Australian Government
Geoscience Australia

AUSGEO news
ISSUE 89 Mar 2008

Contents

ISSUE 89 Mar 2008

Editor
Words Worth Writing

Assistant Editors
Stephen Ross

Graphic Design
Lindy Gratton

Web Design
Maria Bentley

SSN 1035-9338

Geoscience Australia
GPO Box 378
Canberra ACT 2601 Australia
cnr Jerrabomberra Avenue &
Hindmarsh Drive

Symonston ACT 2609 Australia

Internet: www.ga.gov.au

Chief Executive Officer
Dr Neil Williams

Subsctiptions
Stephen Ross
p: +61 2 6249 9263
f: +61 2 6249 9926
www.ga.gov.au/about/corporate/
ausgeo_news.jsp

Sales Centre
p: +61 2 6249 9966
f: +61 2 6249 9960
e: sales@ga.gov.au
GPO Box 378
Canberra ACT 2601 Australia

Editorial enquiries
Len Hatch
p: +61 2 6249 9015
f: +61 2 6249 9926
e: len.hatch@ga.gov.au

Australian Government
Geoscience Australia

AUSGEO news
ISSUE 89 Mar 2008

CEO comment

Neil Williams – CEO Geoscience Australia

This issue of *AusGeo News* features several articles relating to Geoscience Australia's programs to provide pre-competitive information to support industry's search for new offshore and onshore energy resources, our marine research to help characterise and protect Australia's valuable marine environment and our contributions to the mitigation of the effects of natural hazards.

There is a report on the first of the scientific marine reconnaissance surveys in the remote eastern frontiers area of Australia's Economic Exclusion Zone which is an important part of our offshore frontier basin research to identify a new oil province. The survey captured high-resolution data covering the entire survey region. The seabed mapping will provide data for an assessment of marine habitats and biota whilst subsurface imaging will be available to enable industry to assess the petroleum potential of selected basin areas.

Another major article examines the factors controlling formation of the world-class sandstone uranium deposits in south-central Kazakhstan. Hydrocarbons seem to have played a crucial role in the formation of these and other large sandstone-type uranium deposits. This research may point to the potential for the discovery of large sandstone-hosted uranium mineralization in Australia where only two per cent of our known uranium resources are in sandstone deposits.

Time information is fundamental to most geological studies, particularly resource exploration, because the date of a geological process can be crucial to assessing its potential to form mineral deposits. Although the quantitative measure of time is natural radioactive decay each of the isotopic decay measures in common use has specific advantages and limitations. The article on the different geological 'clocks' discusses improving synchronisation between them.

There is also a report on the marine survey off the eastern coast of New South Wales which provided valuable data and information on the seabed along the continental shelf including submarine landslides. The information gathered will also assist in developing models to assess the risk of tsunamis along the Australian coastline.

There is also an overview of the recently released Natural Hazards in Australia: Identifying Risk Analysis Requirements which provides the first consistent and consolidated view of the issues relating to assessing the risk. The report was developed with input from over 20 authors from private companies through to state and Australian Government agencies and should meet the needs of emergency managers for years to come.

Natural Hazards Online is another valuable product for emergency managers and decision makers involved in emergency management. The website consolidates, for the first time, the broad range of information, data, maps, models and decision support tools available about natural hazards. Other new products reported on include new geophysical datasets covering areas in Queensland (Mt Isa and the Cooper Basin), the Northern Territory (Tanumbirini) and northeast Tasmania as well as the new topographic General Reference Map of Australia at 1:5 million scale.

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

Neil Williams

Australian Government
Geoscience Australia

AUSGEO news
ISSUE 89 Mar 2008

Survey of remote eastern frontier basins completed

New survey delivers high-quality prospectivity and environmental data

Andrew Heap, Riko Hashimoto and Nadege Rollet

A marine reconnaissance survey designed to map crustal architecture, sea-bed topography and deep sea environments in a remote eastern part of Australia's Exclusive Economic Zone (EEZ) has captured high-resolution data over the entire survey region. Shipboard gravity and magnetics are assisting in the delineation of basin geometries and structural architecture of the crust. Multibeam bathymetry data has provided a detailed map of the sea floor and assisted in the identification of sampling sites for the collection of geological and biological data in these deep-sea environments.

The seabed mapping will provide an understanding of marine habitats and biota, while subsurface imaging will be used in the assessment of the petroleum potential of selected basin areas.

Conducted between 6 October and 22 November 2007 using the New Zealand Government's research vessel *Tangaroa*, the survey was the first of a series of scientific marine reconnaissance surveys in remote frontier areas of Australia's EEZ to be completed as part of Geoscience Australia's Offshore Energy Security Program (*AusGeo News* 84).

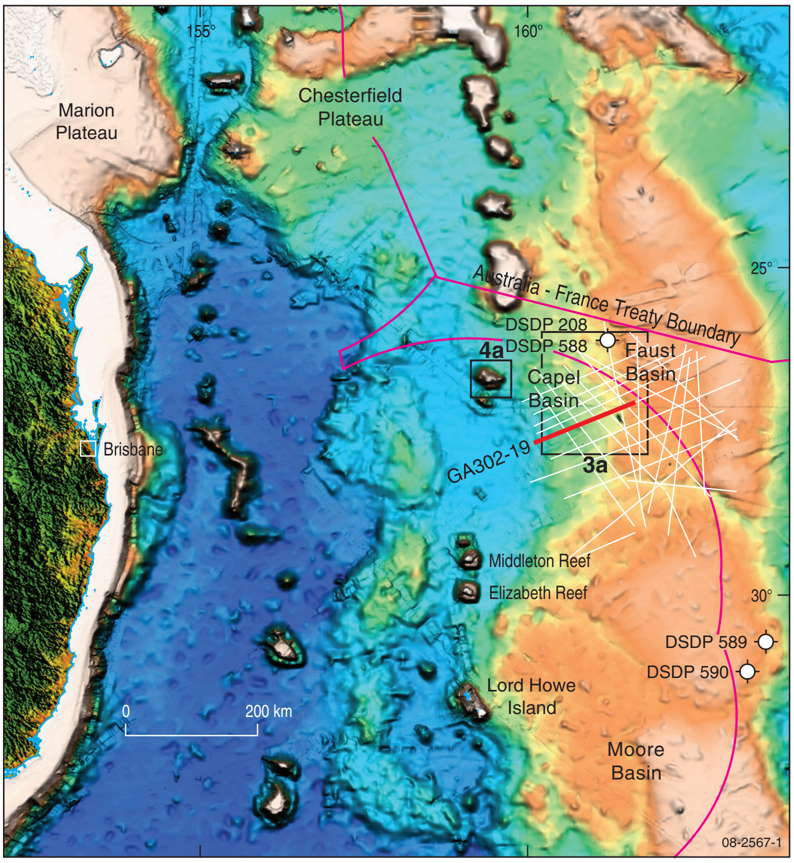


Figure 1. The study area, showing the location of S302 seismic lines (white), seismic profile depicted in figure 2 (red), political boundaries (pink) and existing drill holes.

The targeted area

The study area is 760 kilometres east of Brisbane in water depths of between 1200 and 2700 metres. Centred over the Capel and Faust Basins (figure 1) the study area forms part of a submerged marginal plateau that extends for nearly 1600 kilometres offshore of eastern Australia. A second study area, the Gifford Guyot, about 600 kilometres east of Brisbane, was selected to investigate the physical environments and ecological significance of seamounts. Water depths around this seamount are between 250 and 3100 metres.

Data and information gathered build on previous Geoscience Australia surveys—the AUSFAIR MD 153 survey in 2006 and the Capel–Faust S302 seismic survey completed in early 2007 (*AusGeo News* 86).

The Capel and Faust Basins are a frontier area for scientific investigations and have potential

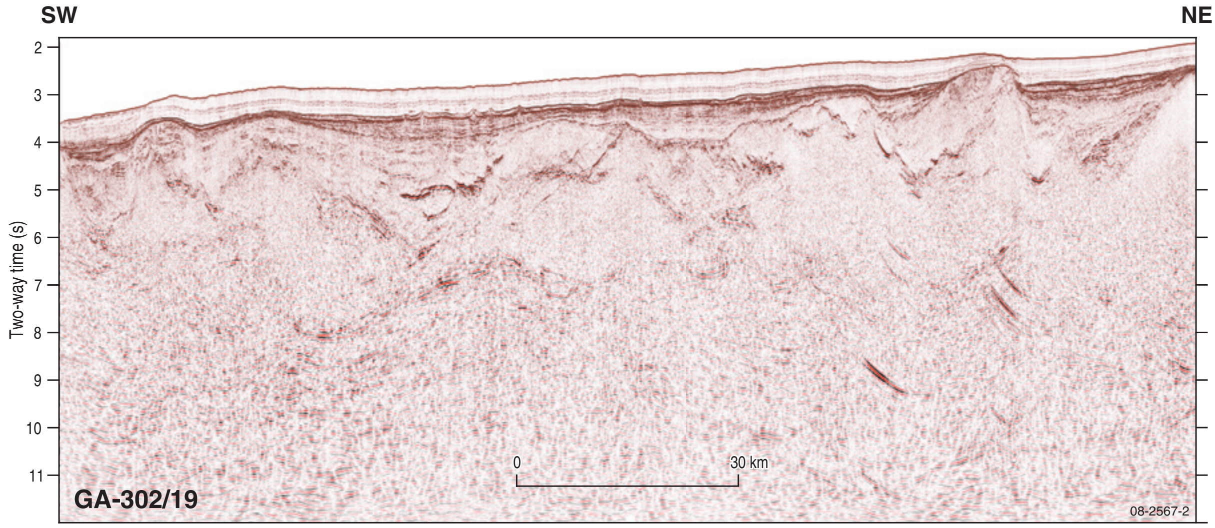


Figure 2. Profile along Line 19 of the S302 seismic survey, revealing a number of sediment-filled depocentres. The line location is shown in figure 1.

for petroleum exploration. Before the S302 survey, the seismic coverage of the area was sparse, comprising lines acquired during the Shell RV *Petrel* survey and the Australian Geological Survey Organisation S177 (1996) and S206 (1998) surveys. The only significant drilling to date consists of two Deep Sea Drilling Program holes, DSDP 208 and 588 (figure 1), which reached a maximum depth of 594 metres below the seabed in nannofossil chalk of Upper Maastrichtian (Cretaceous) age.

The MD 153 and S302 surveys in 2006 and 2007 collected new geophysical and sample data in a preliminary assessment of the area for its petroleum prospectivity. The S302 survey acquired approximately 6000 kilometres of high-quality 2D seismic data with line spacing of 15–35 kilometres, which revealed the presence of many new depocentres within the area, containing up to seven kilometres of sediments (figure 2).

Although modelled satellite gravity data provided an indication of the spatial extent of the depocentres, the seismic coverage was insufficient to validate the earlier gravity interpretations. Hence, a geophysical dataset that included shipboard gravity, magnetics, and multibeam sonar was required to map basin depocentres at the appropriate scale.

Objectives

The marine survey had three key scientific objectives:

- collect high-resolution geophysical data and geological samples to improve the understanding of the geological structure, evolution and petroleum prospectivity of the Capel–Faust area.
- characterise the physical properties of the seabed associated with the Capel and Faust Basins and the Gifford Guyot
- characterise the abiotic and biotic relationships on an offshore submerged plateau, a seamount, and areas associated with fluid escape features.

Seabed mapping focused on delineating the respective geomorphic features, and specifically targeted areas where the underlying geological structure (as indicated by the S302 seismic survey data) appeared to have an effect at the seabed, such as basement faults creating a potential for fluid migration to the seabed. Sediment and biological samples and video footage were collected to identify seabed features and investigate the marine life in these deep-sea environments.

Preliminary results

Over 45 days at sea, each study area was mapped for 100% spatial coverage using multibeam sonar, sub-bottom profiler, and marine magnetic and gravity meters. At 25 000 square kilometres, the area of seabed mapped is the largest of any marginal plateau in Australia and provides some of the most detailed imagery of seabed environments for these features. Despite its size, the mapped area makes up only 0.2% of Australia's EEZ.

Multibeam sonar revealed the morphology of the seabed, while sub-bottom profiler data revealed the structure of shallow subsurface sediments. Favourable weather conditions permitted acquisition of gravity and magnetic data at a high resolution over most of the survey area, providing a dataset expected to significantly improve the quality of regional geophysical coverage and to assist in defining the basin architecture.

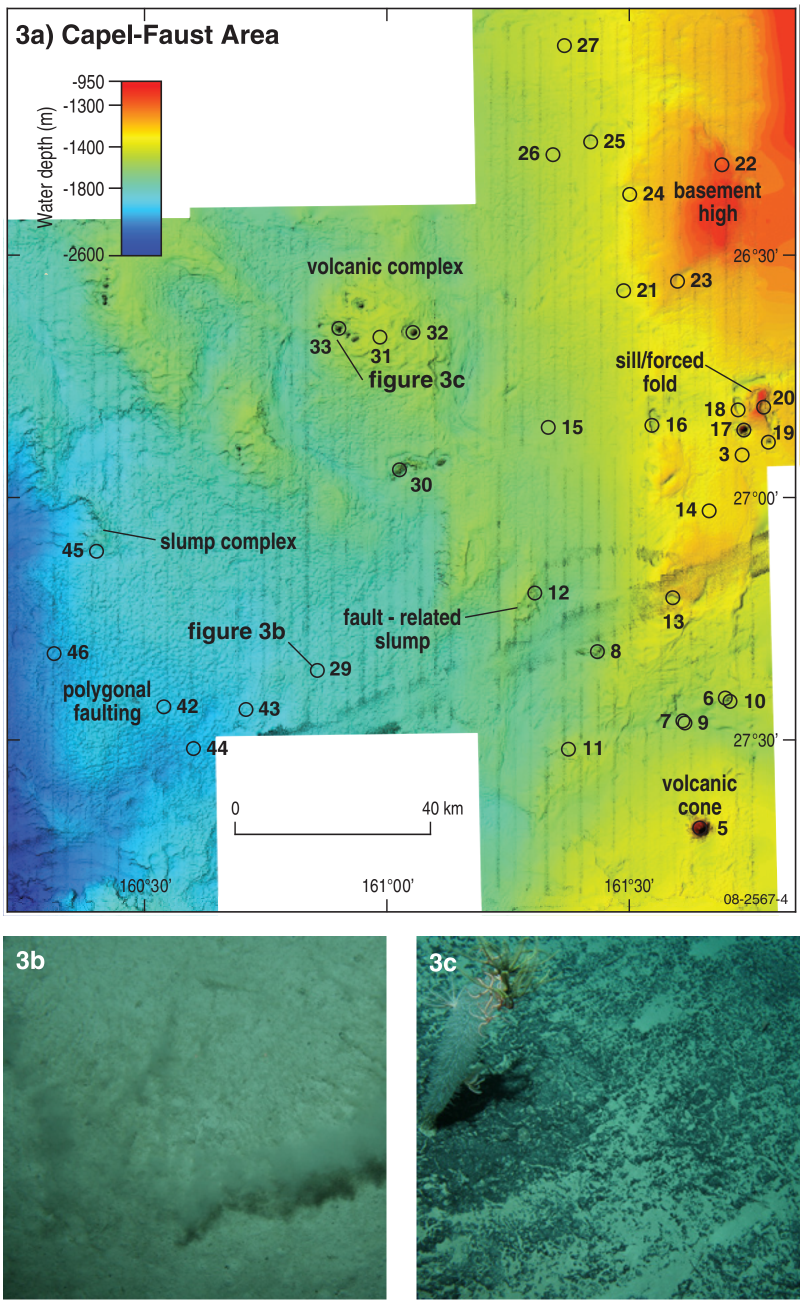


Figure 3. (a) Multibeam bathymetry image of the seabed in the Capel–Faust area, showing the sampling locations and some of the morphological features, (b) photograph of dewatering of pelagic sediments in region of polygonal faulting, (c) photograph of basalt reef containing examples of the moderate cover of benthic biota.

A total of 42 priority sites were selected for detailed investigation (figures 3 and 4), covering specific seabed environments and features that may assist in the assessment of the region's petroleum prospectivity and provide ecologically important information. A range of different samples were collected at each site to characterise the seabed geology and benthic biota (table 1).

In the Capel–Faust area, a thick blanket of pelagic nannofossil mud and sand mantles most of the seabed. Rock outcrops, mostly associated with igneous activity, are isolated. The survey revealed features and seabed habitats such as slumps, plains, ridges, volcanic cones, moats and possible mega-pockmarks. An intriguing discovery was the extensive region of polygonal faulting on the western margin of the study area (figure 3a). This seabed texture is a surface expression of the underlying faulting and is caused by sediment dewatering, a process that was captured in underwater video footage (figure 3b). This is the first time such a process has been directly observed on the Australian margin.

Preliminary analysis of the bathymetric imagery in conjunction with previously acquired seismic data indicates a generally strong spatial correlation between seabed features and the underlying geological structure. Slumps appear to be associated with areas of fluid escape, basement faults and the rugged basement topography beneath the sediment cover. The trends of some seabed features appear to follow depocentre margins, basement highs, and igneous intrusions buried by over two kilometres of sediment in some places.

Biota was sparse across the study areas. Hard substrates, which consist mainly of basalt outcrop, contained moderate biota, with many sessile organisms (figure 3c). Benthic biota was less visible in areas covered with soft sediment; those regions were characterised by numerous burrows, mounds and tracks, indicating an abundant infauna.

A secondary outcome of the survey was the detailed mapping of the Gifford Guyot, a 3000-metre undersea volcano about 600 kilometres east of Brisbane (figure 4a). High-resolution multibeam bathymetry data revealed the 15 million year old guyot to be a complex structure, comprising basalt (figure 4b) draped with pelagic nannofossil sand and mud, and characterised by numerous slumps, aprons/fans, and slides on its steep margins. At a depth of 250 metres, the relatively flat top of the guyot contained raised rocky reefs and six-metre high sand dunes.

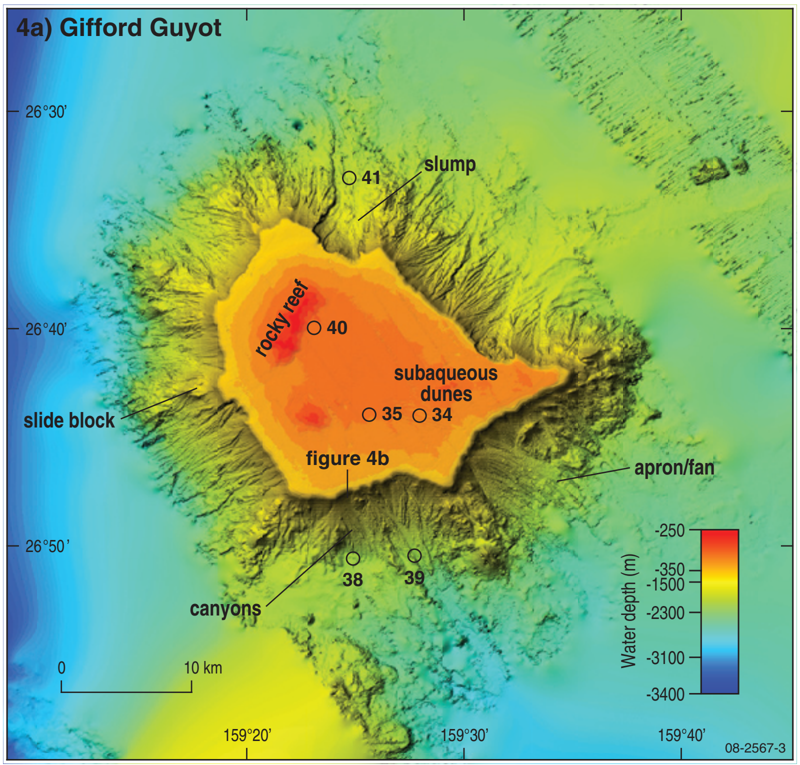


Figure 4. (a) Multibeam bathymetry image of the seabed over the Gifford Guyot, showing the sampling locations and morphological features, (b) photograph of basaltic rock recovered from the guyot flanks.

The flat top is presumed to have been formed by prolonged erosion during numerous lowstands of sea level over the past 15 million years. This spectacular feature is the first guyot to be mapped in such detail on the eastern margin of Australia, and has produced some of the best topographic data from a seamount anywhere in the world. The geophysical and geological data collected from the seamount will further our understanding of its formation and sedimentary environments. Biological data collected will help determine the significance of seamounts as hotspots for the deep-sea ecology of remote eastern Australia.

Implications

Information and data collected on the survey will be used to support the work programs of the Department of Resources, Energy and Tourism and the Department of the Environment, Water, Heritage and the Arts. These new data will be used in assessing the region's environmental significance and the design of a national system of representative marine protected areas. In addition, together with 2D seismic data acquired earlier, all information will be available, at cost of transfer, to enable industry to better assess the hydrocarbon potential of the Capel and Faust Basins.

The survey also provided an opportunity for 16 university students from Australia, Sri Lanka, Fiji and Papua New Guinea to undertake crucial training in marine science and fieldwork as part of the University of the Sea program, which is designed to provide students with opportunities which would otherwise not be available to them.

Table 1. Data collected on the survey.

Data type	Total recovery
Geophysical	
Multibeam sonar	25 800 km^2
Sub-bottom profiler	10 900 line-km
Gravity and magnetics	10 900 line-km
Physical	
Camera tows	42 (>40 hours video and >4000 still images)
Box cores	15
Piston cores	14
Rock dredges	13
Benthic sleds	11
Conductivity, turbidity, and depth casts	7
Grabs	3

For more information on marine management

phone Andrew Heap on +61 2 6249 9790

email andrew.heap@ga.gov.au

For more information on petroleum

phone Riko Hashimoto on +61 2 6249 9141

email riko.hashimoto@ga.gov.au

Related articles/websites

AusGeo News 84: Extra $75m for offshore oil work

www.ga.gov.au/ausgeonews/ausgeonews200612/offshore.jsp

AusGeo News 86: Promising results from Capel and Faust Basins seismic survey

www.ga.gov.au/ausgeonews/ausgeonews200706/seismic.jsp

Australian Government
Geoscience Australia

AUSGEO news
ISSUE 89 Mar 2008

Association of large sandstone uranium deposits with hydrocarbons

The geology of uranium deposits in Kazakhstan points to similar deposits in Australia

Subhash Jaireth, Aden McKay and Ian Lambert

Sandstone uranium deposits account for approximately 30% of annual global production, largely through in situ leach (ISL) mining. Most of this production has come from deposits in the western United States, Niger and Kazakhstan. In Australia, sandstone-hosted uranium is being produced from the Beverley deposit in the Frome Embayment of South Australia, and a second ISL mine is under development at Honeymoon in the same region.

Such deposits form where uranium-bearing oxidised groundwaters moving through sandstone aquifers react with reducing materials. The locations of ore zones and the sizes of mineral deposits depend, among other factors, on the abundance and reactive nature of the reductant. Hence, the nature and abundance of organic material in the ore-bearing sedimentary sequence may be of critical importance for the formation of sandstone uranium deposits.

In sandstones rich in organic material (containing debris of fossil plants or layers of authigenic, or in situ generated, organic material) the organic matter either reduces uranium directly with bacteria as a catalyst, or through the production of biogenic hydrogen sulfide (H_2S: Spirakis 1996). In sandstones relatively poor in organic material, it has been proposed that the reduction is caused either by H_2S (biogenic as well as nonbiogenic) produced from the interaction of oxidised groundwater with pyrite in the sandstone aquifer (thiosulfate produced initially by oxidation of pyrite breaks down to form reduced sulfur), or from the introduction of reduced fluids/gases (H_2S, hydrocarbons or both) along favourable structures (Spirakis 1996).

This paper outlines the geology of the world-class sandstone uranium deposits in the Chu-Sarysu and Syrdarya basins in the south-central portion of Kazakhstan, which are hosted by sandstones relatively poor in organic matter (figure 1, table 1). We highlight the crucial role that hydrocarbons appear to have played in the formation of these and other large sandstone type uranium deposits. Based on the model developed, we conclude that there is considerable potential in Australia for the discovery of large sandstone-hosted uranium mineralisation, including in little explored regions underlain by basins with known or potential hydrocarbons.

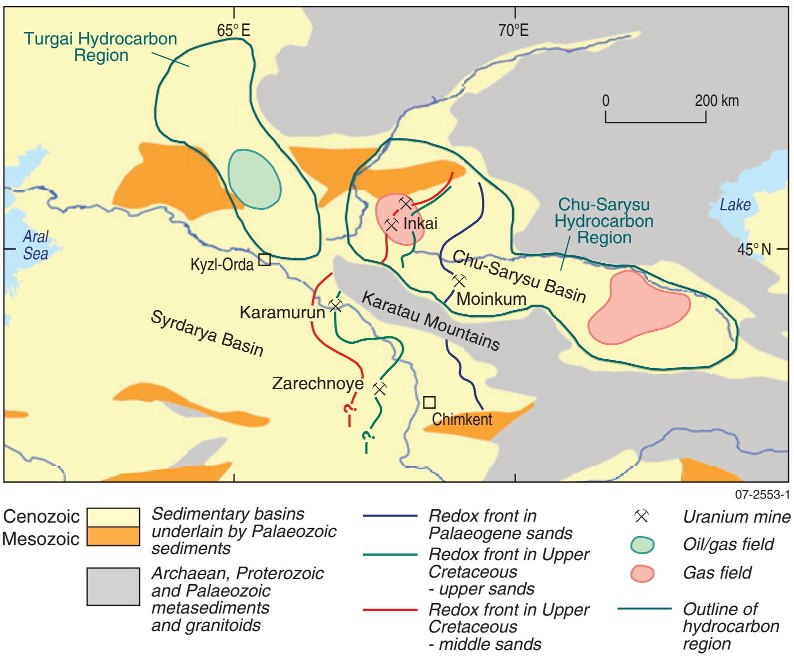


Figure 1. Regional geology of Chu-Sarysu and Syrdarya basins, southern Kazakhstan. Geological data plotted from the Generalized Geological Map of the World (1995), Geological Survey of Canada Open File 2915d. Boundary of the hydrocarbon basins and location of oil and gas fields in the underlying Permian rocks from a map produced by Blackbourn Geoconsulting (http://www.blackbourn.co.uk/databases/hydrocarbon/chusarysu.html).

Table 1 Uranium resources, organic carbon and sulfides in basins hosting major resources of sandstone uranium deposits

Basin/sub-basin	Resources ('000 tonnes U_3O_8)	Organic carbon (wt%)	Iron sulfide (wt%)
Chu-Sarysu and Syrdarya	1340[a]	< ~ 0.03–0.05[b]	0.1[c]
Callabonna (Frome Embayment)	41.2[d]	< 0.05 to 0.5[e]	Traces[e]
Wyoming	320[f]	0.5[c]	1 to 4[c]
South Texas	45 to 80[g]	<0.16[h]	0.5 to 4[h]

a Fyodorov (1999); b Petrov (1998); c Fyodorov (1996); d Ozmin database, Geoscience Australia (2007); e Heathgate Resources (1998); f after de Voto (1978); g Dhalkamp (1993); h Goldhaber et al (1978)

The geological setting in Kazakhstan

The Chu-Sarysu and Syrdarya basins of Kazakhstan are components of a large artesian basin that was split into two main components following the Pliocene uplift of the Karatau Mountain Range (figure 1). The basins are filled with thick sandstone aquifers capped by impermeable shaly beds. Mineralisation, often as roll fronts, is hosted by sands of Upper Cretaceous and Palaeocene–Eocene age.

The Chu-Sarysu Basin is more mineralised than the Syrdarya Basin and contains larger uranium deposits, which are hosted by a Late Cretaceous – Palaeogene age multicoloured clay–gravel–sandstone sequence deposited in a continental environment. The large deposits include Inkai, Moinkum, Karamurun and Zarechnoye. In the Syrdarya Basin, the host is a grey clay – sandstone sequence formed in coastal-marine and continental conditions (Petrov 1998).

The roll fronts display mineral and geochemical zoning typical of oxidation–reduction fronts associated with sandstone uranium deposits elsewhere. Hydroxides of iron dominate the oxidation zone, whereas the reduced zones are dominated by iron sulfides (pyrite and marcasite). The uranium zone is enriched in rhenium, zinc, copper, silver, cobalt, molybdenum, nickel and vanadium. Significant enrichments of selenium occur towards the contact with the zone of reduction.

"Based on the model developed, we conclude that there is considerable potential in Australia for the discovery of large sandstone-hosted uranium mineralisation."

The ore zones extend for 20 to 30 kilometres along the redox front; in plan, they form ribbons 50 to 800 metres wide (rarely, 1.7 kilometres). In cross-section, the zones are asymmetric roll-fronts, tabular bodies and lenses. Thickness varies from five metres to more than 25 metres. Uranium mineralisation occurs as coffinite and pitchblende, which are finely dispersed in the clay matrix and also infill cavities in sandstone (Petrov 1998). The depth of uranium ore varies from 100 metres to more than 800 metres (Fyodorov 1996).

The source of uranium in the deposits is not clear. It could have been derived from Ordovician and Silurian metasediments and granites exposed in the Tyan-Shan Ranges along the southeastern flanks of the basin, which also provided the detrital material for the sedimentary sequence hosting mineralisation. Uranium-bearing hydrothermal vein deposits hosted in pre-Mesozoic metasediments along the northeastern flanks of the Chu-Sarysu Basin could also have been a source (Petrov 1998). Further uranium could have been contributed from devitrification of volcanic tuff interbedded with Palaeocene/Eocene sands.

Lead–lead isotope model ages suggest that mineralisation occurred in three more or less continuous stages starting from Late Oligocene – Middle Miocene and continuing into Late Pliocene to Quaternary time (Mikhailov and Petrov 1998). Tectonic reactivation during the Late Oligocene – Middle Miocene created palaeogeographic conditions favourable for large-scale groundwater flow from the palaeo Tyan-Shan region in the southeastern flanks of the basin.

The regional extent and general distribution of the redox fronts in the basins suggests that the palaeo-groundwater flow direction was predominantly from the southeast to the northwest. Groundwaters probably entered permeable aquifers adjacent to the Tyan-Shan uplands (Petrov 1998) and flowed towards discharge zones in the general region of the Aral Sea.

Late Pliocene – Quaternary ages of mineralisation coincide with intensive tectonic activity associated with orogenic movements in the Tyan-Shan and the uplift of the Karatau Mountains, along a pre-existing regional fault, which created the present-day hydrodynamic regime. Groundwater flows associated with the Karatau uplift only caused minor changes in the configuration of the mineralised regional redox fronts created in the Late Oligocene – Middle Miocene (Petrov 1998).

Although organic material in the ore-bearing grey sandstones is quite low (generally <0.03–0.05%; table 1), Petrov (1998) believes that it was enough (with a minor contribution from iron sulfides) to produce large sandstone uranium deposits. Petrov ascribes the lack of direct correlation between uranium and the concentration of organic material to coalification of organic material, which caused loss of active organic reductants such as waxy bitumen and humic acids.

Chu-Sarysu oil and gas basins

The Late Cretaceous to Palaeogene continental and marine sedimentary sequence that hosts world-class sandstone uranium deposits is underlain by a Palaeozoic sequence up to five kilometres thick containing oil and gas (figure 2; Bykadorov et al 2003). The Chu-Sarysu hydrocarbon basin is made up of two sequences: lagoonal to marginal-marine salt-bearing strata of Famenian – Early Carboniferous age; and alluvial-lacustrine red-beds of Middle Carboniferous – Permian age. The latter include 500 metres of Permian evaporites. Visean and Early (pre-salt) Permian sandstones host minor volumes of gas. The southeastern part of the basin contains hydrocarbon source rocks and also hosts the principal oil and gas fields. Famenian – Early Carboniferous marls and black shales and Permian bituminous marls with high total organic carbon may be an additional source, with Permian salts acting as a regional cap (Bykadorov et al 2003).

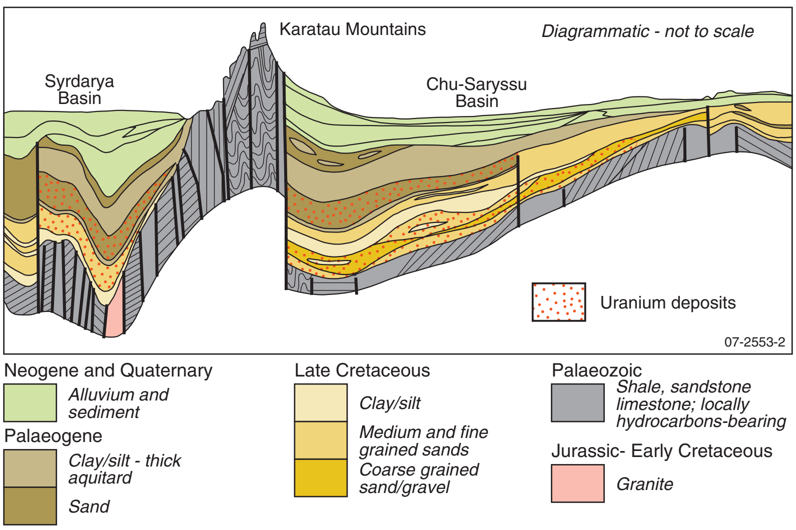


Figure 2. Cross-section of Chu-Sarysu and Syrdarya basins (looking northwest) (Yazhikov 1996).

Aubakirov (1998) suggested that the uranium mineralisation formed at a geochemical trap created by an influx of reduced fluids/gases (hydrocarbons and H_2S) along relatively deeply penetrating structures. Chemical analyses of drill core samples through the ore zones show that hydrocarbon gases have accumulated along the redox front. Some authors consider that this accumulation of hydrocarbon gases facilitated large-scale ore formation over extensive redox boundaries (Fyodorov 1999), although the detailed geochemical (including

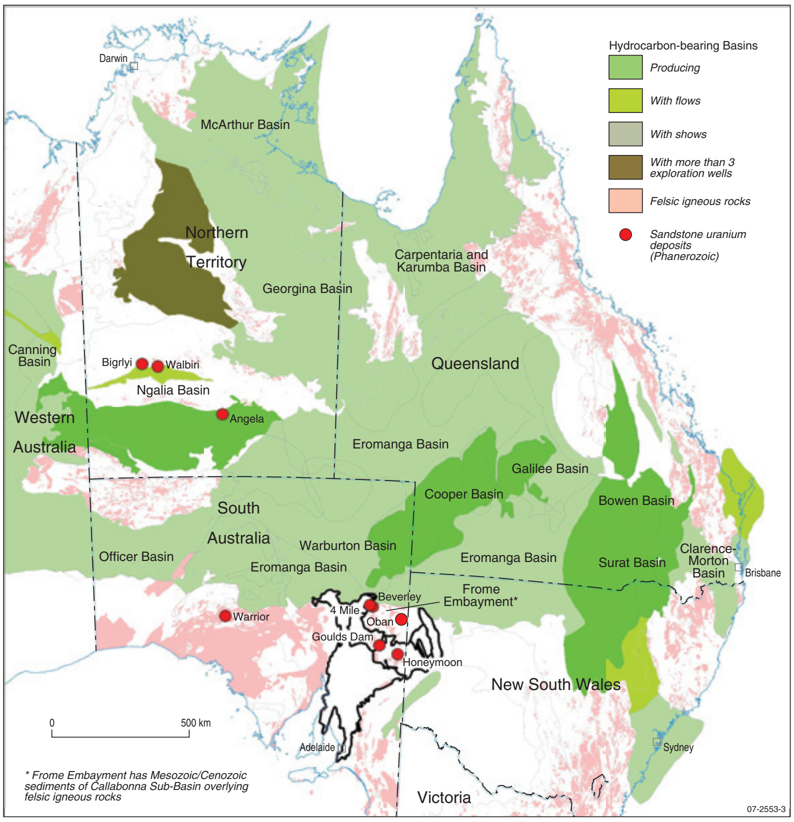


Figure 3. Maps showing hydrocarbon-bearing onshore basins of Australia and Archaean/Proterozoic terranes with uranium-rich felsic rocks. Data for hydrocarbon-bearing basins from Geoscience Australia's dataset of Sedimentary basins. Outcropping felsic rocks (NSW, Northern Territory, Queensland, Tasmania, Victoria) from Geoscience Australia's 1:1 000 000 Surface Geology of Australia map. Felsic rocks in SA and WA extracted from the solid geology maps of SA and WA (Solid Geology of South Australia, 2006 and 1:500 000 Interpreted Geology Map of Western Australia, June 2001) respectively.

sulfur and carbon isotopic) studies required to define more precisely the role of hydrocarbons and/or H_2S in the Chu-Sarysu and Syrdarya basins have not been conducted.

Based on the observed features, we propose that the one condition conducive to formation of the large Kazakhstan sandstone uranium deposits (table 1) is the organic-poor nature of the highly permeable sands in the large Cretaceous and younger artesian basin, which ensured sustained flow of uranium-bearing oxidised groundwater in the aquifers. The other favourable condition would have been the localised availability of active reductants in the form of hydrocarbon gases (including H_2S) leaking from Permian hydrocarbon reservoirs (figure 1). A rapid and localised reduction might be critical to form relatively large deposits, and tectonic activation of faults in the Late Oligocene – Middle Miocene could have facilitated ingress of the necessary hydrocarbon gases, particularly at the margins of the hydrocarbon reservoir where the seal was less effective. These conditions resulted in the location of roll fronts at distances of 300 to 350 kilometres from the uranium basin margin.

In other roll-front systems (such as in the Wyoming Basin), oxidised waters encounter reducing materials distributed through the aquifer and the redox roll front migrates progressively down dip. Under these conditions, the potential for very large deposits is considered lower and the deposits tend to occur within about 60 kilometres of the margins of the sandstone uranium basins.

Examples in China and Texas

The close spatial association between sandstone uranium deposits and hydrocarbon-bearing basins observed in the Chu-Sarysu Basin is not unique. In recent years, sandstone uranium deposits closely associated with hydrocarbon-bearing basins have been identified in the Ordos and Songlio basins in China (for example, Huang Xian-fang et al 2005).

Further afield, in the Texas Uranium Region (Texas Coastal Plain), uranium mineralisation in organic-poor sandstones has been attributed by several researchers to the influx of H_2S along faults from hydrocarbon reservoirs at depth (Reynolds and Goldhaber 1978).

Implications for Australia

Australia holds roughly 30% of global uranium resources recoverable at <US$80/kg U (Reasonably Assured plus Inferred Resources). Over 90% of those resources are in Olympic Dam, a hematite breccia complex (also known as iron oxide – copper – gold – uranium) deposit, and in unconformity-related uranium deposits. Only about 2% of Australia's known uranium resources are in sandstone deposits, despite apparently favourable geological settings for this style of uranium mineralisation.

Organic-rich sands of the Eyre and Namba formations (Cainozoic) are hosts for sandstone uranium deposits in the Frome Embayment and are a focus for ongoing and successful uranium exploration.

However, geological settings similar to that of the Chu-Sarysu and Syrdarya Basins can be identified in a number of hydrocarbon-bearing basins in Australia. For instance, hydrocarbon reservoirs in the Cooper Basin underlie several sandstone aquifers in the Eromanga Basin (figure 3). This implies that the organic-poor parts of aquifers further from basement outcrops should be evaluated, as they could contain uranium mineralisation where hydrocarbons or H_2S leaked from hydrocarbon reservoirs.

In summary, based on the model (figure 4) developed in this paper for large sandstone uranium deposits and the information presented in figure 3, we conclude that there is considerable potential for new, economically significant, sandstone-type uranium systems in Australia, particularly in the following areas:

- northern Frome Embayment (Eromanga Basin adjacent to Mt Painter and Willyama/Olary inliers)
- Lake Eyre area (Eromanga, Arckaringa, Arrowie and Warburton Basins in proximity to Mt Painter and Peake and Denison inliers)
- Eromanga, Cooper, Warburton and Galilee Basins
- Surat, Bowen, and Clarence-Morton Basins
- Carpentaria and Karumba Basins adjacent to Mt Isa Inlier and Georgetown inliers
- Georgina Basin
- Amadeus and Ngalia Basins
- Officer and Canning Basins
- McArthur Basin.

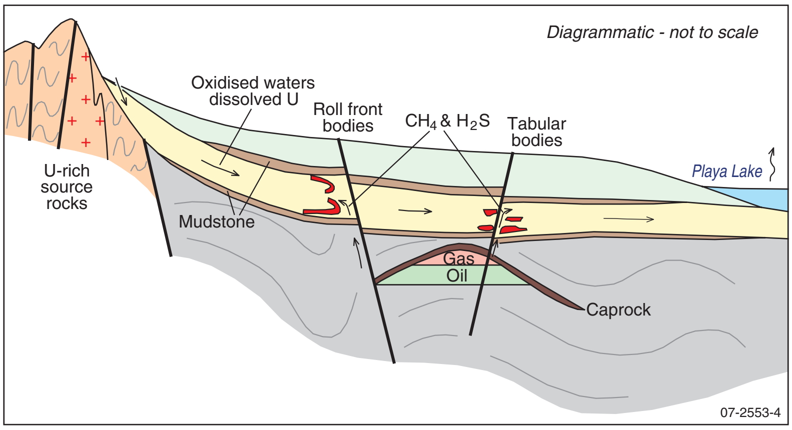


Figure 4. Diagrams showing proposed model. Uranium is carried in oxidised groundwaters and reduced by hydrocarbons and/or H_2S released from the underlying oil and/or gas field. Both roll-front and tabular ore bodies can result from the process. During ore deposition hydrocarbons are often oxidised to form carbonates.

Within these basins, areas at the margins of the hydrocarbon cap-rocks and near to active structures would be of particular interest.

Reduction of uranium-bearing waters by hydrocarbons should typically result in the formation of carbonates within and near ore zones. An Australian example of such diagenetic carbonate zones (without associated uranium mineralisation) has been described for the hydrocarbon-bearing Vulcan sub-basin (O'Brien and Woods 1995).

Large sandstone uranium systems containing relatively massive zones of carbonates may be visible on seismic sections, as is the case in the Vulcan sub-basin. Other datasets useful for the exploration of sandstone uranium systems include oxidation state of groundwaters and sandstones from hydrogeochemistry; colour of sandstone (and other indicators of oxidation state); distributions of hydrocarbon cap rocks; porosity and permeability of sandstone aquifers; and active structures.

Conclusions

We propose that potentially large sandstone uranium mineralisation is most likely to occur where three criteria are met:

- hydraulic connections to uranium-enriched source rocks
- presence of permeable sandstone aquifers, with impermeable rocks above and below that seal the aquifer
- hydrocarbon accumulations in the sequence underlying the aquifers together with features that could have facilitated migration of hydrocarbon gases into the uraniferous aquifer, in particular areas at the margins of hydrocarbon cap-rocks and where there has been reactivation of structures.

This model has been applied to Australia at regional scale, leading to the conclusion that there is considerable scope for discovery of major sandstone uranium mineralisation of the general type being mined in Kazakhstan.

For more information

phone Subhash Jaireth on +61 2 6249 9419
email subhash.jaireth@ga.gov.au

Acknowledgments

We thank Lynton Jaques, Graham Logan, Yanis Miezitis and Roger Skirrow who reviewed this paper and Neale Jeffery who provided cartographic and drafting support.

References

Aubakirov KhB. 1998. On the deep origin of ore-forming solutions in the uranium deposits in platform sequence of depressions (with Chu-Sarysu Province as an example). Geology of Kazakhstan 2(354):40–47.

Bykadorov VA, Bush VA, Fedorenko OA, Filipova IB, Miletenko NV, Puchkov VN, Smirnov AV, Uzhekenov BS & Volozh AV. 2003. Ordovician–Permian palaeogeography of Central Eurasia: Development of Palaeozoic petroleum-bearing basins. Journal of Petroleum Geology 26:325–350.

Dahlkamp F J. 1993. Uranium Ore Deposits. Berlin, Springer–Verlag.

de Voto RH. 1978. Uranium Geology and Exploration. Lecture Notes and References. Colorado School of Mines

Fyodorov GV. 1996. A comparative description of the geological-technological characteristics of the sandstone-hosted uranium deposits in Wyoming and Southern Kazakhstan. In: In Situ Leach Uranium Mining. Proceedings of International Atomic Energy Agency Technical Committee Meeting, Almaty, Kazakhstan, September 1996.

Fyodorov GV. 1999. Uranium deposits of the Inkai–Mynkuduk ore field, Kazakhstan. In: Developments in Uranium Resources, Production, Demand and the Environment. Proceedings of International Atomic Energy Agency Technical Meeting, Vienna, June 1999. IAEA-TECDOC 1425: 95–112.

Heathgate Resources. 1998. Beverley Uranium Mine. Environmental Impact Statement. Unpublished.

Huang Xian-fang, Liu De-chang, Du Le-tian & Zhao Ying-jun. 2005. A new sandstone type uranium metallogenetic type—'structure—oil, gas type'. In: Jingwen Mao & Bierlein FP (eds), Mineral Deposit Research: Meeting the Global Challenge. Proceedings of the Eighth Biennial SGA meeting, Beijing, China, August 2005, 265–268.

Mikhailov VV & Petrov NN. 1998. Age of exogene uranium deposits in south and south-east Kazakhstan according to the lead-isotope study. Geology of Kazakhstan 2(354): 63–70.

O'Brien GW & Woods EP. 1995. Hydrocarbon-related diagenetic zones (HRDZs) in the Vulcan sub-basin, Timor Sea: Recognition and exploration implications. APEA Journal 220–251.

Petrov NN. 1998. Epigenetic stratified-infiltration uranium deposits of Kazakhstan (in Russian). Geology of Kazakhstan 2(354): 22–39.

Reynolds RL & Goldhaber MB. 1978. Origin of a South Texas roll-type uranium deposit: I. Alteration of iron – titanium oxide minerals. Economic Geology 73:1677–1689.

Spirakis CS. 1996. The roles of organic matter in the formation of uranium deposits in sedimentary rocks. Ore Geology Reviews 11:53–69.

Yazhikov, V. 1996. Uranium raw material base of the Republic of Kazakhstan and prospects of using in situ leach mining for its development. In: In Situ leach uranium Mining. Proceedings of IAEA Technical Committee Meeting, Almaty, Kazakhstan, September 1996.

Australian Government
Geoscience Australia
AUSGEO news
ISSUE 89 Mar 2008

Synchronising clocks in rocks

Refined isotopic decay measures increase dating accuracy

Geoff Fraser

Time information is fundamental to most geological studies, particularly in guiding resource exploration, because the date of a geological process can be crucial to assessing its potential to form mineral deposits.

In most cases the only quantitative measure of time is natural radioactive decay. Isotopic decay measures in common use in geochronology include measures of the decay of uranium to lead (U–Pb), potassium to argon (K–Ar), rubidium to strontium (Rb–Sr), and rhenium to osmium (Re–Os).

Each provides an independent geological 'clock' with specific advantages and limitations, and can provide timing constraints on different geological processes. Consequently, application of multiple geochronological methods can often provide more complete understanding than the use of any single method.

Geoscience Australia's geochronology toolkit has been augmented since 2001 by the argon^{40}/argon^{39} method—a variant of the K–Ar method. The ^{40}Ar/^{39}Ar method complements Geoscience Australia's long-established strength in U–Pb SHRIMP zircon geochronology by providing timing information from different minerals and for different geological processes.

> "Reconsideration of the published ^{40}Ar/^{39}Ar ages in the light of improved synchronisation of the isotopic clocks reconciles the apparent discrepancy between ^{40}Ar/^{39}Ar and U–Pb ages."

For example, the ^{40}Ar/^{39}Ar method can be used to:

- directly date potassium-bearing hydrothermal minerals in ore-related alteration zones
- reconstruct cooling and thermal overprinting histories in medium- to high-grade metamorphic terranes
- date mica-fabrics in shear-zones.

This information is most useful when integrated with U–Pb zircon ages from magmatic rocks to reconstruct a more complete sedimentary, magmatic, metamorphic and metallogenic history of a terrane.

However, when comparing geological ages derived from contrasting isotopic methods (for example, U–Pb versus ^{40}Ar/^{39}Ar), it must be recognised that each of these methods involves inherent uncertainties related to decay constants, the age and homogeneity of standards, and other physical parameters. At best, these so-called external uncertainties create 'fuzzy' ages and, if not properly accounted for, can lead to misleading geological interpretations.

One approach to improving the current situation is to calibrate the ^{40}Ar/^{39}Ar timescale against the U–Pb timescale based on careful comparisons of ^{40}Ar/^{39}Ar and U–Pb ages from volcanic rocks. Such intercalibration is the subject of ongoing international research, and the existing dataset indicates that the two timescales may be offset by almost 1% (for example, Min et al 2000, Villeneuve et al 2000, Kwon et al 2002).

In simple terms, the clocks are not perfectly synchronised. While a 1% offset may not sound like much, in Palaeo- and Mesoproterozoic rocks this translates to age offsets in the order of 15 to 20 million years.

Several geochronological studies carried out at Geoscience Australia over recent years illustrate the importance of improved synchronisation of the U–Pb and $^{40}Ar/^{39}Ar$ isotopic clocks. For example, discrepancies in $^{40}Ar/^{39}Ar$ and U–Pb ages for Au–Cu mineralisation at Tennant Creek have been problematic for the past decade, and have led to contrasting interpretations (Compston & McDougall 1994, Wyborn et al 1998). Reconsideration of the published $^{40}Ar/^{39}Ar$ ages in the light of improved synchronisation of the isotopic clocks reconciles the apparent discrepancy between $^{40}Ar/^{39}Ar$ and U–Pb ages (figure 1 and Fraser et al, submitted). In turn, this allows more confident interpretation of the timing of Au–Cu mineralisation and its association with local magmatic rocks, with particular mineral exploration implications.

Similar examples exist in relation to tin–tungsten–tantalum mineralisation in the Davenport Ranges region, south of Tennant Creek, and gold mineralisation in the central Gawler Craton. In each of these examples, improved synchronisation of the $^{40}Ar/^{39}Ar$ and U–Pb isotopic clocks provides improved timing relationships between mineralisation and magmatism.

Ongoing international research to improve the synchronisation of isotopic clocks is expected to provide further improvements in geological applications of geochronology.

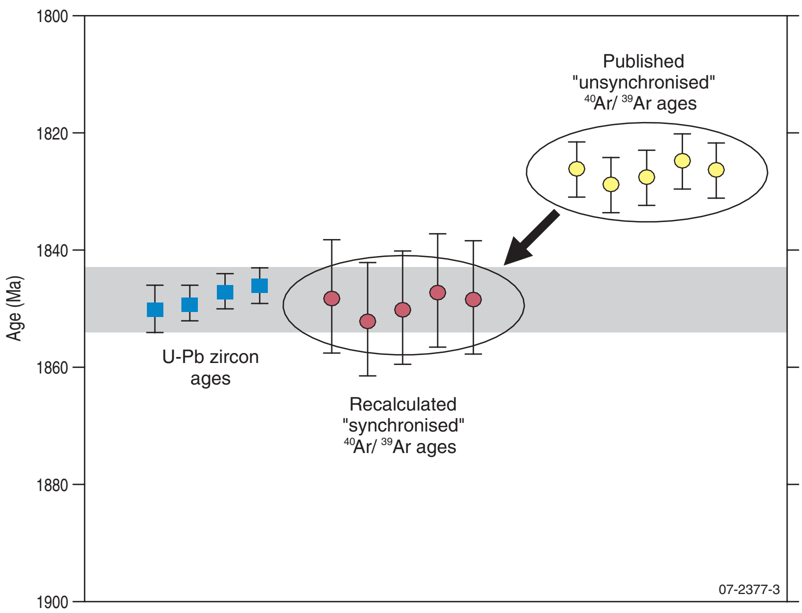


Figure 1. Isotopic age constraints for Au–Cu mineralisation at Tennant Creek, showing the effect of recalculating published $^{40}Ar/^{39}Ar$ ages using a revised potassium decay constant derived via intercalibration with the U–Pb timescale (Kwon et al 2002).

For more information

phone Geoff Fraser on +61 2 6249 9063
email geoff.fraser@ga.gov.au

References

Compston DM & McDougall I. 1994. $^{40}Ar/^{39}Ar$ and K–Ar age constraints on the Early Proterozoic Tennant Creek Block, northern Australia, and the age of its gold deposits. Australian Journal of Earth Sciences 41:609–616.

Fraser GL, Hussey K & Compston DH. Submitted. Timing of Palaeoproterozoic Cu–Au–Bi and W-mineralisation in the Tennant Creek region, northern Australia: Improved constraints via intercalibration of $^{40}Ar/^{39}Ar$ and U–Pb ages. Submitted to Precambrian Research.

Kwon J, Min K, Bickel PJ & Renne PR. 2002. Statistical methods for jointly estimating the decay constant of ^{40}K and the age of a dating standard. Mathematical Geology 34:4.

Min K, Mundil R, Renne PR & Ludwig KR. 2000. A test for systematic errors in $^{40}Ar/^{39}Ar$ geochronology through comparison with U/Pb analysis of a 1.1-Ga rhyolite. Geochimica et Cosmochimica Acta 64:1.

Villeneuve M, Sandeman H & Davis WJ. 2000. A method for intercalibration of U–Th–Pb and $^{40}Ar/^{39}Ar$ ages in the Phanerozoic. Geochimica et Cosmochimica Acta 64:23.

Wyborn L, Budd A & Bastrakova I. 1998. Metallogenic potential of the felsic igneous rocks of the Tennant Creek and Davenport Provinces, Northern Territory: Is the enigma of the source of the gold at Tennant Creek resolved. AGSO Research Newsletter 29:26–28.

The author

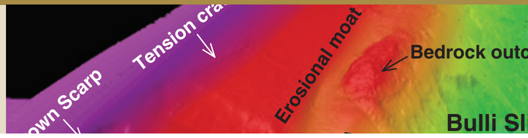
Geoff Fraser was a Distinguished Geoscience Australia Lecturer (DGAL) for 2007, and this article is based on his DGAL presentation.

Australian Government
Geoscience Australia

AUSGEO news
ISSUE 89 Mar 2008

Revealing the continental shelf off New South Wales

Cross-agency work increases understanding of tsunami hazard and risk



Kriton Glenn

The results of a 15-day marine survey off the New South Wales coast have provided a regional understanding of the morphology and mass wasting history of the continental slope between Jervis Bay and Forster (figure 1).

While providing a view of previously unknown submarine rivers, bedrock outcrops and multiple deepwater canyons, the survey gathered baseline data that helped Geoscience Australia assess the probability and implications of localised submarine mass failures or underwater landslides.

Harnessing expertise from several areas across Geoscience Australia as well as university specialists, the survey team assessed the continental slope, particularly in areas where it is thought that submarine mass failures could generate tsunamis. The data were presented and discussed at the recent international Submarine Mass Movements and their Consequence Symposium in Greece.

The physiography of the east Australian margin is largely controlled by the original shape of the basement. The survey data reveal that the New South Wales continental slope, despite being characterised by a very slow sedimentation rate, has been prone to extensive sediment mass wasting over time.

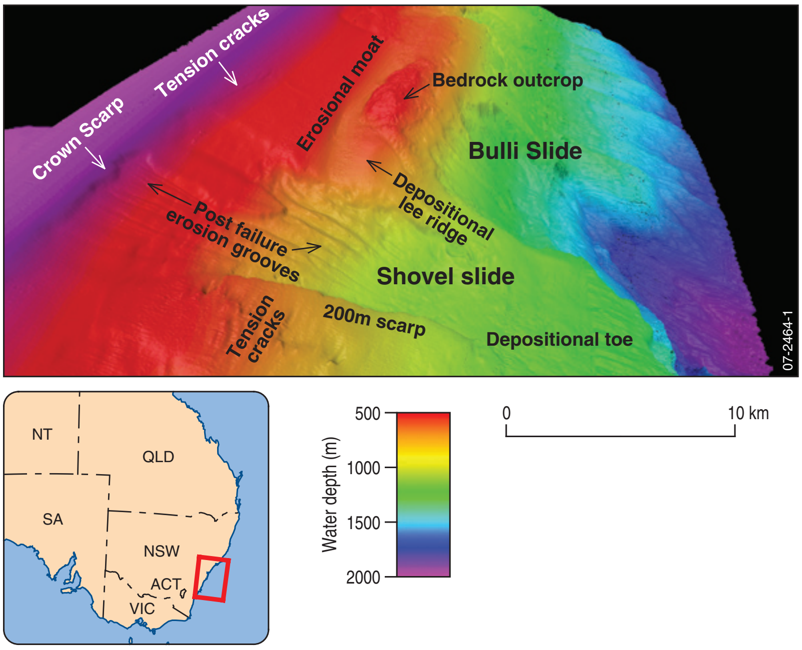


Figure 1. The slope failure architecture and slip-plane geometry of the Shovel Slide. Inset: the survey area off the New South Wales coast.

New features discovered

Many remarkable features were also seen for the first time, such as mid slope channels off the Hunter region. Some of these channels have levees and a V shaped morphology, suggesting that both active erosion and deposition are taking place.

Additionally, a series of large pockmarks (~600 metres in diameter and ~70 metres deep) were found in water depths exceeding 1300 metres. The ages of the pockmarks are hard to determine, as they are formed as a result of an ongoing gas or liquid escape from much deeper in the geological profile. Seismic data indicate that the fluid is migrating along faults and escaping via these features into the water column. The profiles show little infilling of the steep walls of the pockmarks, indicating an active erosional process.

Submarine landslides revealed

The swath bathymetry also revealed the slope failure architecture and slip plane geometry of several submarine mass failure sites. The sites that have failed include the Bulli (~20 km^3), Shovel (~7.97 km^3; figure 1), Birubi (~2.3 km^3) and Yacaaba (~0.24 km^3) slides.

The sub-bottom profiles illustrate the nature of the failures and highlight two distinct types: those related to the sediment bedding planes in the Cainozoic sediment wedge and those related to the critical dynamics of the seaward face of volcanic highs, slope angle and sediment load.

The survey also helped to identify potential failure sites across much of the continental slope. Sites identified as potential failure zones displayed retro-gradational failure and surface cracking, and some are subject to localised slope undercutting. Taking these factors into consideration and assessing the location of vulnerable sediment accumulations, future programs will seek to identify and assess additional areas susceptible to failure along Australia's continental slope.

Predicting tsunami risk

This survey provided essential information for developing models to assess the risk of tsunamis to the Australian coastline. The data were coupled with tsunami model outputs to develop a palaeo-tsunami investigation program that seeks to determine if and when tsunamis have occurred along the New South Wales coast.

The results of this type of scientific enquiry provide a model for further assessment of tsunami risk along the Australian continent.

For more information

phone Kriton Glenn on +61 2 6249 9379
email kriton.glenn@ga.gov.au

Data acquired:

- ~9200 square kilometres swath bathymetry
- 3414 kilometres sub-bottom profiles

Australian Government
Geoscience Australia

AUSGEO news
ISSUE 89 Mar 2008

Creating safer communities

New resource will help reduce the impact of natural hazards in Australia

Miriam Middelmann

'No state or territory in Australia is immune to the impact of natural disasters. As well as having an enormous economic cost, natural disasters inflict a massive social cost on the community. Although disaster response, recovery and mitigation are reasonably developed in Australia, risk analysis, which provides the foundation for risk reduction, has received less attention.' (Middelmann 2007, page xi)

Every Australian has experienced the effect of natural hazards. For some, the effect might be as small as the increased cost of bananas following tropical cyclone Larry. Those less fortunate have felt the direct impact of a natural disaster on their home and community. These effects may be tangible (such as loss of a car or business opportunity) or intangible (for example, loss of personal memorabilia, personal injury or increased stress levels). Intangible loss is much more difficult to measure, and its impacts may last long after tangible effects have ceased to be significant.

The recently published *Natural hazards in Australia: Identifying risk analysis requirements* (Middelmann 2007) contains something of interest to everyone. The report details rapid-onset natural hazards, including tropical cyclones, floods, severe storms, bushfires, landslides, earthquakes and tsunami, and illustrates and describes the impact that natural hazards have on Australia. It also includes details and images of significant natural disaster impacts in Australia, including Cyclone Tracy (1974), the southeast Queensland floods (1974), the Sydney hailstorm (1999), the Ash Wednesday bushfires (1983) and the Thredbo landslide (1997).

Although much has been done to reduce risk to Australian communities, some recent events declared as natural disasters, such as the floods in Queensland in January 2008, serve as a reminder of the continuing impact on the community. This is why analysing the risk is so important.

'Accurately modelling the likely impacts of natural hazards on communities provides decision makers with the tools to make more informed decisions aimed at reducing the impact of natural hazards.' (Middelmann 2007, page 4)

> "A good understanding of the risk from natural hazards is vital to minimise their potential impacts."

Natural disaster impact and risk analysis

The early chapters of *Natural hazards in Australia* highlight the impact that natural disasters have had on Australia and introduce the concept of risk. Together, these chapters illustrate the need for analysing risk and provide the background for subsequent hazard-specific chapters.

A good understanding of the risk from natural hazards is vital to minimise their potential impacts. 'Risk analysis' (the systematic process used to understand and assess the level of risk) provides essential input to planning an emergency response and prioritising resources for sound mitigation practice. Risk analysis is an important step in the risk management process.

'Risk is analysed by considering the combined effects of likelihood and consequence that produce disasters. Assessing likelihood involves assessing the frequency or probability of natural hazard events. Consequences are examined by collecting the information on the elements likely to be exposed to the impact of the hazard phenomenon, such as buildings, infrastructure and people, and gathering information on their vulnerability to a particular hazard.' (Middelmann 2007, pages xii–xiii)

Natural hazards in Australia also examines the economic and social impact of natural disasters, the distribution of natural hazards in Australia, and the role that human activities play in creating and mitigating disasters.

'As Australia's population and density of living continue to grow, so does the potential impact of a natural disaster on the Australian community. Increasing numbers of people, buildings and infrastructure assets are being exposed to natural hazards as the pressures for urban development extend into areas of higher risk.' (Middelmann 2007, page xi)

Among the questions answered are 'What was the most expensive natural hazard in Australian history?' and 'Which hazard caused the most fatalities?'. The report also illustrates how a single major event can change the perceived wisdom about hazards. For example, the historical cost of earthquakes is attributed largely to one event—the 1989 Newcastle earthquake. Therefore, we also need to gather evidence on prehistoric impacts of natural hazards.

The distribution of natural hazard impacts may be more random for some hazards than for others. For example, the threat to Australian communities from bushfires and thunderstorms increases during the summer. During that period, tropical cyclones (including severe winds, storm tides and flooding) also become more prevalent and pose a threat to the northern half of Australia. Climate change might also affect the future distribution of some natural hazards.

Government policy on natural disasters plays a vital role in mitigating their impacts. Governments are involved in minimising risk, particularly in such areas as land-use planning, construction standards and emergency management.

Two events with particularly high impacts, both on the communities affected and in changing government policy, occurred in 1974: the floods in the Brisbane region in January and Cyclone Tracy in Darwin in December (figure 1). The Natural Disasters Organisation (now Emergency Management Australia) was formed following the Brisbane floods, and Cyclone Tracy reinforced the necessity of disaster mitigation (Walker 1999). *Natural hazards in Australia* also emphasises the need for close links between policy makers, researchers, practitioners and the community in reducing the impact of natural hazards.

Figure 1. Destruction caused by tropical cyclone Tracy in Darwin, Northern Territory, December 1974. Photo courtesy of Bureau of Meteorology.

Finding out about natural hazards

The report examines some key questions in chapters covering each of the major hazards. These include:

- What is a landslide, tsunami or severe storm?
- How are they caused and where do they occur?
- What is the potential influence of climate change on meteorological hazards such as tropical cyclones, floods and bushfires?
- How is the risk analysed for each hazard? What issues are involved and what data are needed?

The report also outlines some of the information gaps that reduce our ability to analyse the risk for each hazard more rigorously. Common themes that emerge include the need for more research into the vulnerability of buildings and infrastructure to natural hazards, and the potential impact of climate change. The need for good data to inform the risk analysis process is emphasised throughout the report.

Data collection is a long-term investment which requires the ongoing support of all levels of government, the private sector and the community. Where the data are inadequate, the ability to analyse and effectively reduce the impact of natural hazards is severely limited. (Middelmann 2007, page xiii)

Many government and non-government agencies, groups and individuals are involved in the management of natural hazards (figure 2). An overview of the roles and responsibilities at all levels of government, as well as industry, coordinating groups, professional bodies and research institutions, is included for each hazard. The role of the courts and legal institutions, property developers, the media, and the general community is also explained where relevant.

Figure 2. A firefighter fighting a blaze from the Great Alpine Road, near Bruthen, Victoria, January 2007. Photo courtesy of Country Fire Authority Public Affairs / Martin Anderson.

Background

Natural hazards in Australia was developed in response to a Council of Australian Governments report, *Natural disasters in Australia—Reforming mitigation, relief and recovery arrangements* (COAG 2004), which identified a need to develop systematic and rigorous risk assessments and establish a nationally consistent system of data collection, research and analysis. It also relates and contributes to the National Risk Assessment Framework (NRAAG 2007) prepared by all levels of government, which identified the need to produce consistent information on risk, so that risks can be compared for different locations and for different hazards.

The entire report and individual chapters can be downloaded from Geoscience Australia's website. A hardcopy version of the report can be obtained from the Geoscience Australia Sales Centre.

For more information

phone Miriam Middelmann on +61 2 6249 9240 or the Geoscience Australia Sales Centre on Freecall 1800 800 173 (in Australia) or +61 2 6249 9966

email miriam.middelmann@ga.gov.au or sales@ga.gov.au

Acknowledgments

The report was developed by Geoscience Australia in partnership with the former Australian Government Department of Transport and Regional Services. Technical expertise was provided by Geoscience Australia, the Bureau of Meteorology and CSIRO, with additional contributions from other agencies and individuals. Valuable input from state and territory agencies in the scoping stages directed the report's focus.

References

COAG (Council of Australian Governments). 2004. Natural disasters in Australia. Reforming mitigation, relief and recovery arrangements. A report to the Council of Australian Governments by a high level officials' group, August 2002. Department of Transport and Regional Services, Canberra.

Middelmann M (ed). 2007. Natural hazards in Australia: Identifying risk analysis requirements. Geoscience Australia, Canberra.

NRAAG (National Risk Assessment Advisory Group). 2007. A national risk assessment framework for sudden onset natural hazards. Implementation Plan endorsed by the Australian Emergency Management Committee, April 2007.

Walker GR. 1999. Designing future disasters—An Australian perspective. In: Britton NR (ed), The changing risk landscape: Implications for insurance risk management. Aon Group Australia Ltd, Sydney.

Related websites

Natural Hazards in Australia: Identifying Risk Analysis Requirements

www.ga.gov.au/hazards/reports/nhiar/

Natural disasters in Australia, Council of Australian Governments (COAG)

www.infrastructure.gov.au/disasters/index.aspx

NRAAG (National Risk Assessment Advisory Group). 2007. A National Risk Assessment Framework for Sudden Onset Natural Hazards.

www.ga.gov.au/image_cache/GA10027.pdf

Emergency Management Australia

www.ema.gov.au/

Bureau of Meteorology

www.bom.gov.au/

in brief

Graduate project strengthens community ties

Each year Geoscience Australia's new graduate recruits are challenged to independently develop, undertake and report on a group project that has clear links to Geoscience Australia's key priorities. The 2007 graduate project was designed to assist the assessment of tsunami risk in Western Australia, and to further strengthen ties with local emergency services and the community.

The project was developed in conjunction with Geoscience Australia's Natural Hazard Impacts Project (NHIP), which is developing modelling techniques that enable the estimation of coastal inundation and impact during tsunami events. Collaborative research by Geoscience Australia and the Fire and Emergency Services Authority (FESA) of Western Australia has led to a higher tsunami risk being assessed for the northwest of Western Australia and, as a result, the development of inundation models for several coastal communities in this region, including Onslow and Exmouth.

GPS surveying was undertaken in Onslow and Exmouth to ascertain the quality of the Digital Elevation Models (DEM) used in the inundation models. The survey data was used to assess the validity of the DEM, and integration of the revised data into the original inundation models resulted in improved accuracy in estimating impacts. In addition, vital on-the-ground visual inspection of those areas predicted for inundation was conducted to assess the accuracy of the modelled scenarios, including the identification of areas that appear vulnerable to inundation.

Community awareness of tsunami risk was raised through a community-specific tsunami awareness brochure produced by the graduates and distributed to key community and emergency personnel in Onslow. The graduate recruits represented Geoscience Australia at several community meetings in Onslow, where inundation models, produced by Geoscience Australia, were presented. These meetings provided an insight into specific community concerns in the event of a tsunami, and provided an opportunity to observe how research conducted at Geoscience Australia can be utilised in the public domain.

Figure 1. Sunset in Onslow, Western Australia.

The interaction between community members and the graduates during the field work and at community meetings fortuitously led to new anecdotal evidence of past tsunami events in Onslow. A particular highlight was the discovery of a letter written in 1883 that describes the impact of a tsunami – probably triggered by the Krakatau volcanic eruption in Indonesia – on a farming community in Western Australia.

References

Burbidge D & Cummins P. 2007. Assessing the threat to Western Australia from tsunami generated by earthquakes along the Sunda Arc. In: Natural Hazards, 43:319–331.

Related websites/articles

Fire and Emergency Services Authority of Western Australia, Tsunami webpage

www.fesa.wa.gov.au/internet/default.aspx?MenuID=372

Natural Hazards Online, tsunami

www.ga.gov.au/hazards/tsunami/

AusGeo News 83: Modelling answers tsunami questions

www.ga.gov.au/ausgeonews/ausgeonews200609/modelling.jsp

Geoscience Australia's graduate program

www.ga.gov.au/jobs/graduate/?skip_jobs_list_filter_on=1 *in brief*

Spatial Excellence Award for tsunami modelling

Geoscience Australia and the Fire and Emergency Services Authority of Western Australia (FESA) have received a joint Asia-Pacific Spatial Excellence Award (APSEA) for their work on Tsunami Risk Modelling for Emergency Management. The award, in the Spatially Enabled Government category, recognises projects that use spatial information and technology to improve government productivity, efficiency, service delivery, and help agencies integrate 'customer-centric' service delivery models.

Prior to the Indian Ocean tsunami of 26 December 2004, tsunami were rarely considered an emergency management issue for Australian coastal communities and as a result there was limited understanding of tsunami risk. However, the 2004 event clearly demonstrated the catastrophic nature of tsunami and the numerous impacts along the Western Australia coast highlighted the threat tsunami pose. Consequently, Geoscience Australia and FESA formed a collaborative research partnership to address the issue.

The two key components of this partnership were, firstly, the development and application of state-of-the-art science in order to model the tsunami risk, and effective communication of this science to inform and underpin emergency management plans. The engagement and response from stakeholders was a significant contributing factor to the project's success. The project was conducted within the risk management methodology adopted by the emergency management community, and, for the first time in Australia, has led to best practice spatially-enabled tsunami science underpinning emergency management plans.

The project used and developed a range of spatial products to deliver maps as well as geospatial datasets to the Western Australian emergency managers. These improve the capacity of FESA to integrate the results with other state-level datasets to further improve their service delivery. In addition to the quality of the spatial outputs, the methodology adopted in this project forms a basis for other jurisdictions to understand their tsunami risk.

'This collaboration demonstrated the effectiveness of the Australian and state governments in harnessing and sharing the resources and information available to enable and improve efficiency' observed Dr Chris Pigram, Deputy CEO of Geoscience Australia, when accepting the award. He also pointed out how the integration of science and emergency management has been pivotal in the success of the project as the scientific outputs had been tailored and targeted to address the needs of the communities at risk.

Dr Chris Pigram, Deputy CEO of Geoscience Australia, accepting the Spatial Excellence Award during an APSEA ceremony held at Luna Park, Sydney, on Thursday 22 November.

product news

Australia's resource stocks remain healthy overall

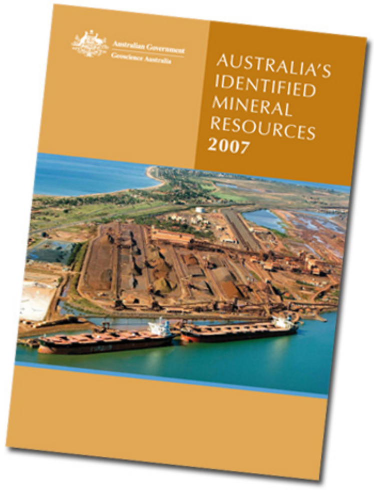
During 2006 Australia's economic demonstrated resources of mineral sands (ilmenite, rutile and zircon), nickel, tantalum, uranium, thorium, zinc and lead remain the world's largest while Australia ranks amongst the top six worldwide for economic demonstrated resources of bauxite, black coal, brown coal, copper, gold, iron ore, lithium, manganese ore, niobium, silver and industrial diamond.

Over the same period Australian mineral exploration spending rose by 29 per cent to a record $1463.9 million. This growth reflects increased prices for many commodities on the back of anticipated strong and growing demand, particularly from China.

These statistics and other important information on Australia's future capacity to produce mineral resources are included in *Australia's Identified Mineral Resources 2007*. This publication is an annual nation-wide assessment of Australia's ore reserves and mineral resources, which takes a long-term view of what is potentially economic.

The assessment includes data on mining company estimates of ore reserves as well as evaluations of long-term trends in mineral resources, international rankings, summaries of significant exploration results, mining industry developments and an analysis of mineral exploration expenditure.

Australia's Identified Mineral Resources 2007 provides government, industry, the investment sector and the general community with an informed understanding of Australia's known mineral endowment and levels of exploration activity.



For more information

phone Aden McKay on +61 2 6249 9230
email aden.mckay@ga.gov.au

Related websites

Australia's Identified Mineral Resources 2007
www.ga.gov.au/minerals/exploration/resources_advice/AIMR2007.jsp

The commodity sections are also accessible via the Australian Mines Atlas
www.australianminesatlas.gov.au

New geophysical datasets released

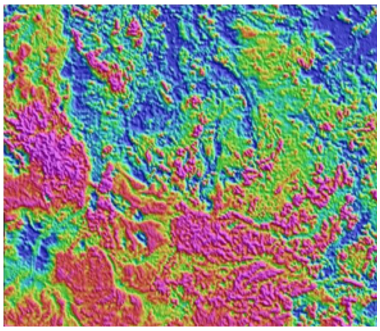
Datasets from five new geophysical surveys have been released since November 2007. These include four new airborne magnetic and radiometric surveys which cover part of the Mount Isa and Croydon regions in Queensland, the Tanumbirini area in the Northern Territory and northeast Tasmania. New gravity data covering part of the Cooper Basin in southwest Queensland have also been released.

The data for all the surveys were acquired during 2007 in surveys conducted and managed by Geoscience Australia on behalf of the Geological Survey of Queensland, the Northern Territory Geological Survey and Mineral Resources Tasmania.

The data have been incorporated into the national geophysical databases. The point-located and gridded data for the five surveys can be obtained free online using the GADDS download facility.

For more information

phone Murray Richardson on +61 2 6249 9229
email murray.richardson@ga.gov.au



Related websites

Geological Survey of Queensland
www.dme.qld.gov.au/mines/about_us.cfm

Northern Territory Geological Survey
www.nt.gov.au/dpifm/Minerals_Energy/

Mineral Resources Tasmania:
www.mrt.tas.gov.au

Table 1. Details of the gravity surveys.

Survey	Survey type	Date of Acquisition	1:250 000 Map Sheets	Station spacing/ orientation	Stations	Contractor
Cooper Basin South (Qld)	Gravity	October – December 2007	Canterbury, Barrolka, Durham Downs, Tickalara, Windorah, Eromanga, Thargomindah, Bulloo, Adavale (pt), Quilpie (pt), Toompine (pt), Eulo (pt).	4.0 x 4.0 km east – west	9213	Atlas Geophysics

Table 2. Details of the airborne surveys.

Survey	Survey type	Date	1:250 000 Map Sheets	Line spacing/ terrain clearance/ orientation	Line km	Contractor
Croydon (Qld)	Magnetic, Radiometric, Elevation	June – September 2007	Burketown, Croydon, Donors Hill, Normanton, Millungera	400 m 80 m east – west	100 320	UTS Geophysics
East Isa South (Qld)	Magnetic, Radiometric, Elevation	November 2006 – July 2007	McKinlay, Manuka, Mackunda, Winton, Brighton Downs, Maneroo	400 m 80 m east – west	144 731	Fugro Airborne Surveys
Tanumbirini (NT)	Magnetic, Radiometric, Elevation	July – September 2007	Hodgson Downs, Tanumbirini, Beetaloo	400 m 80 m east - west	49 437	UTS Geophysics
North – East Tasmania (Tas)	Magnetic, Radiometric, Elevation	March – September 2007	NE Tasmania	200 m 90 m east - west	51 532	GPX Airborne

Natural hazard information online

Natural Hazards Online is a new resource available to emergency managers, researchers and the general public. It is a website that presents information about natural hazards including bushfire, cyclone, earthquake, flood, landslide, severe weather, tsunami, and volcano.

Natural Hazards Online is a joint initiative between Geoscience Australia and Emergency Management Australia, and was established as a contribution to the Disaster Mitigation Australia Package. The website was developed in response to the Council of Australian Governments (COAG) Report on reforming mitigation, relief and recovery arrangements for natural disasters in Australia which identified the need 'to ensure a sound knowledge base on natural disasters and disaster mitigation'.

This is the first time in Australia that a single website has been created to consolidate the broad range of information, data, maps, models and decision support tools available about natural hazards. The site provides users with a 'one stop shop' for natural hazards information ensuring that available content is easy to find and access.

The website provides details about each hazard, the processes behind their occurrence, where they occur in Australia and how they impact on communities. A selection of previous natural hazard events is described and a series of links are available for those who would like to find out more about a particular event.

Photographs and images are available for each type of hazard as well as reports published by Geoscience Australia which can be downloaded from the site. Guidelines and reports published by other agencies as well as a series of maps and databases can also be accessed.

A number of key emergency response tools are easily accessible through Natural Hazards Online, including the Joint Australian Tsunami Warning Centre, the Sentinel bushfire monitoring system, the Bureau of Meteorology's tropical cyclone warning service and national weather warnings summary.

Users can also access the Global Disaster Alert and Coordination System, the Australian Disaster Information Network and the new report Natural Hazards in Australia: Identifying Risk Analysis Requirements. The website includes databases detailing riverine flood studies, recent and historic earthquakes, and landslides, as well as a link to an online risk prevention game.

The website also presents information about risk modelling, emergency management, and natural hazard policy as well as information about expert committees working to reduce the impact of natural hazards in Australia.

Natural Hazards Online is currently receiving approximately 17 000 hits per month. Eighty percent of these hits are from new visitors to the site, and the website presently holds the number one ranking on

'Google' for a natural hazards search on Australian pages.

New information and tools are being added to the website as they become available, to provide emergency managers and other decision makers involved in disaster risk reduction with important resources which will help them to assess the hazard, vulnerability and risk posed by natural disasters and make informed decisions about their management.

For more information

phone Monica Osuchowski
+61 2 6249 9717
email monica.osuchowski
@ga.gov.au

Related websites/articles

Natural Hazards Online
www.ga.gov.au/hazards

Emergency Management Australia
www.ema.gov.au/naturaldisasters

AusGeo News 84: Landslide Database Interoperability Project
www.ga.gov.au/ausgeonews/ausgeonews200612/inbrief.jsp#inbrief2

AusGeo News 82: New Riverine Flood Hazard & Risk Studies Database
www.ga.gov.au/ausgeonews/ausgeonews200606/productnews.jsp#product4

product news

New reference map covers Australia

Geoscience Australia has recently released a new version of its popular 1:5 million scale topographic General Reference Map. This is the first version to be fully digitally derived from Geoscience Australia's renowned 1:250 000 scale (GEODATA 250K) vector data whereas previous versions of the map were compiled using traditional cartographic techniques.

Production involved selecting the features to be included on the map from base data and cartographically revising this larger scale data to fit the smaller scale map. Location names were also reviewed to ensure consistency and compliance with the geographic names allocated by state and territory authorities.

Bathymetric features from Geoscience Australia's Australian Bathymetric Topography Grid were included to enhance the map and show the depth of the oceans and seas around the continent. This bathymetry data complements the hypsometric elevation shown on the land areas of the map to create a visually appealing product.

The General Reference Map is packaged in a plastic sleeve which includes an informative cover insert and is available in flat (ideal for framing) and folded versions and should appeal to a wide range of professional and recreational users. It is planned to release the derived data as a 1:5 million GEODATA (vector) dataset for GIS use. The General Reference Map of Australia (fifth edition) is available from map retailers or direct from Geoscience Australia.

For more information

phone Geoscience Australia Sales Centre on Freecall 1800 800 173 (within Australia) or +61 2 6249 9966

email sales@ga.gov.au

events calendar

2008 APPEA Conference and Exhibition	6 to 9 April
Australian Petroleum Production and Exploration Association Perth Convention & Exhibition Centre Contact: Sane Event Management Pty Ltd PO Box 149, Hurstville BC NSW 1481	p +61 2 9553 1260 f +61 2 9553 4830 e appea2008@saneevent.com.au www.appea2008.com.au
AMEC National Mining Congress 2008	**22 to 24 May**
Association of Mining and Exploration Companies Perth Convention & Exhibition Centre Contact: AMEC, PO Box 545 West Perth WA 6872	p 1300 738 184 (within Australia) f 1300 738 185 (within Australia) e events@amec.org.au www.ameccongress.com.au/
AusIMM International Uranium Conference 2008	**18 and 19 June**
Australasian Institute of Mining and Metallurgy Adelaide Convention Centre Contact: Alison McKenzie, Senior Coordinator, Conferences & Events, The AusIMM, PO Box 660, Carlton South Vic 3053	p +61 3 9658 6123 f +61 3 9662 3662 e alisonm@ausimm.com.au www.ausimm.com
Australian Earth Sciences Convention 2008	**20 to 24 July**
Geological Society of Australia & Australian Institute of Geoscientists Perth Convention & Exhibition Centre Contact: International Conferences and Events Pty Ltd, Suite 4, 73 Hay Street, Subiaco WA 6008	p +61 8 9381 9281 f +61 8 9381 9560 e aesc2008@iceaustralia.com www.iceaustralia.com/aesc2008/
33rd International Geological Congress	**6 to 14 August**
Norway Convention Centre Contact: Conference-Congress AS, PO Box 2694 Solli No 0204 Oslo	p +47 2256 1930 f +47 2256 0541 e secretariat@33igc.org www.33igc.org/coco/
EABS III –Eastern Australasian Basins Symposium	**14 to 17 September**
Petroleum Exploration Society of Australia (NSW/ACT) Sydney Convention & Exhibition Centre Contact: Conference Action PO Box 576, Crows Nest NSW 1585	p +61 2 9437 9333 f +61 2 9901 4586 e eabs@conferenceaction.com.au
14 ARSPC–14th Australasian Remote Sensing and Photogrammetry Conference	**29 September to 3 October**
Darwin Convention Centre Contact: Spatial Sciences Institute, Conference Action PO Box 576, Crows Nest NSW 1585	p +61 2 6282 2282 f +61 2 6282 2576 e info@spatialsciences.org.au
Mining 2008	**29 to 31 October**
Hilton Brisbane Contact: Vertical Events PO Box 1153 Subiaco WA 6904	p +61 8 9388 2222 f +61 8 9381 9222 e info@verticalevents.com.au www.verticalevents.com.au