock.

The National Water Commission funded infill flying east of Darwin within the Woolner Granite AEM survey area. The additional lines are targeting aquifers in Mesozoic sediments which are used for agricultural purposes. The survey results are expected to assist a review of regional groundwater resources and indicate whether salt water incursion from coastal or estuarine areas is a potential issue.

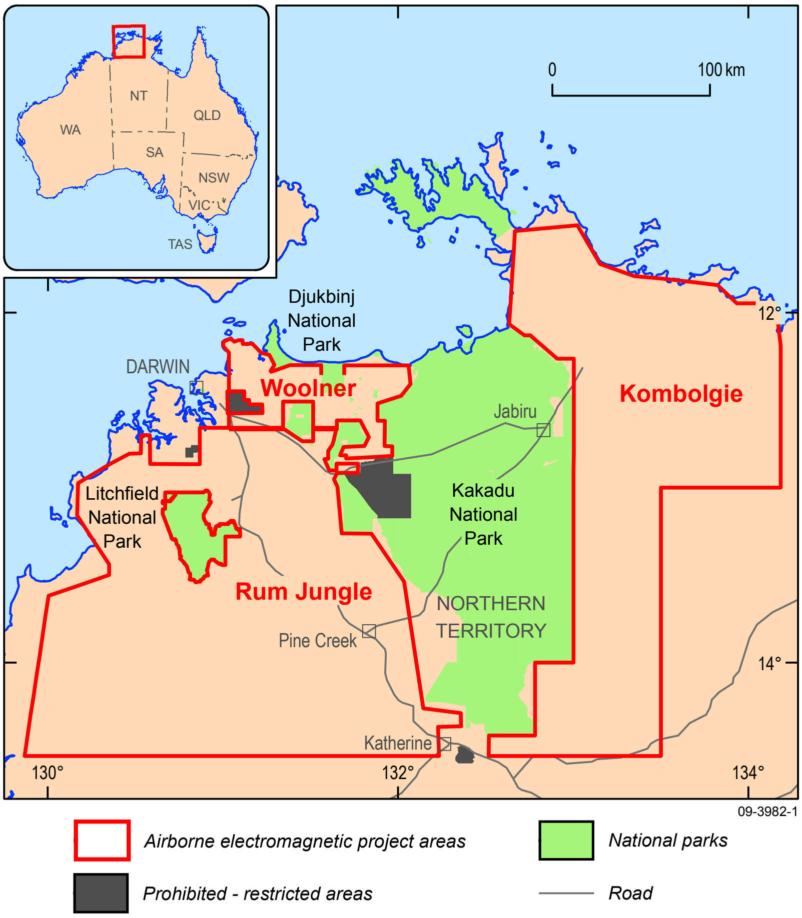



**Figure 2.** Pine Creek airborne electromagnetic survey area.

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ISSUE 95 Sept 2009



## Georgina Basin-Arunta Inlier Survey

Geoscience Australia, in collaboration with the Northern Territory Geological Survey (NTGS), recently completed a 373 kilometre deep seismic traverse across the south-western Georgina Basin (figure 3). The survey was primarily funded through Geoscience Australia's Onshore Energy Security Program. An extension of the seismic line was funded by the NTGS. Release of the Georgina Basin seismic data is currently scheduled for late 2010.

The principal objective of the Georgina seismic line is to support the assessment of hydrocarbon prospectivity in the southern Georgina Basin. The survey transect commences in the Paleoproterozoic Davenport Province to the north, traverses the southwest of the Georgina Basin over the Cambrian Dulcie Trough and crosses the Arunta Region in the south. The seismic line aims to determine the depth of burial of organic-rich middle Cambrian source rocks, image potential hydrocarbon structural and stratigraphic traps, and shed light on deformation and fault reactivation expected from the Alice Springs Orogeny. The seismic data will also support assessment of the geothermal potential of the area by imaging high heat-producing granites and overlying cover.

The Arunta Region includes uranium and thorium bearing vein pegmatites which are likely to be located in preferred structural sites.

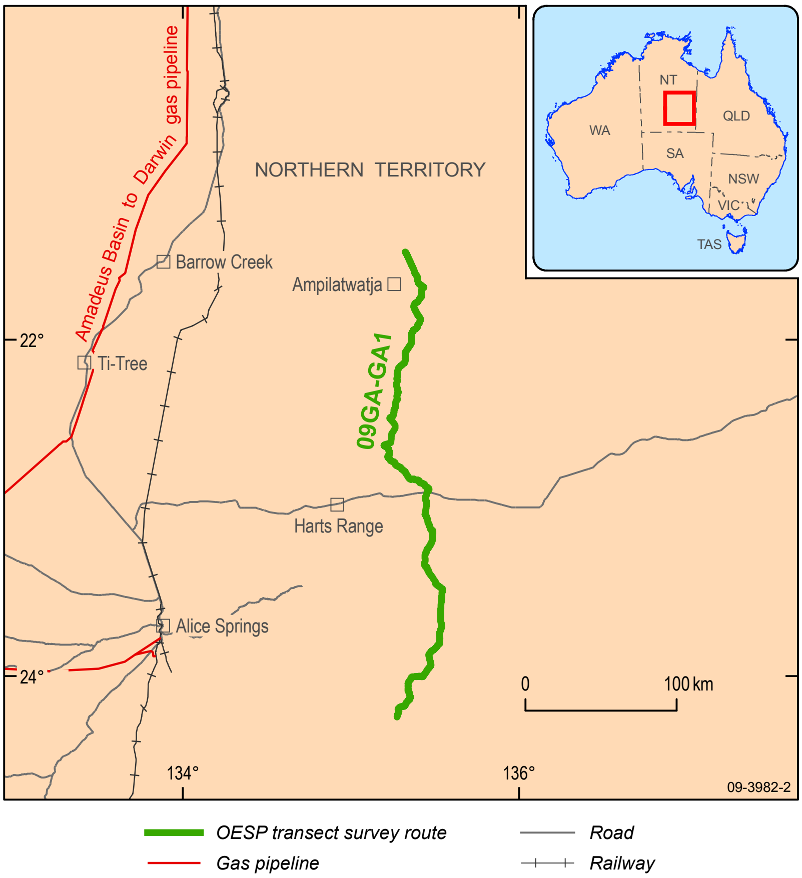


**Figure 3.** Georgina Basin-Arunta Inlier seismic traverse line location map.

The seismic acquisition will image the large-scale crustal framework of the Arunta Region and provide context for the emplacement of these intrusions. Finally, the seismic line will provide constraints on a broad, 2000 kilometre long west-northwest trending aeromagnetic lineament which crosses the region. This feature is thought to represent the axis of a major Cambro-Ordovician tectonic event.

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Seismic acquisition
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### *Related websites/articles*

*AusGeo News 94*: Southwest Margin surveys completed
www.ga.gov.au/ausgeonews/ausgeonews200906/surveys.jsp

in brief

## Broken Hill Managed Aquifer Recharge Project

A multi-disciplinary Geoscience Australia team have commenced the second phase of the Broken Hill Managed Aquifer Recharge (MAR) Project, in western New South Wales (figure 1). The project aims to map and characterise the groundwater aquifer (or underground storage) systems in the Darling Floodplain, and identify suitable targets to develop a managed aquifer recharge (MAR) borefield. This project is part of the Australian Government's commitment to invest up to $400 million to reduce evaporation and improve water efficiency at Menindee Lakes in western New South Wales. This will help secure Broken Hill's water supply and allow for significant amounts of water currently stored at Menindee Lakes to be returned to the environment. The project is managed through the Australian Government Department of the Environment, Water, Heritage and the Arts.

Following on from the initial scoping study and Phase 1 studies, the second phase of the Broken Hill MAR Project involves the acquisition of new data including:

- a light detection and ranging (LiDAR) survey
- an airborne electro-magnetic (AEM) survey of the region
- a seismic reflection survey
- drilling and pump tests
- surface and groundwater characterisation
- a program of borehole geophysics (electromagnetic and gamma logging)
- petrophysics and laboratory analysis including groundwater characterisation.

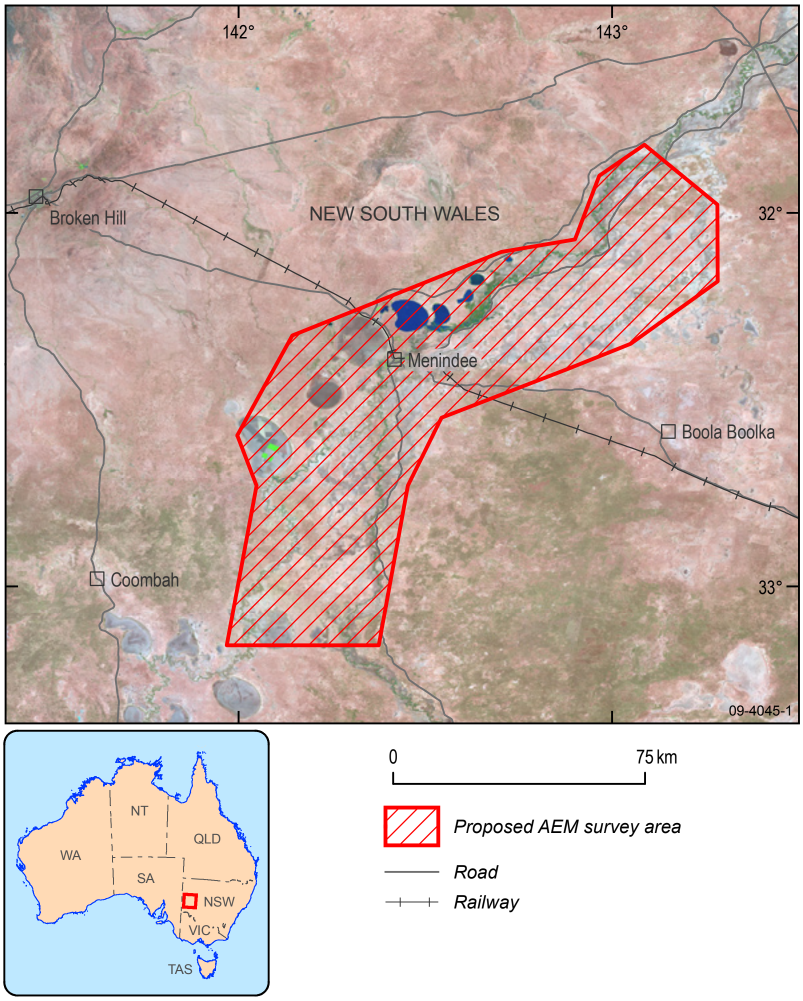


**Figure 1.** The survey area for mapping of groundwater resources and ground water quality, Menindee Lakes, western New South Wales.

If the next phase determines the use of groundwater resources is sustainable and an aquifer storage system is practicable, a detailed engineering assessment will be undertaken to fully test this new approach. This option has the potential to contribute significantly to the delivery of the Australian Government's Menindee Lakes commitment.

The AEM survey is being conducted using the SkyTEM time domain system operated by Geoforce Pty Ltd, and involves acquiring 31 834 line kilometres of data at a line spacing of between 200 and 300 metres. The drilling program will involve drilling up to 50 boreholes to assist with calibration and validation of the AEM survey, and to collect samples for geological and hydrogeochemical analysis. A limited program of pump tests will be carried out to assist with aquifer characterisation, and the boreholes will be completed as piezometers to establish a baseline monitoring network.

The project will also obtain up to 40 kilometres of high resolution shallow seismic reflection data to assist with borefield delineation. These datasets will be integrated using a holistic 4D systems-based approach to quantify groundwater resources and identify suitable targets to develop a MAR borefield. Regular project updates will be available through Geoscience Australia's website.

### *For more information*

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### *Related websites*

Broken Hill Managed Aquifer Recharge Project
www.ga.gov.au/groundwater/broken-hill-survey/broken-hill-survey.jsp

Department of the Environment, Water, Heritage and the Arts, Groundwater website (including the Menindee Lakes initial scoping study)
www.environment.gov.au/water/environmental/groundwater/index.html

## Testing the On-Site Inspection regime in Kazakhstan

The Comprehensive Nuclear-Test-Ban Treaty is a cornerstone of the international regime for the non-proliferation of nuclear weapons and is an essential foundation for the pursuit of nuclear disarmament. The Treaty's total ban on any nuclear explosion will constrain the development and quantitative improvement of nuclear weapons.

After adoption by the United Nations General Assembly, the Treaty was opened for signature in New York on 24 September 1996. Since then it has achieved strong worldwide support with 181 out of 195 member countries signing the Treaty, of which 148 have since ratified it. The key countries yet to ratify the Treaty are China, the Democratic People's Republic of Korea, Egypt, India, Indonesia, Iran, Israel, Pakistan and the United States of America. The Treaty will not come into force before these countries ratify it.

**Figure 1.** Aerial view of the IFE08 Base Camp with part of the former Soviet Union nuclear test site near Semipalatinsk, Kazakhstan, in the background.

In order to monitor compliance with the Treaty, a global verification regime is being established. An International Monitoring System (IMS) coupled with an International Data Centre (IDC) are monitoring for evidence of nuclear explosions in the atmosphere, oceans or underground. Once the Treaty has entered into force, if a suspected nuclear explosion is detected by the IMS and IDC, an On-Site Inspection could be called. Consequently, a team of 40 inspectors would investigate *in brief*

the location in question to verify whether a nuclear explosion has indeed been conducted in violation of the Treaty.

During a five-week period between late August and early October 2008, an Integrated Field Exercise (IFE08) was conducted at the former Soviet nuclear test site near Semipalatinsk in Kazakhstan. The exercise was the most extensive On-Site Inspection field exercise conducted to date and included a full simulation of a possible investigation scenario. This allowed the current state of readiness of the inspection regime to be tested.

During part of the exercise, Dr. Matthew Purss of Geoscience Australia's Nuclear Monitoring Project, participated as an inspector. Dr Purss worked with an international team of geophysicists to conduct magnetic, electrical and electromagnetic field measurements over areas of interest to the scenario. Some of these areas included sites where underground nuclear tests had been conducted at Semipalatinsk by the former Soviet Union.

The exercise provided a wealth of information that will help bring the Treaty's verification system closer to a state of readiness. Work is now underway by the Comprehensive Nuclear-Test-Ban Treaty Organization to implement lessons learned during the exercise that will further develop the inspection component of the verification regime for when the Treaty enters into force.

### For more information

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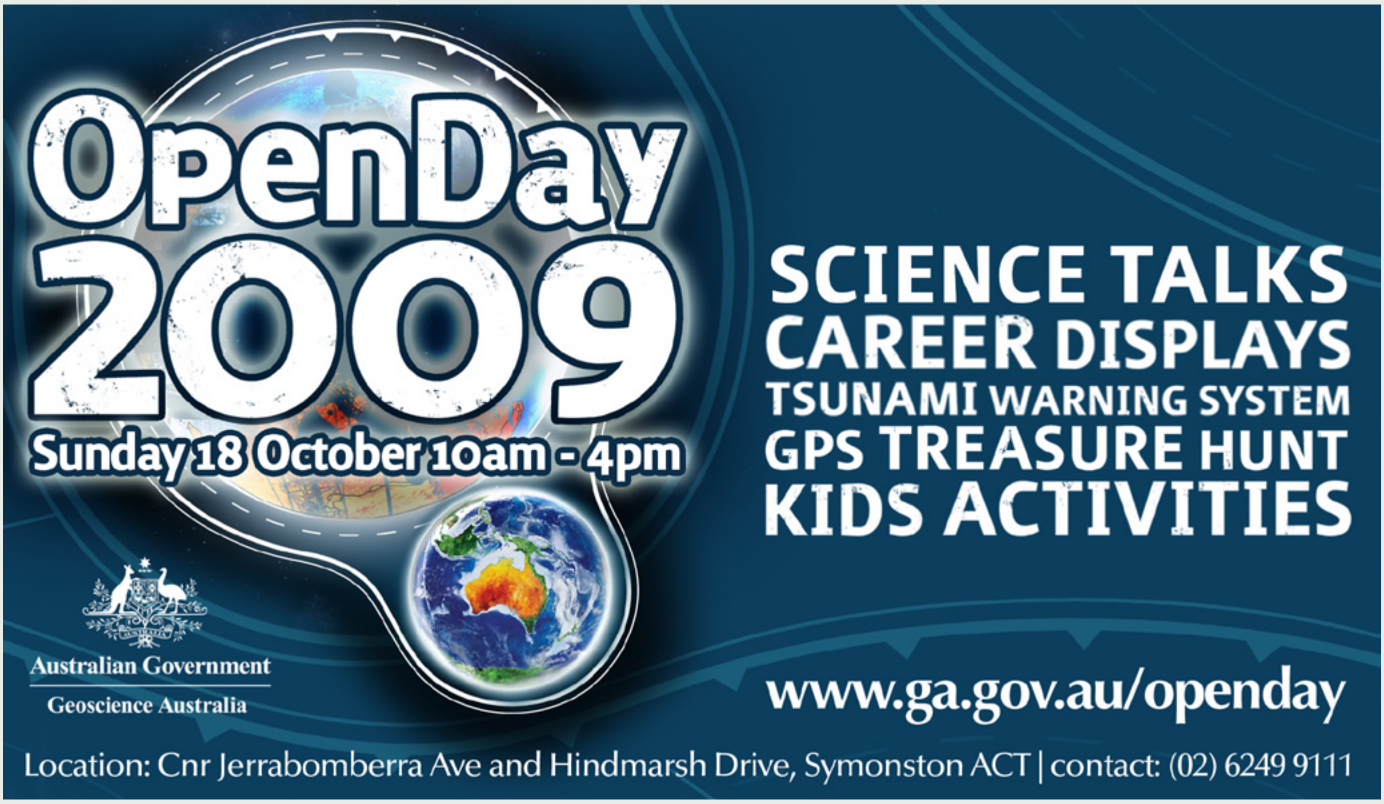
### Related websites

Comprehensive Nuclear-Test-Ban Treaty Organization
www.ctbto.org



## New maps cover the Red Centre

The vast and spectacular MacDonnell Ranges, located west of Alice Springs in the Northern Territory, are an outstanding example of an ancient landscape sculptured by nature. The West MacDonnell Ranges National Park, which offers visitors many opportunities to explore and appreciate the scenic beauty and history of the area, is the subject of two new 1:100 000 scale topographic maps titled West MacDonnell National Park (maps 1 and 2) recently released by Geoscience Australia.

The maps will be invaluable for emergency managers responding to emergencies, such as search and rescue operations, making the Red Centre a safer place for tourists. The topographic maps are useful for tourists engaged in bushwalking, four wheel driving and sight seeing. The reverse side of each map depicts the same area using a satellite image with an overlay of major roads as well as insets featuring aerial photographs of points of interest.

The maps are part of a pilot project made possible by increased Australian Government investment in the tourism industry through the National Landscapes initiative. The program identifies and promotes distinctive and inspirational destinations to domestic and international visitors. It is the result of collaboration between the Department of Resources Energy and Tourism (Geoscience Australia's parent department) and the Department of the Environment, Water, Heritage and the Arts.

During compilation of the map there was extensive consultation with Northern Territory Government agencies including the Departments of Planning and Infrastructure and Natural Resources, Environment and The Arts. The maps are available for $11.95 from the Geoscience Australia Sales Centre and map retailers.


### *For more information or to order a copy*

**visit** www.ga.gov.au/products

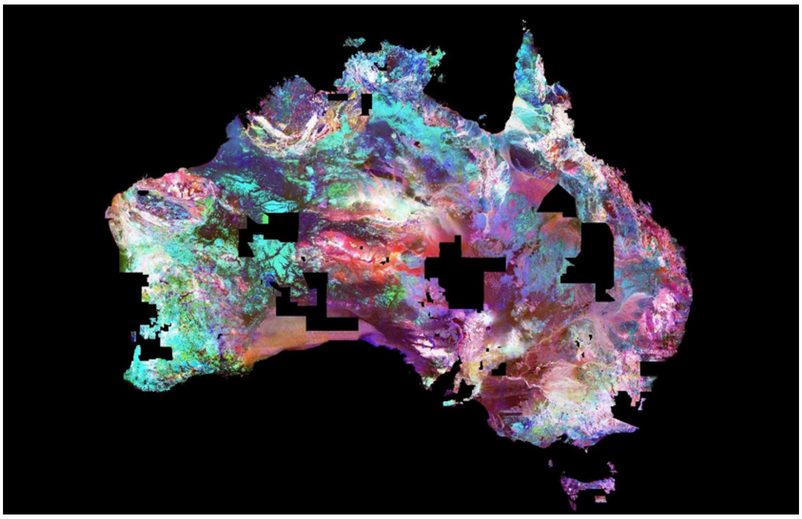
Map 1: GeoCat 68385

Map 2: GeoCat 68386

## Geophysical datasets

### *Radiometric Map of Australia updated*

The Radiometric Map of Australia is part of a range of digital radiometric products that directly assist exploration for uranium and thorium as well as the assessment of geothermal resources. It also benefits environmental studies and soil and geological mapping.



The digital gridded radiometric datasets that are part of the Radiometric Map contain data recently acquired by the state geological surveys and Geoscience Australia. This updated release also contains a new radiometric ratio grid - $U^2$/Th - which will directly assist exploration for uranium.

The updated grids can be downloaded free-of-charge from the Australian governments' Geophysical Archive Data Delivery System (GADDS).

## New edition of Index of Gravity Surveys

The second edition of the *Index of Gravity Surveys* complied by P Wynne and M Bacchin (Geoscience Australia Record 2009/07) was recently released. It is the latest compilation of metadata for over 1700 gravity surveys held in the Australian National Gravity Database. These surveys have been conducted by or for the Australian, state and territory governments, private industry, educational institutions and other research organisations.

The Index includes metadata for each survey, presented in a tabular format with details of one survey on each page, as well as two lookup tables to help clients identify surveys. These tables list:

- surveys in alphabetical order with their corresponding Geoscience Australia Survey Identification numbers
- all 1:1 million scale gravity map sheets covering continental Australia as well as the Survey numbers of surveys covered on each map sheet.

There are also two maps showing the gravity coverage over Australia and the gravity station locality.

The open file data can be downloaded free-of-charge in ER Mapper format from the Australian governments' Geophysical Archive Data Delivery System (GADDS). A full copy of the Index in PDF format is available for download through Geoscience Australia's website.

### For more information

Radiometric Map of Australia

**phone** Murray Richardson on +61 2 6249 9229
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Index of Gravity Surveys

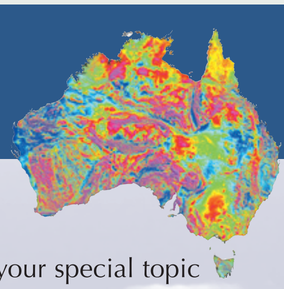
**phone** Phil Wynne on +61 2 6249 9463
**email** phil.wynne@ga.gov.au

### Related websites

Geophysical Archive Data Delivery System (GADDS)
www.geoscience.gov.au/gadds

Index of Gravity Surveys (Geoscience Australia Record 2009/07)
www.ga.gov.au/products/servlet/controller?event=GEOCAT_DETAILS&catno=68264

**AusGeoRef**
Australian Geoscience References



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events

## *spatial@gov* Conference

The inaugural ***spatial@gov*** Conference was held at the National Convention Centre, Canberra, on 15 and 16 June 2009. The conference focussed on the 'business of government' and how business at all levels of government can be made more effective and efficient through the use of spatial resources.

Presenters included representatives of the spatial community from most Australian jurisdictions and New Zealand as well as the Chair of ANZLIC (the Spatial Information Council) and a range of senior government officials. International presenters included the Open Geospatial Consortium and the Chinese Ambassador to Australia who provided an insight into spatial activities in China and potential linkages to the Australian spatial community.

Attendees gained an insight into the broad range of areas benefiting from the efforts of the spatial community. The presentations provided many examples of the benefits of using 'place' or 'location' as an enabler for government activities. These activities included social inclusion, water, health, climate change, local government, Indigenous cultures and communities. There were also presentations on data delivery and access, new approaches to mapping, and future directions for spatial technologies.

The conference attracted 352 delegates, 67 presenters, 25 sponsors and 19 exhibitors. It was organised by eight of the key spatial information associations and organisations representing all areas of the spatial sector including the government, academia and the commercial communities.

Geoscience Australia was the main conference sponsor and the Office of Spatial Data Management convened the conference. A number of tertiary level students and several indigenous and remotely located spatial professionals were able to attend the conference because of various sponsorship arrangements.

The conference demonstrated a new energy and spirit of cooperation between the government and other sectors within the spatial community. The feedback from delegates, sponsors and technical exhibitors was very positive and all expressed a desire to attend another ***spatial@gov*** event. As a result, planning has already commenced on ***spatial@gov*** 2010.

**Figure 1.** Left to right: Ben Searle, General Manager, Office of Spatial Data Management; Dr Neil Williams PSM, CEO Geoscience Australia; Senator Kate Lundy, Senator for the ACT; and Warwick Watkins, Chair ANZLIC and Director-General, Department of Lands, New South Wales, following the opening of the conference by Senator Lundy.

### *For more information*

**visit** www.spatial.gov.au/

events calendar

| Spatial Diversity SSC 2009 | 28 September to 2 October |
|---|---|
| Surveying and Spatial Sciences Institute<br>Adelaide Convention Centre<br>Contact: ICMS Pty Ltd, 84 Queensbridge Street, Southbank, Victoria 3006 | p +61 3 9682 0244<br>f +61 3 9682 0288<br>e ssc2009@icms.com.au<br>www.ssc2009.com |
| **Geothermal 2009: Making Renewable Energy Hot** | **4 to 7 October** |
| Geothermal Resources Council 33rd Annual Meeting<br>Peppermill Resort<br>Reno, Nevada USA<br>Contact: GRC, PO Box 1350, Davis, CA 95617 | p +1 530 758 2860<br>f +1 530 758 2839<br>www.geothermal.org/ |
| **China Mining Congress** | **20 to 22 October** |
| Ministry of Land and Resources, China<br>Tianjin Binhai International Convention & Exhibition Centre, Beijing<br>Contact: Julie Zhu (Registration Service) | p +86 22 2312 0923<br>f +86 22 2312 0583<br>e info@mining-expo.com<br>www.china-mining.com/ |
| **Mining 2009 Resources Convention** | **28 to 30 October** |
| Hilton Hotel, Brisbane<br>Contact: Vertical Events, PO Box 1153<br>Subiaco WA 6904 | p +61 8 9388 2222<br>f +61 8 9381 9222<br>e info@verticalevents.com.au<br>www.verticalevents.com.au/mining2009/ |
| **Australian Geothermal Energy Conference and Trade Show** | **10 to 13 November** |
| Australian Geothermal Energy Association<br>Hilton Hotel, Brisbane<br>Contact: Impact Environmental Conferences<br>PO Box 5057, Port Macquarie NSW 2444 | p +61 2 6583 8118<br>f +61 2 6583 8065<br>e ausgeothermal@impactenviro.com.au<br>www.impactenviro.com.au/ausgeothermal/ |
| **NAPE Expo 2010** | **11 & 12 February** |
| American Association of Professional Landmen<br>GBR Convention Center, Houston, Texas, USA<br>Contact: NAPE, 4100 Fossil Creek Boulevard, Fort Worth, Texas 76137 USA | p +1 817 306 7171<br>f +1 817 847 7703<br>e info@napeexpo.com<br>www.napeonline.com |
| **PDAC 2010 International Convention & Trade Show** | **7 to 10 March** |
| Prospectors and Developers Association of Canada<br>Metro Toronto Convention Centre, Toronto, Canada<br>Contact: PDAC, 135 King Street East, Toronto, Ontario M5C IG6 | p +1 416 362 1969<br>f +1 416 362 0101<br>e info@pdac.ca<br>www.pdac.ca/ |
| **XXIV FIG International Congress 2010** | **11 to 16 April** |
| International Federation of Surveyors<br>Sydney Convention & Exhibition Centre<br>Contact: Tour Hosts Congress & Exhibition Organisers<br>GPO Box 128, Sydney NSW 2000 | p +61 2 9265 0700<br>f +61 2 9267 5443<br>e fig2010@tourhosts.com.au<br>www.fig2010.com/ |

***For more information*** on Geoscience Australia's involvement in the above events phone Suzy Domitrovic on +61 2 6249 9571 (email suzy.domitrovic@ga.gov.au)