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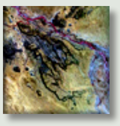
In brief

Product News



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CEO comment

Neil Williams – CEO Geoscience Australia

$134 million in new program funding for Geoscience Australia

The Prime Minister's Energy Security Initiative, announced on August 14, included the injection of $134 million in new program funding into Geoscience Australia. This additional funding will enable Geoscience Australia to supply petroleum and mineral exploration companies with new geoscience information necessary to reduce exploration risk and encourage exploration in new frontier areas.

Geoscience Australia's Big New Oil program of pre-competitive seismic data acquisition, enhancement and access will be expanded over the next five years at a cost of $75 million. This will allow data to be acquired from offshore areas that span up to two million square kilometres, more than three times the area covered by the last program which has proved successful in attracting new exploration to frontier offshore areas such as the Bremer Sub-basin. The improved data will be extensively promoted to the petroleum exploration industry decision-makers in Australia and overseas.

The package includes $59 million to enable Geoscience Australia to pioneer innovative, integrated geoscientific research to better understand the geological potential of onshore Australia for both minerals and petroleum. This will be done through the application of the latest geophysical imaging and mapping technologies.

This issue reports on the Gawler Minerals Promotion Project which outlines the contribution made by this 5-year project in partnership with Primary Industries and Resources South Australia to increase exploration in South Australia through the development of new integrated understanding of crustal architecture, tectonic evolution and controls on mineralisation. Key outcomes are a coherent model for gold and copper mineralisation in the eastern and central Gawler Craton, and the development of new methods for 'uncovering' frontier provinces.

There are also reports on Geoscience Australia's contributions to research to protect Australia from natural disasters and mitigate their future impacts. Following Cyclone Larry in far North Queensland, Geoscience Australia staff, in collaboration with other agencies, helped with the early assessment of the structural damage to residential and commercial buildings as well as regional and farm-level assessments of the economic impact.

Geoscience Australia's tsunami impact modelling is already contributing to development of emergency management plans. Our research into geological records of tsunamis, which extends the tsunami record by thousands of years, will also provide a means of assessing future risk.

Record nickel prices have prompted a boom in nickel exploration and a timely review of the geological settings and resources of Australia's nickel sulphide deposits placing them in a global context will assist nickel explorers. There is also a report on the compilation of datasets of various metallogenic parameters for the Tasman Fold Belt in Victoria which will greatly assist the exploration industry's search for intrusion-related mineralisation systems, notably gold and base metals.

New products reported on include: new geophysical datasets for Mt Isa, Paterson province, East Arunta and the Bowen-Surat regions; new sources of satellite imagery; and new seabed minerals maps that show known offshore mineral occurrences.

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GAWLER *Project breaks cover*

New datasets aid area selection and targeting

Roger Skirrow, Patrick Lyons, Anthony Budd, Evgeniy Bastrakov

Over the past five years, the Gawler Mineral Promotion Project has shed considerable light on the 1590 Ma iron oxide–copper–gold (IOCG) mineral systems of the eastern Gawler Craton and the coeval lode-gold systems of the central Gawler Craton. The project, under the National Geoscience Accord, has been a joint-effort of Geoscience Australia and Primary Industries and Resources South Australia.

Acquisition and interpretation of deep crustal seismic reflection data in the region of the giant Olympic Dam Cu–Au–U mine (see *AusGeo News 76*) delivered huge gains in our understanding of the crustal architecture and tectonic evolution of the eastern and central Gawler Craton. We now recognise that the IOCG mineralisation, which includes the Olympic Dam deposit, occurred inboard of a convergent margin, with first-order controls on fluid pathways being northwest-trending thrust faults.

The three-dimensional picture afforded by the seismic results constrains our interpretation of potential-field data and enables clear comparisons with the Mesozoic–Cainozoic IOCG systems of the Andean margin of South America.

Apart from geophysics, other advances in the project have come from granite studies and geochemistry. We have also refined and improved the geochronological framework of the eastern and central Gawler Craton.

The result is a coherent model of mineralisation of the eastern and central Gawler Craton that links the IOCGs with their coeval lode-gold deposits for the first time. This knowledge gives explorers valuable spatial guides towards mineralisation in these almost completely hidden terranes.

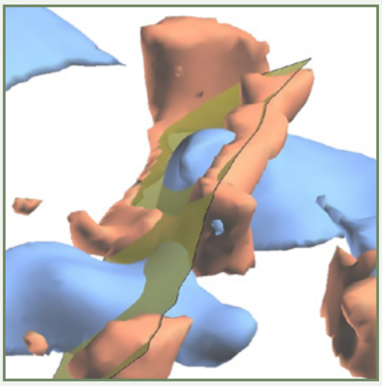

Figure 1. Three-dimensional inversion of magnetic and gravity data predicts the distribution of haematite and magnetite alteration, represented here as isosurfaces (haematite in brown, magnetite in blue). Mapping the distribution of iron oxides associated with IOCG mineralisation also gives information about possible structures controlling mineralisation, such as the fault-plane shown in green, allowing explorers to define drill targets. Although this example covers an area of about 30 km by 30 km, the inversion method is independent of scale.

Potential-field data

In areas of little or no outcrop, potential-field data are critical to understanding the geological make-up of the basement. Because the Gawler Craton is particularly deficient in outcrop—with the crystalline basement of the eastern Gawler Craton almost completely covered by younger rocks—potential-field data are vital for gaining necessary regional knowledge of the prospective basement.

Interpretation of potential-field data is normally constrained by the extent of available petrophysical and spatial data, but these data may be difficult to obtain. Fortunately, the unique density and magnetisation of the iron oxide alteration of IOCG mineralisation allows us to map the likely locations of ore deposition using 3D inversion of the potential-field data (figure 1), even where constraints are lacking (see *AusGeo News 74*).

New subdivision of Hiltaba granites

A new subdivision of the Hiltaba Association granites (which supersedes the Hiltaba Suite) and their comagmatic Gawler Range volcanics comprises four supersuites. The Roxby and Venus Supersuites show A-type characteristics, while the Venus and Malbooma Supersuites are I-type.

Significantly, the A-type granites were hotter and required more elevated geotherms than the I-types. The Olympic copper–gold province in the eastern Gawler Craton is characterised by the presence of A-type supersuites, indicating that the elevated crustal temperatures of the eastern Gawler Craton at 1590 Ma were a key ingredient for generating IOCG mineralisation.

The lower temperature I-type supersuites show many of the characteristics of granites associated with intrusion-related gold deposits. These granites are more abundant in the central Gawler gold province.

There is no demonstrated direct genetic link between the granite supersuites and the broadly coeval IOCG and lode-gold mineralisation. It may be that the granites are symptomatic of certain crustal geotherms that determine the style of mineralisation, with the hotter crust producing some of the conditions required for IOCG mineralisation and cooler crust leading to lode-gold mineralisation.

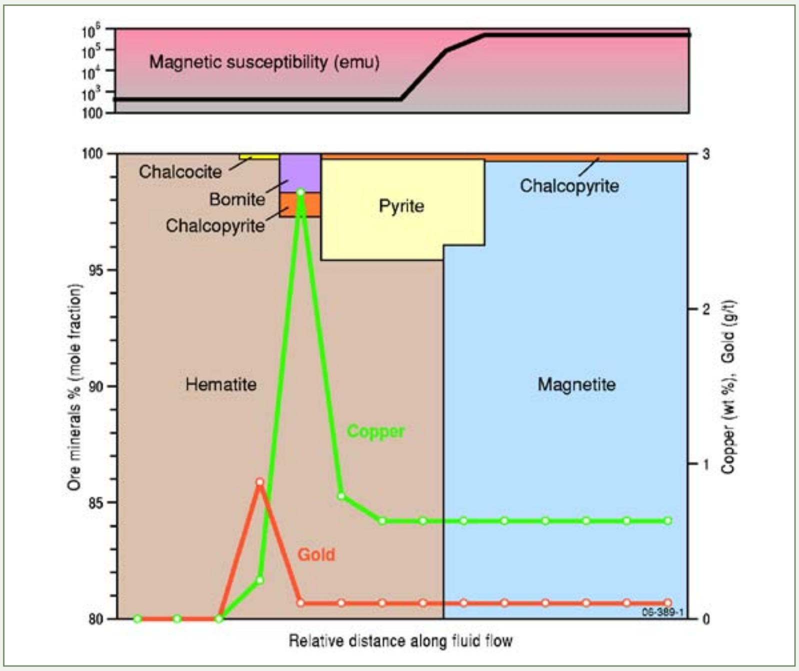

Figure 2. Computer modelling shows that flushing of magnetite alteration, containing sub-economic copper and gold, by oxidised fluids produces haematite alteration and upgrades copper and gold. The characteristic suite of sulfides associated with IOCG mineralisation is predicted. A consequence is that maxima of magnetic anomalies are not optimal drill targets for copper–gold. One must combine mineralogical data with magnetic and gravity data to locate haematite alteration adjacent to magnetite alteration.

Chemical modelling

Chemical modelling predicts that reaction of a low-grade magnetite protore (containing 0.1% Cu, in chalcopyrite, and 0.1 g/t Au) with an oxidised fluid may result in a mineral assemblage with appreciable upgrading of copper and gold (up to ~3% Cu as bornite, chalcocite and chalcopyrite; up to 1 g/t Au) (figure 2). Mineralisation will be contained within the haematite alteration zone adjacent to the magnetite–haematite oxidation front. Our modelling agrees with observations from several known occurrences of copper–gold mineralisation in the Gawler Craton and shows that favourable sites of mineralisation are less likely within magnetite alteration, but may occur at the juncture of offset haematite and magnetite alteration zones. The two-stage upgrading model complements previously published models of copper and gold precipitation due to simultaneous mixing of reduced and oxidised fluids in accounting for the range of styles of copper–gold mineralisation in the eastern Gawler Craton.

Mineral potential map

A 1:500 000 scale map released in February this year—*Iron oxide Cu–Au (–U) potential of the Gawler Craton, South Australia* (figure 3)—summarises key results of work on IOCG systems and shows the distribution of several ‘essential ingredients’ of IOCG ore-forming systems, including:

- supersuites of the Hiltaba granites
- faults and shear zones with interpreted age of youngest significant movement
- copper geochemistry (>200 ppm) from drillholes intersecting crystalline basement
- hydrothermal alteration assemblages and zones, based on drillhole logging
- distribution of IOCG alteration based on inversion modelling of potential-field data
- host sequence units considered important in localising IOCG alteration and mineralisation
- neodymium isotopic data and the mineral isotopic ages of late Palaeoproterozoic to early Mesoproterozoic magmatism and hydrothermal minerals
- prioritised areas of maximum potential for IOCG mineralisation.

The map may be downloaded from the Gawler Project website.

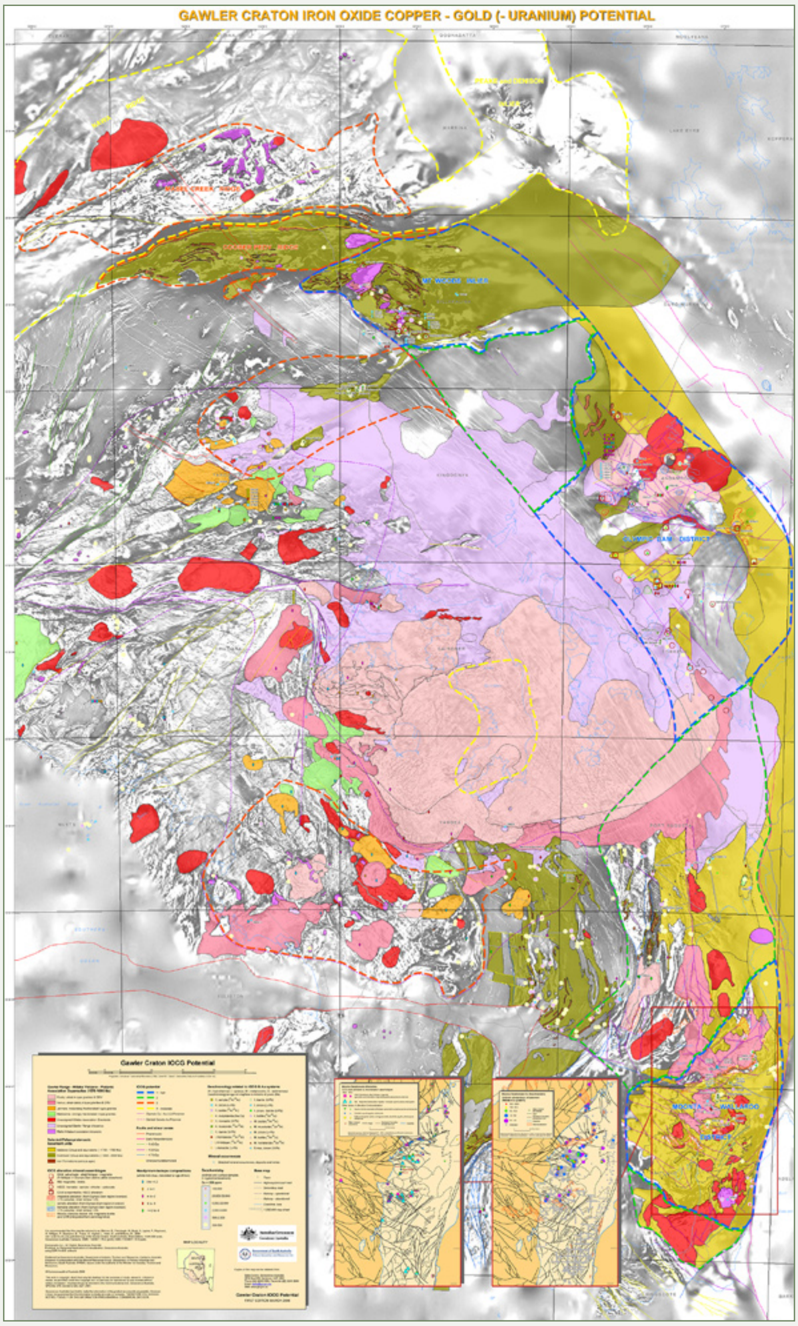

Figure 3. Iron oxide Cu–Au (–U) potential of the Gawler Craton, South Australia map produced by the Gawler Mineral Promotion Project is a summary of ‘essential ingredients’ for IOCG mineralisation in the Gawler Craton. *This map can be downloaded from the Gawler Project website.*

Project lessons

The Gawler Mineral Promotion Project demonstrated how to come to grips with the geology and mineralisation of a region generally obscured by hundreds to thousands of metres of cover. The most important lesson is that a multidisciplinary and collaborative approach is essential.

Geophysics, geochemistry, petrology, drillhole data, and geochronology combined to provide guides to ore and to help us understand the tectonic environment of the Gawler Craton’s IOCG mineral systems and coeval lode-gold systems.

We are now able to take what we have learned about working in such a difficult terrane to other frontier parts of the Australian Proterozoic.

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Gawler seismic study.

AusGeo News 74
Thick cover no obstacle to field inversion, Iron oxide Cu–Au (–U) potential of the Gawler Craton, South Australia 1:500 000 scale map.

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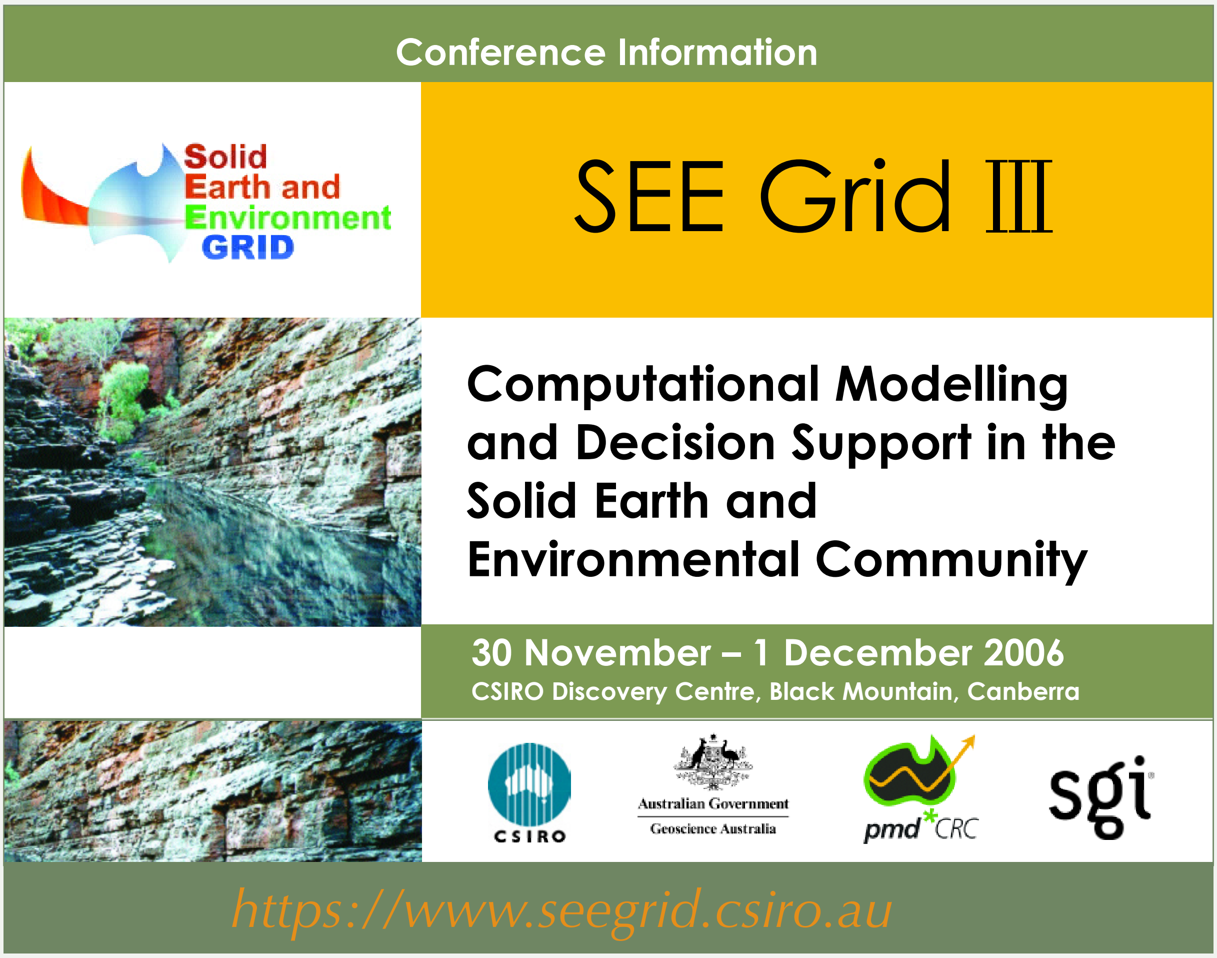

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PRELIMINARY *assessment of Tropical Cyclone Larry*

For a 'midget' cyclone, Larry packed a nasty punch

Adrian Hitchman, Bob Cechet, Mark Edwards, Geoff Boughton (TimberEd Services, Perth, Western Australia), Mary Milne, Damian Mullaly, Medhavy Thankappan

Severe Tropical Cyclone Larry crossed the far north Queensland coast near Etty Bay around 7 a.m. on 20 March, 2006. It then tracked west–northwest and passed directly over the town of Innisfail (figure 1). Within 48 hours, teams from Geoscience Australia were on the ground to begin a program of assessing building and crop damage. This continued over three weeks and the initial analysis of data collected is presented below.

At landfall, the eye of Tropical Cyclone Larry extended about 20 to 25 kilometres from Mirriwinni in the north to Mourilyan Harbour in the south. A vessel sheltering in the South Johnstone River to the east of Innisfail recorded winds gusting to 225 km/h while gusts as high as 294 km/h were recorded near the peaks of the Bellenden Ker mountain range (1450 metres) and 187 km/h at the Ravenshoe wind farm (about 75 kilometres from the coast) as the weakening cyclone moved inland.

The fast-moving tropical depression travelled westward, weakening throughout the day. By 10 p.m. it had passed to the south of Croydon in Queensland's Gulf country where it continued to bring heavy rain and severe flooding.

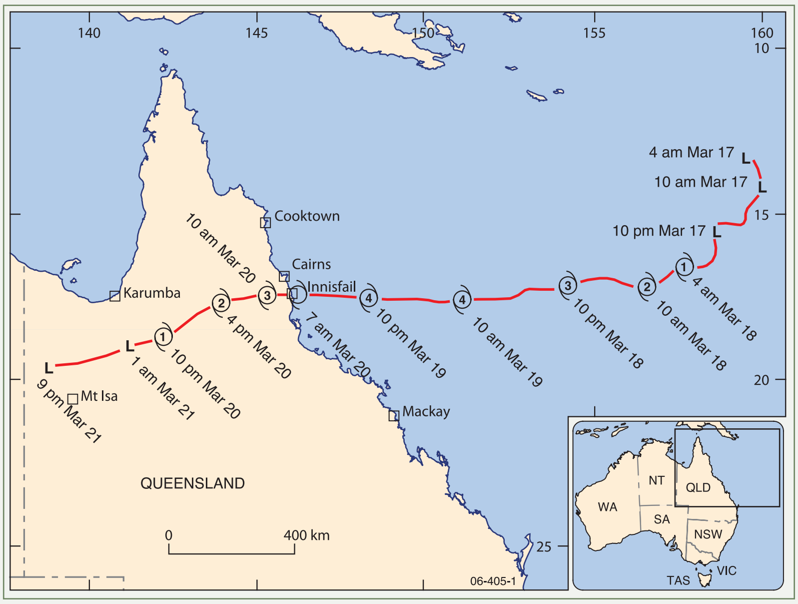

Figure 1. Tropical Cyclone Larry track (Bureau of Meteorology, 2006).

Cyclone description

Tropical Cyclone Larry was classified as a 'midget' cyclone because of the limited range of its destructive winds. Furthermore, coastal communities were not exposed to cyclonic winds and airborne debris for long periods as the cyclone moved relatively quickly at landfall. Low tides at the time also ensured there was no significant storm surge.

Since the 1870s, 22 cyclones have impacted the Innisfail region causing damage from severe wind, storm surge, estuarine flooding or a combination of these hazards (Callaghan 2004). Tropical Cyclone Larry impacted the coast at both high lateral speed and at low tide, causing only wind-related damage. From analysis of impacts to simple structures (such as road signs), preliminary estimates of maximum wind gust speeds at a height of 10 metres are in the order of 55–65 m/s (~200–235 km/h) compared to 50–55 m/s (~180–200 km/h) reached in Tropical Cyclone Winifred, which hit the region in February 1986 (Reardon et al 1986). Further analysis of the data will be required before final wind speeds are determined.

Impact on critical infrastructure

Electricity transmission was cut to the north and southwest of Innisfail. Severe damage to pole-mounted electrical distribution and communications networks was widespread. Power disruption affected other essential utilities such as the hospital, water supply and water treatment works which needed emergency generators. Road and rail access to the region was disrupted for several days by flooding.

Impact on buildings

Severe winds caused by Tropical Cyclone Larry resulted in significant damage to buildings. All townships in the Innisfail region were severely affected.

Table 1. Damage Index: relationship between physical damage and damage costing where the repair cost is expressed as a proportion of the value of the property.

Damage Index (physical)		Damage Index (cost) %
1	Negligible	0
2	Missile to cladding/window	20
3	Loss of half roof sheeting	50
4	Loss of all roofing	70
5	Loss of roof structure	90
6	Loss of half of outer walls	100
7	Loss of all walls	100
8	Loss of half floor	100
9	Loss of all floor	100
10	Collapse of floor supporting piers	100

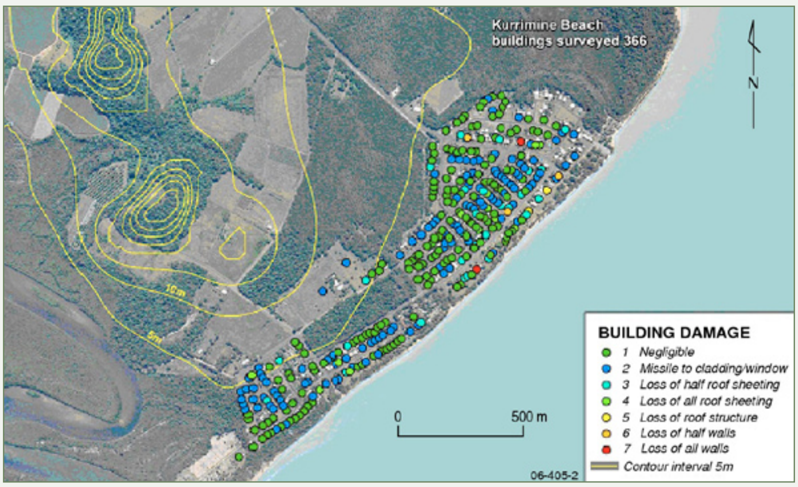

Figure 2. Geographical Information System image displaying the building damage overlain on an aerial photograph for the beachside community of Kurrimine Beach (30 km SSE of Innisfail).

The assessed damage index, which expresses the repair cost as a proportion of the value of rebuilding damaged residential structures (table 1), was calculated for the population of buildings within a number of Innisfail suburbs and nearby townships. Figure 2 shows an example of the spatial analysis conducted for the community of Kurrimine Beach (30 kilometres south–southeast of Innisfail). Figure 3 displays the results as a population percentage (e.g. 25% indicates a damage level equal to 25% of the value of the structures in the local population).

Among residential properties, older homes (pre-1986) tended to suffer the greatest wind damage because of their vulnerable locations (e.g. on ridge tops), building regulations which required limited cyclone-resistance measures at the time of construction, and their lower resilience as a result of aging processes (corrosion, rot, insect attack).

Structures built after Tropical Cyclone Winifred withstood Tropical Cyclone Larry better. This may be because of the revised building standards introduced for domestic construction in the early 1980s and a better understanding of prevention measures following an analysis of the damage inflicted in 1986 by Cyclone Winifred.

Damage to newer homes tended to be comparatively minor and was mostly limited to

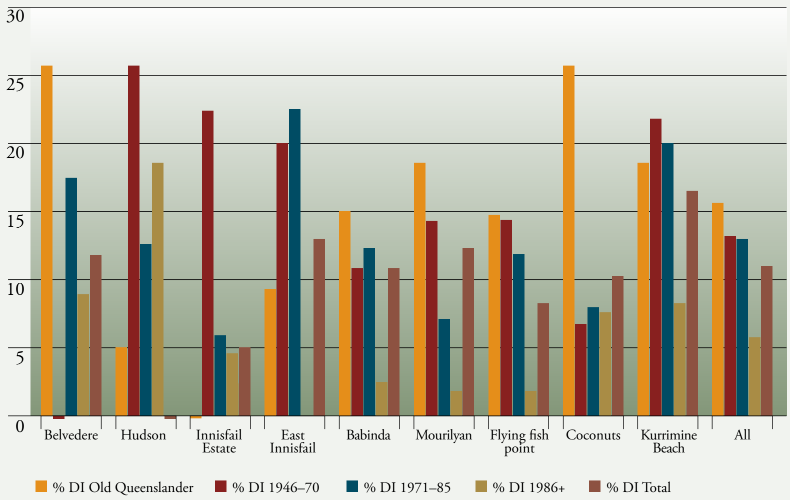

Figure 3. Damage Index (DI) relating to residential building damage (proportion of population value based on repair cost; see table 1.) by region/township impacted by Tropical Cyclone Larry

garage doors, roof tiles, fascias and guttering.

In addition to engineering considerations, the impact of local winds on structures was significantly influenced by geographical terrain, structure height, shielding by upwind structures, and topographical factors. Topographical acceleration of local winds was a very significant factor–severe damage was often confined to exposed ridge tops.

Impact on primary industry

From Tully in the south to sections of the tablelands in the north and as far west as Herberton, wind-related damage to crops was extensive. Banana plantations within a 40 to 50 kilometre radius of the cyclone path were destroyed. Sugarcane crops, which were well advanced for the mid-year harvest, were damaged. The Babinda sugar mill suffered damage to its gas bin and cooling tower. The Mourilyan mill suffered some structural damage, particularly to a boiler chimney stack, whilst the mill at South Johnstone suffered superficial damage. Mill operators indicated that the 2006 cane crush would go ahead, despite widespread damage to crops and industry infrastructure.

Geoscience Australia's response

Geoscience Australia's post-disaster response was multifaceted, beginning with the provision of 2500 maps of the affected area for Department of Defence emergency-response personnel following the initial impact. Our teams were subsequently dispatched to the area, with the first team departing within 48 hours. One of their responsibilities was to collaborate with James Cook University, TimberEd Services and the Australian Building Codes Board to assess structural damage to residential and commercial buildings and infrastructure. Teams recorded building and property information such as construction type, building materials, number of floors, and damage sustained. High resolution satellite imagery was used to complete building and property information, such as roof size, and to locate the structures on land parcels.

As part of the Operation Recovery—Industry Action Group (OR-IAG), Geoscience Australia collaborated with the Queensland Department of Primary Industries and Fisheries (DPIF) to provide regional and farm-level assessments of economic impact for the Cyclone Larry Recovery Taskforce. An initial assessment of the economic impact of the cyclone on Far North Queensland was conducted in collaboration with Monash University, Queensland Treasury's Office of Economic and Statistical Research, and the DPIF (Milne 2006). The assessment incorporated productivity losses sustained by the primary industry sector in addition to government assistance for individuals, households and businesses. Teams of Geoscience Australia and DPIF staff interviewed 85 primary producers about their immediate needs and plans for recovery (figure 4) and recorded the extent of crop damage.

How will the collected data be used?

The collected structural damage information will be useful in a number of ways. It will contribute to a better understanding of extreme cyclonic wind gusts and provide engineers with highly detailed data on the vulnerability of houses and other structures to severe wind. When combined with information from similar events and other sources, the data collected will provide a clearer picture of severe-wind risk for Australian communities. This information will help Australian communities in preparing for future cyclone events and reduce their potential impact.

In addition to the findings of the primary producer survey, which were provided to the Cyclone Larry Recovery Taskforce, Geoscience Australia used field survey data to assess the extent of damage to agricultural areas and validate post-disaster remote sensing imagery (Thankappan 2006). The data collected with the assistance of DPIF have provided detailed estimates of direct economic losses to the agricultural sector. This will be used to assess the long-term impact on the regional economy and provide information to assist policy decisions for recovery (figure 5).

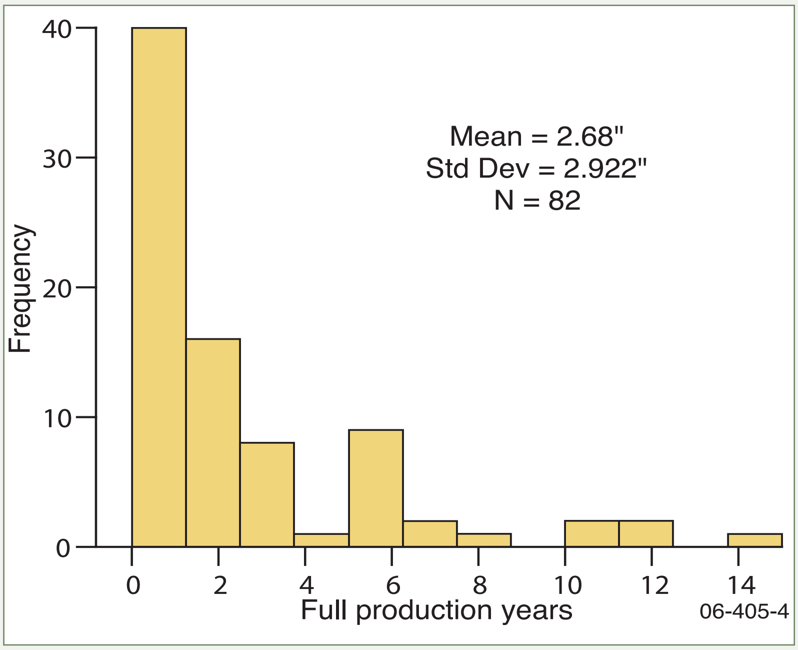

Figure 4. Expected number of years until full crop production is resumed (Milne, 2006).

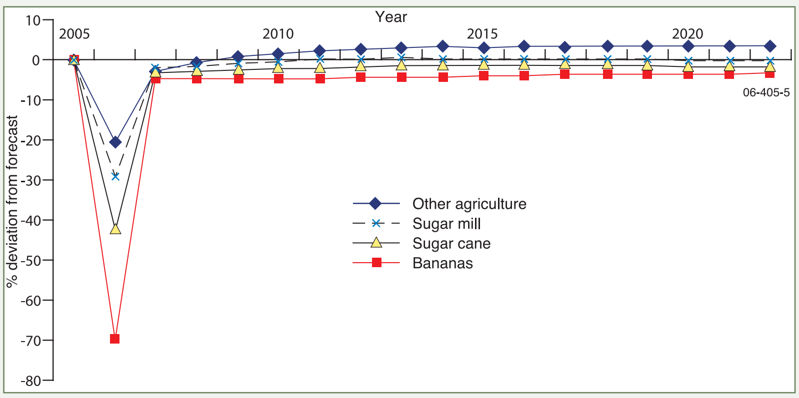

Figure 5. Impact of Tropical Cyclone Larry on selected industries' output: government assistance scenario (% deviation from forecast) (Mullaly and Wittwer 2006).

Results and additional information

Preliminary results from the Tropical Cyclone Larry post-impact surveys, including a review of the meteorological information, can be found in the report from the Cyclone Larry Forum (Cyclone Larry Forum Report 2006). The Bureau of Meteorology has prepared a meteorological report detailing the maximum wind zones associated with Cyclone Larry (Callaghan and Otto 2006). The Cyclone Testing Station at James Cook University has issued a report detailing the damage to buildings from Cyclone Larry (Boughton et al 2006). A whole-of-government report on Larry's impact (due December 2006) is being coordinated by the Bureau of Meteorology for the Queensland Tropical Cyclone Coordination Committee. Geoscience Australia will continue to post updates of our analysis of the impact through our website (Geoscience Australia 2006).

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More information

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events

International Earth Science Week celebrations

International Earth Science Week 2006, to be celebrated from 8 to 14 October, will provide an opportunity for everyone involved in the earth sciences to share the significance of their work with the broader community.

This year's theme of 'Citizen's Science' aims to encourage everyone, adults and children alike, to participate and learn about the contribution of the earth sciences to the wellbeing of our society and environment.

Geoscience Australia has been the national coordinator of Earth Science Week events in Australia since 1999 and continues to promote the week and encourage participation by scientific and cultural communities across the country.

The 2006 Earth Science Week poster has been distributed nationally and the national Earth Science Week website includes information on activities in each state and territory as well as ideas for themed events and activities. Geoscience Australia also encourages organisations to share details of their Earth Science Week activities with the rest of Australia by posting their event information.

The 2006 Earth Science Week poster depicts a sparse rocky terrane which highlights several areas of current geoscience research. Topographic and 3D mapping support the search for new mineral resources while mapping of the seabed provides clues for the future discovery of petroleum. Other features include the melting ice as a gentle reminder of the climate change challenge and working scientists represent the diversity of careers within the geosciences.

More information

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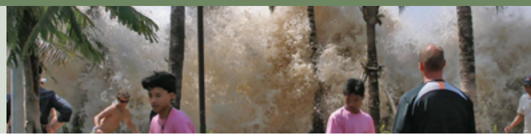
Modelling *answers tsunami questions*

New research will help emergency planners



Ole Nielsen, Jane Sexton, Duncan Gray and Nick Bartzis

The Indian Ocean tsunami on 26 December 2004 demonstrated the potentially catastrophic consequences of natural hazards. In addition to humanitarian assistance, the Australian Government's response included the establishment of the Australian Tsunami Warning System (ATWS) and greater priority for research into hazard and risk modelling of tsunami impacts.

Determining tsunami risk

Geoscience Australia aims to define the economic and social threat posed to urban communities by natural hazards such as tsunamis. Predictions of the likely impacts of tsunamis can be made through the integration of earthquake and tsunami hazard research, community exposure and socioeconomic vulnerabilities. By modelling the likely impacts on urban communities as accurately as possible and building these estimates into land use planning and emergency management, we can better prepare communities to respond to tsunamis when they occur.

One critical component in understanding tsunami risk is being examined by the Risk Assessment Methods Project (RAMP) at Geoscience Australia which has been developing a hydrodynamic inundation modelling tool developed specifically to estimate the consequences of possible tsunami impacts on Australian communities.

Modelling methodology

Tsunami hazard models have been available for some time. They generally work by virtually converting the energy released by a subduction earthquake into a vertical displacement of the ocean surface. The resulting wave is then propagated across a sometimes vast stretch of ocean using a relatively coarse linear model based on bathymetries with a typical resolution of two arc minutes.

The maximal wave height at a fixed contour line near the coastline (say, 50 metres) is then reported as the hazard to communities ashore. Models such as Method of Splitting Tsunamis (MOST) (Titov & Gonzalez 1997) and the URS Corporation's Probabilistic Tsunami Hazard Analysis (Somerville et al 2005) follow this paradigm.

The severity of a hydrological disaster is critically dependent on complex bathymetric and topographic effects near the area of interest. For example, during the 1993 Okushiri Island tsunami, a very large run-up was observed at one specific location, whereas surrounding areas received much less inundation (Matsuyama et al 1999). Estimating the impact of a tsunami on a particular community therefore requires modelling of the nonlinear process by which waves are reflected and otherwise shaped by the local bathymetries and topographies. These complex effects generally require elevation data of much higher resolution than is used by the linear models, which typically use data resolutions in the order of hundreds of metres (sufficient to model long-wavelength tsunamis in open water). The data resolution used by nonlinear inundation models, by contrast, is typically in the tens of metres.

The ANUGA model (Nielsen et al 2005)—the result of collaboration between the Australian National University and Geoscience Australia—is suitable for this type of modelling. However, running a nonlinear model capable of resolving local bathymetric

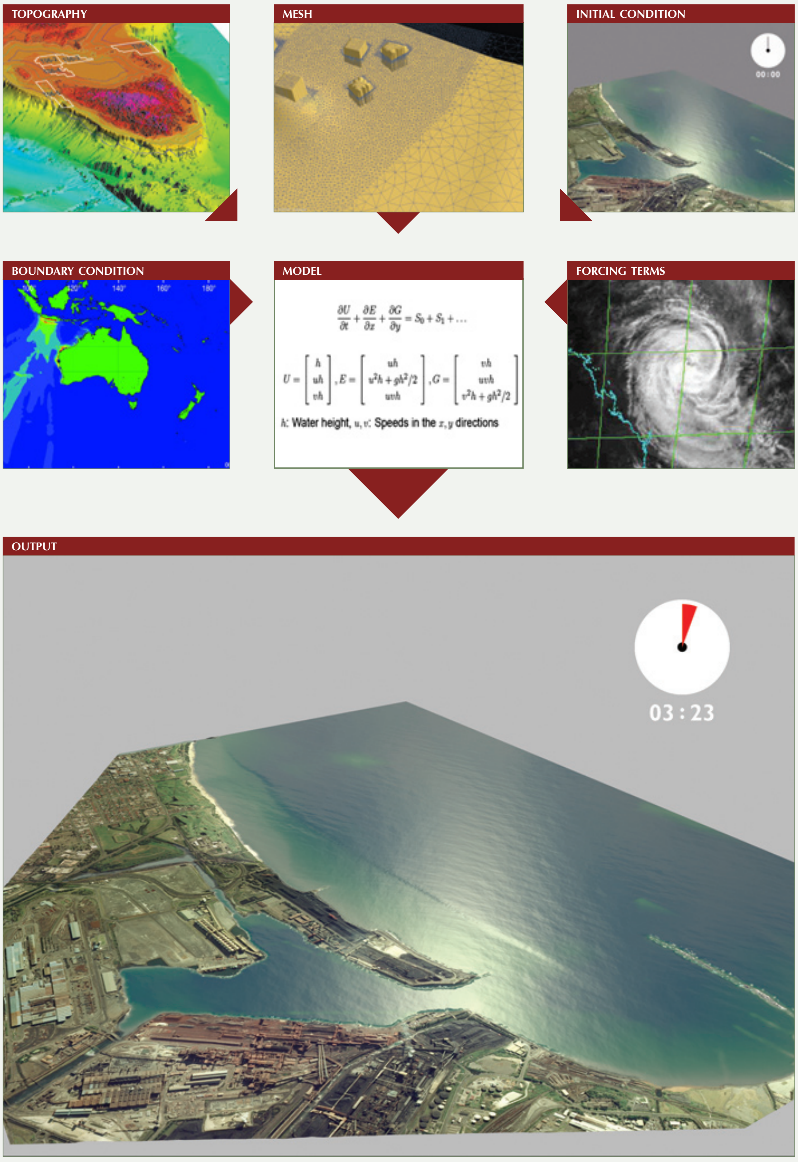


Figure 1. Data requirements for an ANUGA simulation include topography of the study area, a triangular mesh, definition of initial and boundary conditions, and any forcing terms, such as wind stress. Boundary conditions could capture incoming waves from a range of sources, such as output from other models, run-off or tidal variations.

effects and run-up using detailed elevation data requires more computational resources than the typical hazard model, making it inapplicable for complete end-to-end modelling of a tsunami event.

We have adopted a hybrid approach, in which the output from a hazard model such as MOST is used as input to ANUGA at the seaward boundary of its study area. The output of the hazard model thus serves as a boundary condition for the inundation model. In this way, we restrict the computationally intensive part to regions where detailed understanding of the inundation process is required.

Furthermore, to avoid unnecessary computations, ANUGA works with an unstructured triangular mesh rather than the rectangular grids typically used by hazard models. The advantage of an unstructured mesh is that different regions can have different resolutions, allowing computational resources to be directed where they are most needed. For example, one might use very high resolution near a community or in an estuary, whereas a coarser resolution might be enough for deeper water, where the bathymetric effects are less pronounced.

To implement a scenario, the modeller requires suitable initial conditions (such as a tidal height), boundary conditions (such as model data from a subduction zone earthquake), forcing terms (such as wind) and, importantly, bathymetric and topographic data for the study area (figure 1). The calculated run-up height and resulting inundation ashore is determined by these inputs, as well as the cell resolution.

The data should ideally capture all complex features of the underlying bathymetry and topography, and cell resolution should be commensurate with the underlying data. Any limitations in the resolution and accuracy of the data, including the cell resolution, will introduce errors to the inundation maps as well as to the range of model approximations.

Tsunami impact on the North West Shelf

Historical evidence of large tsunamigenic earthquakes off Sumatra with impacts on the Western Australian coastline suggests that communities and infrastructure along that coastline are at risk of tsunami inundation (Cummins & Burbidge 2004).

To better understand the risk, particularly for the significant petroleum production infrastructure off the North West Shelf and near the Sunda Arc trench, the Fire and Emergency Services Authority (FESA) in Western Australia struck a collaborative research agreement with Geoscience Australia. Initial priority areas are Onslow, Port Hedland, Karratha, Dampier, Broome, Busselton and Perth. The study has brought together a number of groups within Geoscience Australia to support the FESA project. The study areas for the first project milestone are Onslow and Port Hedland.

The boundary condition has been defined by the Earthquake and Tsunami Hazard Project model of an Mw 9 earthquake generated east of Java by the Sunda Arc trench (Mw is a logarithmic measure of earthquake size, similar to the Richter scale but better suited to very large events). This event is plausible, but the recurrence rate is not yet known. The earthquake and subsequent tsunami wave in deep water are simulated by MOST, which outputs water height and velocity in space and time. ANUGA then uses this information and propagates the wave through the shallow water and onshore.

The collation of data has proved to be a challenging task. Geoscience Australia's Petroleum and Marine Division has sourced available hydrographic charts ('fairsheets') for regions identified on the North West Shelf. Digitisation of some of these charts is needed, and matching the entire dataset requires suitable metadata to be available (which it seldom is, especially for older datasets). Thanks to the National Mapping and Information Group within Geoscience Australia's Geospatial and Earth Monitoring Division, offshore and onshore datasets for Onslow and Port Hedland have been delivered to RAMP for inundation modelling.

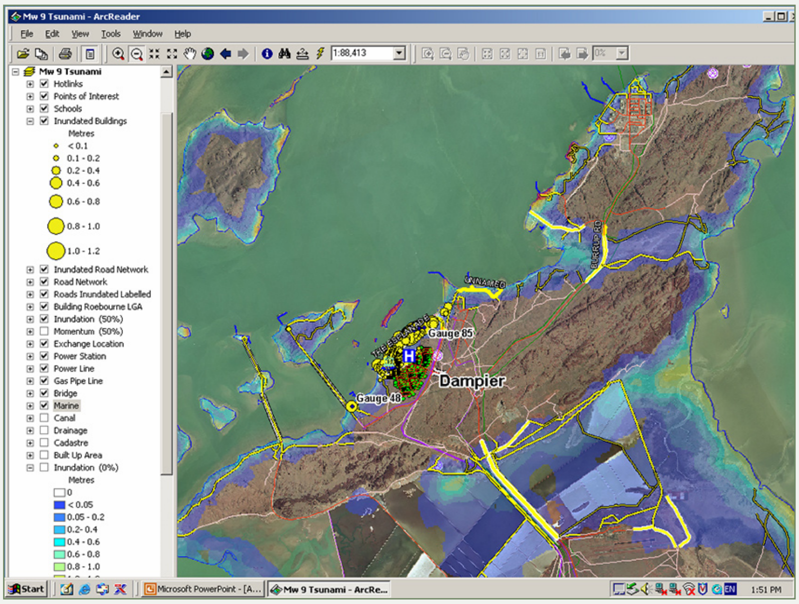


Figure 2. Example of inundation map provided to emergency managers. Here, the map is embedded in a GIS product, enabling emergency managers to use the output as a decision support tool.

Once the inundation modelling has been completed, structural damage and contents loss estimates can be made. RAMP engineering models and the national building exposure database (NBED) are brought together to develop a damage estimate for each simulation. The NBED contains information about residential buildings, people, infrastructure, structure value and building content, and has been created so that consistent risk assessments for a range of natural hazards can be conducted. The damage estimates use the NBED information and predict probability of collapse as a function of the building type, location and inundation depth at the building and floor levels.

Finally, the GIS team within RAMP develops the decision support tool (figure 2), which includes ANUGA outputs, inundation maps, time series for defined point locations, and damage estimates. These outputs are included as layers in the decision support tool, with aerial photography and overlays of critical infrastructure, such as roads. Visualisations developed from the ANUGA output (figure 3) are useful to modellers and planners alike for understanding the behaviour of the tsunami.

The outcome is a tactical decision support tool for use by operational emergency managers as they make decisions on how to mitigate risk to coastal communities. In particular, the tool will provide:

- a better understanding of national tsunami risk and resourcing requirements for particular communities and regions
- scenarios for a wide range of tsunami events for which casualty and infrastructure consequences are predicted, and against which emergency management capability can be assessed
- real-time consequence prediction tools for tactical use by emergency managers to obtain assessments of tsunami impact and expected consequences to guide initial resource deployment.

Further studies

The preliminary hazard modelling has identified communities most at risk from tsunamis generated by subduction zone earthquakes. More detailed modelling, which will be available by the end of 2006, will provide information on return periods so that tsunami risk can be determined. This is consistent with RAMP's objective of defining the national risk from a range of rapid-onset natural hazards in a standardised and consistent way.

The relative tsunami risk can be measured using the modelling techniques we have described, providing a strategic aid to emergency planning. In addition, the precomputed simulations and risk maps will form a library of scenarios for the ATWS, aiding mitigation, warning, response and community recovery in the event of a tsunami disaster.

The recent meeting of the Australian Tsunami Working Group acknowledged the utility of detailed impact modelling for mitigating the effects of tsunamis. However, the biggest barrier to such modelling is the unavailability of reliable, high-resolution bathymetry and elevation data. Geoscience Australia has developed a set of guidelines for state agencies, outlining the requirements for the collection of such data. These guidelines will assist the exchange of data between agencies and guide third parties in the collection of data.

Other state agencies have expressed interest in conducting studies similar to those being done for FESA. Geoscience Australia is committed to working with state emergency managers to understand tsunami risk, and will continue to conduct detailed studies in areas of national interest.

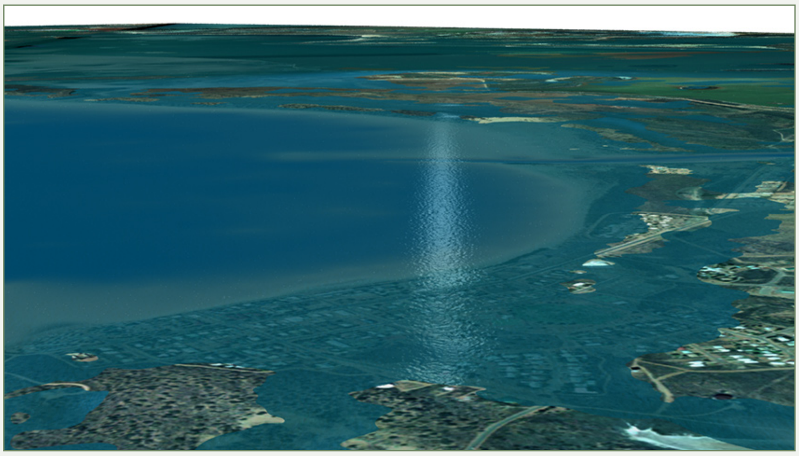


Figure 3. Snapshot of visualisation of tsunami inundation, North West Shelf (photograph courtesy of Department of Land Information, Western Australia).

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Geoscience Australia's impact modelling protecting Australia
link www.ga.gov.au

Risk Assessment Methods Project www.ga.gov.au/urban/projects/ramp/inundation.jsp
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Echoes *of ancient tsunamis*

New research will help gauge the tsunami hazard to Australia

Amy Prendergast

Geological signatures of tsunamis provide clues to tsunami hazards that are unknown or poorly understood from written and instrumental records alone. In northeast Japan, western North America, Norway, and Scotland, tsunami deposits serve as long-term warnings of unusually large tsunamis that could otherwise take these areas by complete surprise (Nanyama et al. 2003; Atwater et al. 2005; Bondevik et al. 2005).

Because there was no historical precedent for an event the size of the Indian Ocean tsunami of 26 December 2004 along the Aceh–Andaman subduction zone, countries affected by the tsunami and their neighbours were not adequately prepared for the disaster. If geological records of tsunamis in the Indian Ocean region had been studied before the event, the regional tsunami hazard may have been recognised and the impact may have been reduced through the implementation of education programs and early warning systems.

Deposits from ancient tsunamis

Historical and instrumental records of tsunamis have been gathered for a much shorter period than the recurrence intervals of large tsunamis. Studying the geological signatures of past tsunamis therefore extends the tsunami record by thousands of years, leading to a better understanding of tsunami frequency, magnitude and flow dynamics, and a greater appreciation of tsunami hazard and risk.

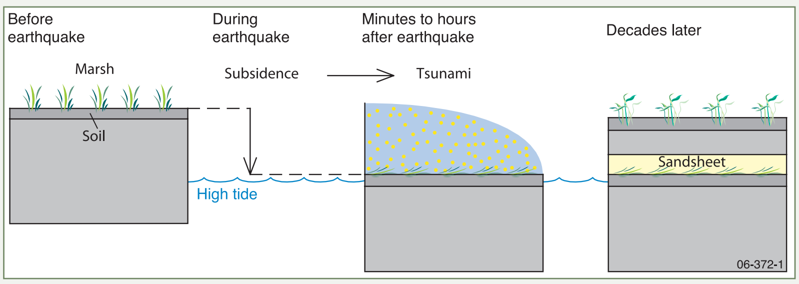

Figure 1. The formation of tsunami deposits during a subduction zone earthquake. Co-seismic subsidence occurs during the earthquake, lowering the land level and drowning coastal marsh deposits. Minutes to hours after the earthquake, several sediment-laden tsunami waves wash over the drowned marshlands, leaving behind sediment sheets. Over the next few decades, the land stabilises, allowing vegetation to recolonise the area and a soil profile to develop.

Geological evidence for tsunamis varies from large boulders to erosional features. The most common tsunami signatures are landward-tapering, higher energy sediment sheets preserved within lower energy depositional environments (figure 1). The composition of the sediment sheets varies with the available onshore and offshore sediments, but fine to medium sand generally dominates.

Tsunami sediment sheets range in thickness from a few centimetres to tens of decimetres, and mantle beach-ridge plain, estuarine marsh or lake bottom sediments. They characteristically have a sharp, erosional contact with the lower unit (usually soil), indicating some scouring before deposition (figure 2). The sediments may contain local or far-field gravel, mud and soil rip-up clasts mixed with sand and silt (figure 3). Multiple, normally graded layers are evident in some deposits, allowing the differentiation of specific waves in the tsunami wave train.

Microfossil assemblages (ostracods, diatoms, foraminifera and pollen) provide evidence of sediments transported and deposited by tsunamis. Tsunami deposits generally contain a mixture of fossils from terrestrial, tidal and deepwater environments, indicating both landward and seaward transport of sediments during inundation and backwash. Geochemical signatures, such as stable isotopes of carbon and oxygen, are also useful in distinguishing sediment sources, as they can be used as indicators of fresh and saltwater influxes.

If several tsunami deposits occur in stratigraphic sequence, dating of the deposits using radiogenic or luminescence techniques allows estimates of tsunami frequency (Cisternas et al 2005). This information can provide the basis for tsunami hazard assessments. Detailed studies of the sedimentology of tsunami deposits can yield constraints on tsunami behaviour, such as flow depth and velocity (Jaffe and Gelfenbaum 2002, Atwater et al 2005), providing empirical data for tsunami modelling and allowing better hazard estimation. The mapped geographical extent of tsunami deposits can contribute to probabilistic hazard maps and to calibration, testing and enhancement of tsunami run-up modelling. Furthermore, tsunami deposits can be a focus for public education about tsunami hazards.

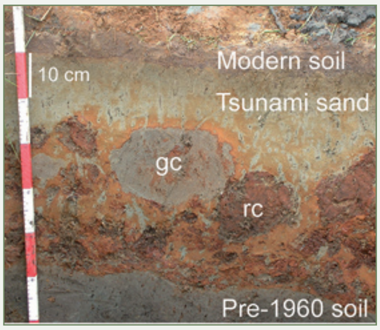

Figure 2. Soil and sediment rip-up clasts in the 1960 Chile tsunami deposit near Maullin, Chile. gc = soil rip-up clast; rc = sediment rip-up clast.

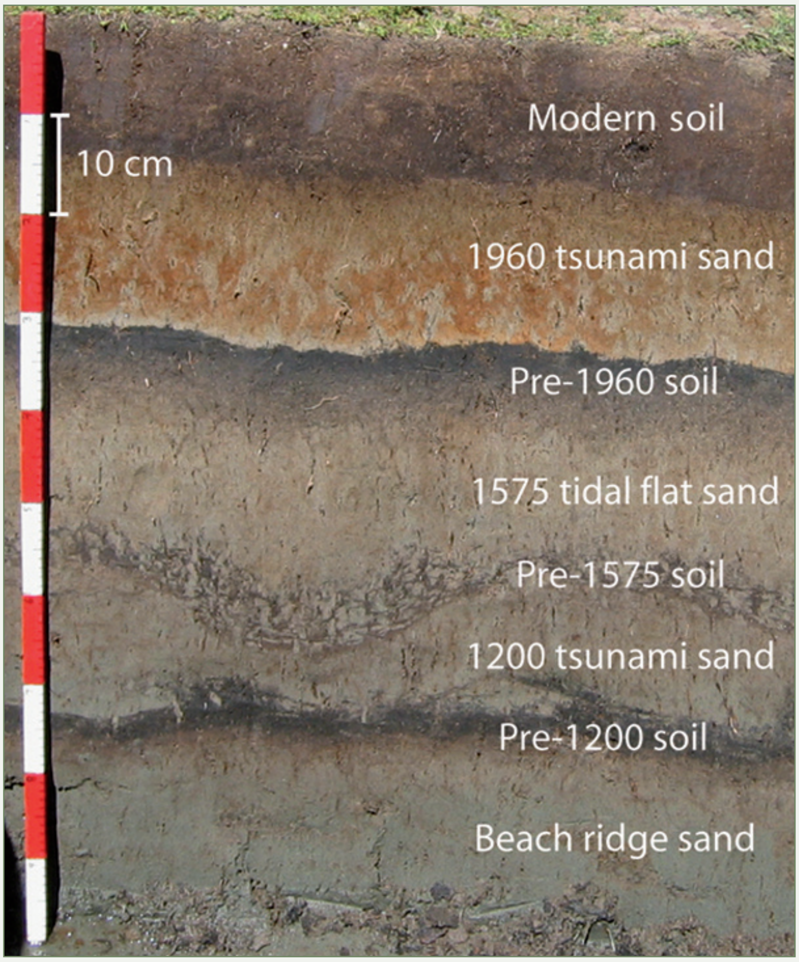

Figure 3. An example of tsunami sediment sheets, soil profiles and tidal flat deposits in stratigraphic sequence from Maullin, Chile. The tsunami events have been constrained by radiocarbon dating (Cisternas et al 2005). Note the sharp contact between tsunami sand sheets and underlying soil, indicating scouring before deposition. The bioturbated pre-1575 soil profile indicates subsidence.

Identification of far-field tsunami deposits is often more difficult than identification of earthquake-generated deposits close to a tsunami source region. In plate margin settings, tsunami sediment sheets are preserved in conjunction with evidence for co-seismic subsidence landward of the subduction zone. Such evidence includes drowned trees in growth position, a change in biota from supratidal to subtidal assemblages, highly bioturbated soil profiles, and a change in deposit sedimentology between the upper and lower units (figure 2). This additional evidence makes identification of a sediment sheet as tsunamigenic more certain. Furthermore, co-seismic subsidence makes it more likely that the tsunami sediment sheet will be preserved.

In coasts prone to severe storm events, tsunami hazard assessment is complicated by

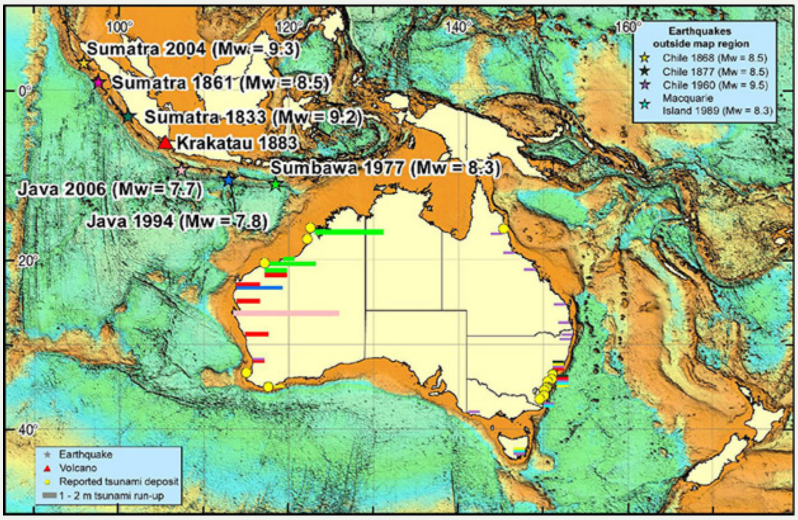

Figure 4. The Australian region, showing locations of tsunamigenic earthquakes and volcanic eruptions, oil and gas production facilities, and palaeotsunami deposits on the Australian coastline (reported from Bryant and Nott 2001). Known tsunami run-up heights are scaled and colour-coded with their sources.

the potential for storm surges to deposit sediment sheets that may be difficult to distinguish from those left by tsunamis. Recent studies of historic tsunami and storm deposits have suggested some criteria for distinguishing between them. These include:

- tsunami deposits are generally of greater lateral extent
- stable isotopic analysis of offshore sediments can be used to identify freshwater flux to the continental shelves caused by storm events.

Nonetheless, the differentiation of palaeotsunami and palaeostorm deposits, particularly for distantly generated events, remains problematic. More work is needed to link the sedimentology of tsunami and storm deposits with the physics of sediment erosion, transport and deposition (Tuttle et al 2004, Atwater et al 2005, Rhodes et al 2006). It is therefore important for the characterisation of the tsunami threat to Australia that evidence be considered not only from the Australian coastline but also from neighbouring subduction zones where there is a better chance of preserving less equivocal tsunami signatures.

Several authors have reported erosional and depositional features along the Australian coastline purported to be tsunamigenic (Bryant and Nott 2001, Switzer et al 2005). However, most are large boulders and erosional features, or their origin is enigmatic. They are not as useful for tsunami hazard estimation because they do not yield information about tsunami frequency.

Hazards from the north…

Tsunamis can be generated by any process that vertically displaces the sea surface, including landslides into the sea, underwater landslides, volcanic collapses and bolide impacts. However, undersea subduction zone earthquakes are the most common mechanism. Tsunamis generated from earthquakes around the Australian margin could potentially reach Australian shores within hours (figure 4).

The Sunda Arc south of Indonesia, where the Australian Plate is subducting beneath the Sunda Plate, poses the greatest tsunami threat to Australia's northwest coast. Although population density is fairly low, iron ore production facilities and extensive oil and gas infrastructure are concentrated in this region (figure 4). Furthermore, if a large tsunami occurs in this region, the remoteness of the settlements along the northwest coastline may hamper the delivery of aid. Tsunami inundation along this coastline, therefore, has the potential to cause considerable human and economic loss.

The 2004 event confirmed that the western Sunda Arc is capable of generating truly giant earthquakes. On the Western Australian coast, the 2004 tsunami displaced boats from their moorings and dragged swimmers out to sea. However, due to the orientation of the arc in relation to the Australian coastline, most tsunami energy was directed away from Australia and towards the Indian Ocean Basin (figure 5a; Dominey-Howe et al, in press).

Open-ocean tsunami propagation modelling has shown that large earthquakes in the eastern Sunda Arc could have a significant impact along Australia's northwest coastline (figure 5b; Burbidge and Cummins, in preparation). The 1977 Sumbawa earthquake and the 1994 Java earthquake in the eastern Sunda Arc generated four-metre to six-metre tsunamis on the northwest Australian coastline. The two earthquakes were rated at Mw 8.3 and Mw 7.8 respectively (Mw is a logarithmic measure of earthquake size, similar to the Richter scale but better suited to very large events). The 2006 West Java earthquake (Mw 7.7) also had a significant impact on parts of the Western Australian coastline.

There is still debate about whether the eastern Sunda Arc is capable of generating earthquakes greater than Mw 9, which could potentially cause a large tsunami along the entire west Australian coast (Burbidge and Cummins, in preparation). This will be important in the future characterisation of tsunami hazard to Western Australia.

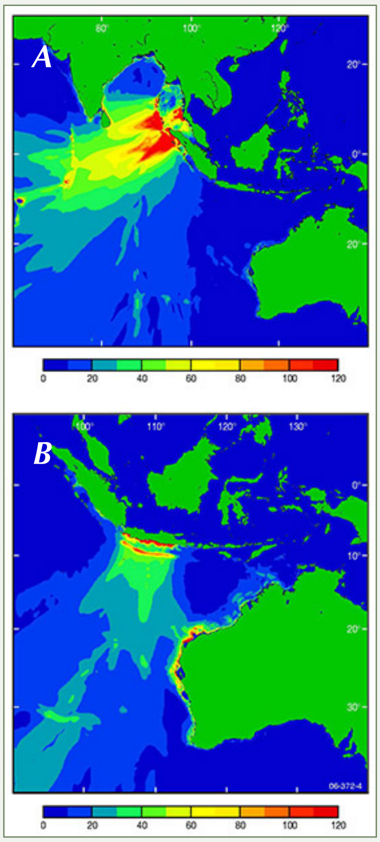

Figure 5. Open-ocean tsunami propagation of Mw 9 earthquakes on the Sunda Arc.
A: The 2004 Sumatra tsunami did not significantly affect Australia (Dominey-Howe et al, in press).
B: An earthquake in Java would have a greater impact on northwestern Australia (Burbidge and Cummins, in preparation). This modelling is accurate for tsunami propagation in deep water. Run-up of the tsunami onto the shoreline is likely to increase the tsunami amplitude severalfold. Figures courtesy of David Burbidge.

… and from the east

Along the eastern Australian coastline, where most Australians live, the tsunami threat comes from several sources. Although they have produced few historical tsunamis, the Solomons trench, the New Hebrides trench off Vanuatu, the Tonga–Kermadec trench north of New Zealand, the Alpine fault in New Zealand and the Puysegur trench south of New Zealand may all have the potential to produce earthquake-generated tsunamis capable of reaching Australian shores. More work needs to be done to characterise the earthquake mechanisms in these regions, including assessments of the maximum magnitude earthquake that each zone might generate and the expected nature of earthquake rupture.

The steep slopes of the continental shelf on the eastern Australian margin may induce underwater landslides capable of producing localised tsunamis. In the Australian Tsunami Database (Allport & Blong 1995), several large waves of unknown source are documented along the eastern coast between Hobart and Newcastle. It has been suggested that these waves—recorded on otherwise calm and clear days—may be localised tsunamis generated by submarine slumps. The most famous such incident occurred on Sydney's Bondi Beach in 1938, when three waves encroached on the beach in quick succession. The backwash was strong enough to drag swimmers out to sea. More than 200 bathers required assistance and five people were drowned on a day that became known as Black Sunday.

Over a hundred features suggested to be slump scars have been identified along the southeast coast between Sydney and Wollongong. Higher resolution bathymetry data and offshore coring and dating are necessary to characterise the age, magnitude and tsunamigenic potential of these features.

Another source of tsunami hazard for the Australian region is the arc of many active volcanoes, in Indonesia and the

Pacific, that encircle the Australian margin. The famous Krakatau eruption of 1883 caused 36 000 deaths in Indonesia and generated a four-metre tsunami in northwestern Australia. The 1453 eruption of Tongola in Vanuatu is reported to have been four times as powerful as Krakatau, but it is not known whether the tsunami generated by this eruption reached Australia.

Geoscience Australia's role in palaeotsunami research

Geoscience Australia has been building expertise in tsunami geology and is well placed to take a leading role in palaeotsunami research and hazard and risk estimation in the region.

In February 2006, staff participated in a field-based training course in Chile, the source location for the Mw 9.5 earthquake and subsequent trans-Pacific tsunami of 1960. The course enabled us to develop our expertise in tsunami geology and fostered collaborative contacts with tsunami geologists from other nations. In May 2006, we continued our collaboration with Indian Ocean and United States scientists through participation in a tsunami deposit reconnaissance program in Java. It is expected that continuing collaboration in this region will help to characterise the tsunami hazard from the enigmatic eastern Sunda Arc subduction zone, which potentially poses the greatest tsunami hazard to Australian shores.

Over the next year, Geoscience Australia will conduct a pilot project focusing on the southeast coast of Australia, where tsunamis might be generated by submarine slumps off the steep continental shelf and by earthquakes south of New Zealand. This project will complement tsunami propagation and inundation modelling and a high-resolution study of the potential of the continental margin to generate underwater landslides.

Future work in the characterisation of tsunami hazard to the Australian region will require onshore and offshore investigations along the Australian coastline, as well as collaboration with regional neighbours, in order to better characterise the threat from plate margin earthquakes. The work will involve interdisciplinary collaboration between sedimentologists, geomorphologists, micropalaeontologists, tsunami modellers and emergency managers. Through an understanding of the magnitude, frequency and flow dynamics of past tsunamis, tsunami deposits can improve our understanding of the tsunami hazard and provide a means of assessing future risk.

More information

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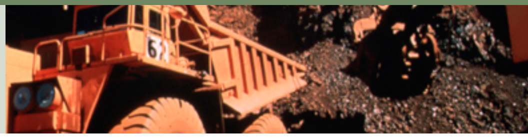
Catching *the nickel boom*



New synthesis will aid nickel explorers

Dean Hoatson, Subhash Jaireth and Lynton Jaques

In August 2006, a tonne of nickel was worth a record $US34 750 on the world market, a 7.7-fold increase from 2001—an astounding performance driven mainly by the urbanisation and industrialisation of China. At that price, global stockpiles of nickel have virtually disappeared, while exploration expenditure and activity are at all-time highs as Australia's nickel industry experiences a 'boom phase' of unparalleled opportunities.

To support Australian explorers, Geoscience Australia has just published *Nickel sulfide deposits in Australia: characteristics, resources and potential*, a comprehensive synthesis in which we review the geological settings and resources of Australia's nickel sulphide deposits at a national scale and place them in a global context for the first time. The paper summarises the key factors that determine the fertility of nickel-bearing magmatic systems, with a predictive focus that should be of considerable interest to companies exploring for nickel deposits.

Evolution **of Australia's nickel sulphide industry and global status**

The discovery of massive nickel–copper sulphides at Kambalda near Lake Lefroy in the Eastern Goldfields of Western Australia on the 28 January 1966 heralded the beginning of the nickel industry in Australia. The sulphides at Kambalda assayed 8.3% Ni and 0.5% Cu over 2.7 metres, and were hosted by unusual ultramafic igneous rocks called komatiites—rocks rich in magnesium, iron and the mineral olivine. Exploration since 1966 has defined a total resource (total production plus remaining reserves and resources) of nickel metal from sulphide ores of approximately 12.9 Mt, and five world-class deposits (each containing at least 1 Mt of nickel metal). In 2006–07, production from nickel sulphide and laterite deposits will reach 212 000 tonnes of nickel and earn around A$4.2 billion in export revenue (ABARE 2006), making Australia the world's third largest producer of nickel after Russia and Canada.

More than 90% of the nation's total known resources of nickel metal from sulphide deposits were defined during the relatively short period from 1966 to 1973, and production from many komatiite-hosted deposits in the Eastern Goldfields began within two years of discovery. Australia is particularly well endowed with world-class komatiite-associated deposits at Mt Keith (3.4 Mt), Perseverance (2.5 Mt), Yakabindie (1.7 Mt), Kambalda region (1.4 Mt), and Honeymoon Well (1 Mt), along with smaller high-grade deposits (assaying 5–9% Ni) at Cosmos, Prospero, Long, Silver Swan and Victor. In contrast, the nickel resources in Australia's tholeiitic mafic–ultramafic intrusions (containing more siliceous igneous rocks than komatiites) are substantially smaller than those in the major foreign deposits.

Exploration for nickel sulphides has been very active since 2001 in most Precambrian provinces of Australia. Record numbers of exploration companies are active in Western Australia (more than 170 in 2006), accounting for more than 90% of the nation's Ni–Cu exploration budget of A$168.1 million (ABS 2006). The main areas of interest include Archaean greenstone belts in the Yilgarn Craton (near Kambalda, Leonora, Leinster and Southern Cross), the northern margins of that craton, the western part of the Pilbara Craton, and the Proterozoic Musgrave, Kimberley, Albany–Fraser and Hamersley provinces. Recent exploration successes include:

- increased resources at previously known deposits (many deposits near Kambalda, Carnilya Hill, Flying Fox T Zero to T5, Radio Hill, Sally Malay)
- delineation of deep and covered mineralised komatiite sequences (Cosmos Deeps, Prospero, Wedgetail, Flying Fox T5)
- new mineralised Precambrian mafic±ultramafic intrusions (Nebo–Babel, Copernicus, Billy Ray)
- new styles of mineralisation and/or new provinces (Collurabbie, Sinclair, Koolyanobbing North, Beasley, and Avebury in western Tasmania).

Classification of Australia's nickel sulphide deposits

Australia's nickel sulphide deposits are associated with ultramafic and/or mafic igneous rocks in three major geotectonic settings:

- Archaean komatiites emplaced in rift zones of granite–greenstone belts
- Precambrian tholeiitic mafic–ultramafic intrusions emplaced in rift zones of Archaean cratons or Proterozoic orogens
- hydrothermal-remobilised occurrences with no apparent age or tectonic constraints.

Most deposits can be classified (table 1) into two orthomagmatic associations that reflect the dominant chemical affinities of the host magma (komatiitic or tholeiitic) and a third association that encompasses hydrothermal-remobilised mineralising systems. The largest and most economically important deposits are associated with Archaean komatiitic rocks in the greenstone belts of the Yilgarn Craton of Western Australia. These deposits account for approximately 82% of the nation's nickel production; minor contributions come from tholeiitic mafic–ultramafic intrusions (~3%) and laterite (~15%) sources.

The world's komatiite-associated Ni–Cu deposits are of specific Archaean and Proterozoic age, with the largest formed at ~2700 Ma and ~1900 Ma (figure 1). In contrast, basal Ni–Cu sulphide deposits do not appear to be age dependent. Large deposits/mining camps associated with continental flood basalt (Noril'sk) and astrobleme (Sudbury) events appear to have a very restricted representation in the geological record. The

Figure 1. Time-nickel sulphide metallogenic event plot showing approximate ages and relative sizes of nickel sulphide deposits and nickel sulphide camps/provinces in the world.

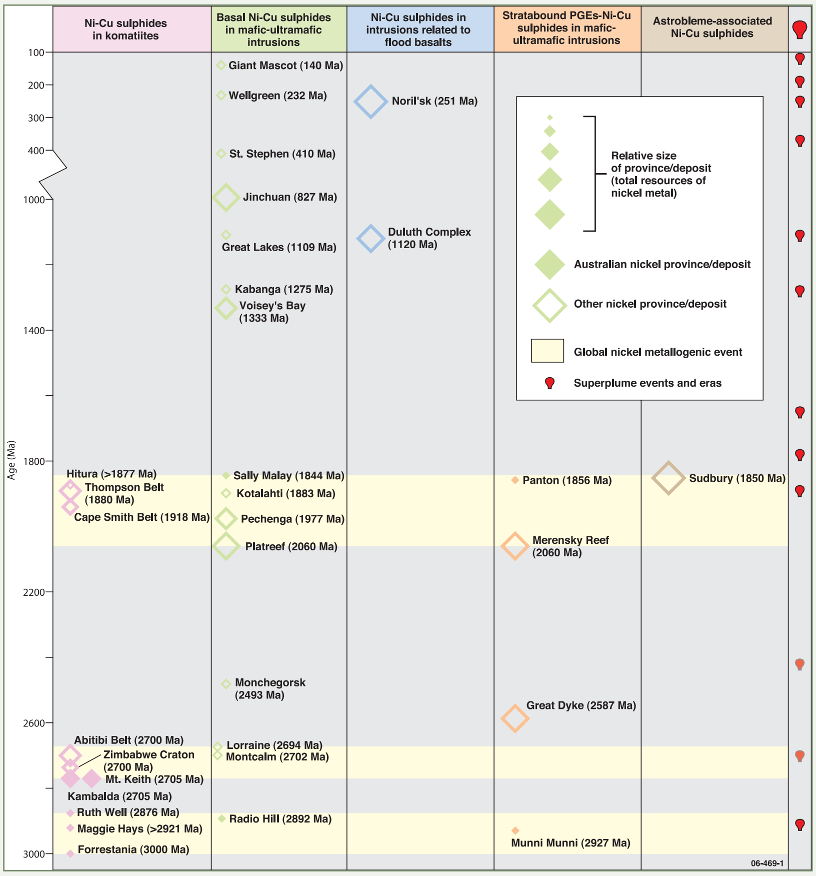


Table 1. Classification of Australia's nickel sulphide deposits

Association	Deposits/prospects	Age (Ma)	Metal association	Ni:Cu
1. Komatiitic				
1A. Massive and/or matrix sulphides at base of olivine cumulate (peridotite) sequences in preferred lava pathways	*Kambalda, WA* Maggie Hays, WA Cosmos, WA	~2900–2700	Ni-Cu±Au±PGE±Co	7-20
1B. Disseminated sulphides in central parts of thick olivine cumulate (dunite) sequences in preferred lava pathways	*Mt Keith, WA* Black Swan, WA Honeymoon Well, WA	~2900–2700	Ni-Cu±PGE±Co	>20
Other komatiitic deposits				
• Sulphides at basal contact of olivine cumulate sequences associated with comagmatic flood basalts	*Beasley, WA*	?2770	Ni-Cu-PGE	NA
• PGE-enriched sulphides associated with komatiitic and tholeiitic mafic-ultramafic rocks	*Collurabbie, WA* ?Daltons, WA	?2900–2700	PGE-Ni-Cu	<2
2. Tholeiitic				
2A. Massive and disseminated sulphides in feeder conduit and/or depressions along basal contacts of mafic±ultramafic intrusions	*Radio Hill, WA* Sally Malay, WA Mt Sholl, WA Nebo-Babel, WA	~2925–2700, ~1850, ~1080	Ni-Cu-Co±PGE	0.5-7
2B. Stratabound disseminated sulphides near ultramafic-gabbroic zone contacts of mafic-ultramafic intrusions	*Munni Munni, WA* Weld Range, WA Windimurra, WA	~2925–2800, ?1850	PGE-Cu-Ni	<2
2C. Stratabound chromitite layers near ultramafic-gabbroic zone contacts of ultramafic-mafic intrusions	*Panton, WA* Eastmans Bore, WA Salt Creek-Plumridge, WA	~1850, ~1300	PGE-Ni-Cu-Au-Cr	5
2D. Discordant bronzitite breccia pipes in mafic-ultramafic intrusions	*Carr Boyd Rocks, WA*	?2700	Ni-Cu	3
3. Hydrothermal-remobilised				
3A. Hydrothermal-remobilised—ultramafic host or ?skarn	*Avebury, Tas*	?360	Ni	Ni>>Cu
3B. Hydrothermal-remobilised—metasedimentary rock host	*Sherlock Bay, WA* Cruickshank, WA	~2925–2700	Ni-Cu	5
Other hydrothermal-remobilised deposits				
• Hydrothermal-remobilised—felsic±mafic±ultramafic rock hosts	*Elizabeth Hill, WA* ?Andover, WA	<2870	Ag-Pb-Ni-Cu±PGE	NA
• Remobilised-metamorphic—metagabbro host	*Corkwood, WA* Bow River, WA	~1865	Ni-Cu-Co	3
• Hydrothermal arsenical-auriferous-bearing quartz-carbonate veins	*Mt Martin, WA* Bamboo, WA	NA	Ni-As-Au	Ni>>Cu

Type examples of deposits/prospects are indicated in italics.
NA – not available

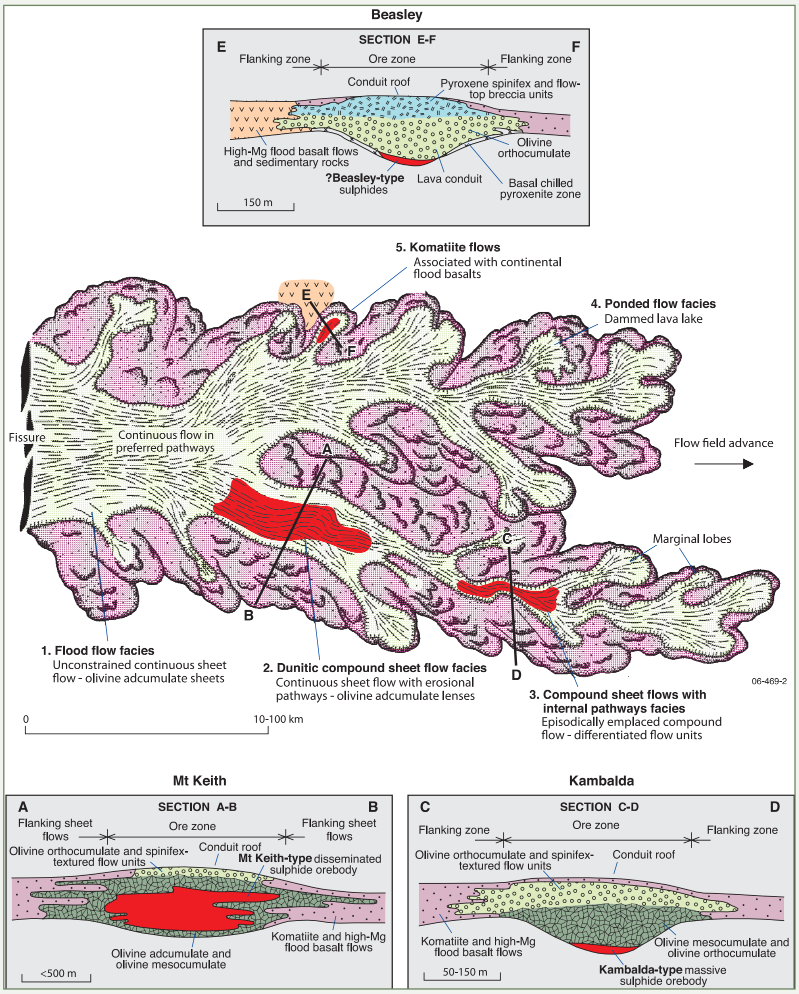


Figure 2. Komatiitic mineralising systems. Schematic section through an inflationary komatiite flow field that developed through sustained eruption of komatiite. The spatial relationships between various komatiite facies and types of nickel mineralisation are shown for the Mt Keith (section A–B), Kambalda (C–D), and Beasley (E–F) type deposits. Modified after Dowling & Hill (1998).

ages of Australia's major deposits correlate with at least three major global-scale nickel metallogenic events at ~3000 Ma (3000 Ma to 2875 Ma), ~2700 Ma (2705 Ma to 2690 Ma) and ~1900 Ma (2060 Ma to 1840 Ma). These events correspond with major periods of juvenile crustal growth and the development of large volumes of primitive komatiitic and tholeiitic magmas. They are thought to have been caused by mantle overturn events associated with mantle plumes or larger superplumes (figure 1).

Fertile versus barren magmatic systems, and prospectivity

Analysis of the world's major komatiite provinces reveals that the most fertile komatiite sequences are generally of late Archaean (~2700 Ma) or Palaeoproterozoic (~1900 Ma) age, have dominantly Al-undepleted chemical affinities (Al_2O_3/TiO_2 = 15 to 25), and form compound sheet flows with internal pathways and dunitic compound sheet flow facies. The preferred pathways (figure 2) assist in focusing large volumes of primitive magma flow (i.e. high-magma flux environments) and facilitate interaction of the magma with a potential sulphur-bearing substrate. The identification of magmatic facies in komatiitic systems is therefore important for assessing economic prospectivity. There is considerable potential for further discovery of komatiite-hosted deposits in Archaean granite–greenstone terranes, including large and smaller high-grade deposits (5–9% Ni), that may be enriched (2–5 g/t) in platinum-group elements (PGE), especially where the host ultramafic sequences are poorly exposed under shallow cover or younger basinal sequences.

In contrast to komatiitic-mineralising systems, the broad criteria for assessing the nickel prospectivity of tholeiitic mafic±ultramafic intrusions and their provinces are less clear. However, a significant exploration advantage for investigating basal Ni–Cu–Co sulphide deposits (such as at Sally Malay, Radio Hill and Nebo–Babel) is that they can occur in small- to medium-sized, sulphur-saturated mafic bodies of various ages. Most Precambrian provinces in Australia and, in particular,

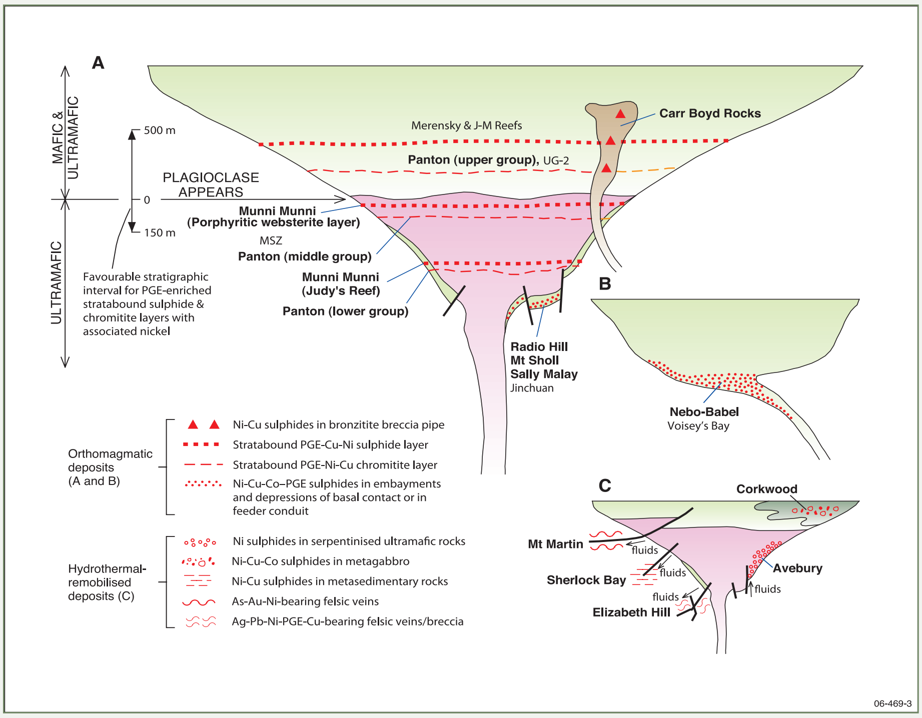


Figure 3. Tholeiitic and hydrothermal mineralising systems. Schematic distribution of orthomagmatic and hydrothermal-remobilised nickel sulphide deposits associated with tholeiitic mafic±ultramafic intrusion.

A. Stratabound, basal, and discordant Ni–Cu–Co and PGE–Ni–Cu deposits in mafic–ultramafic intrusion. Australian deposits (shown in normal type) are Munni Munni, Radio Hill, Mt Sholl (west Pilbara Craton); Carr Boyd Rocks (Yilgarn Craton); and Panton and Sally Malay (Halls Creek Orogen). Foreign deposits (italics) are Merensky Reef and UG–2 Chromitite (Bushveld Complex, South Africa); J–M Reef (Stillwater Complex, USA); MSZ (Main Sulphide Zone–Great Dyke, Zimbabwe); and Jinchuan Intrusion (China).

B. Massive Ni–Cu–Co sulphide deposits in the feeder conduit of mafic-dominated intrusion: Nebo–Babel (Musgrave Province, WA) and Voisey's Bay (Canada).

C. Hydrothermal-remobilised Ni–Cu–±Ag±PGE and other metal deposits hosted by: serpentinised ultramafic (Avebury), deformed mafic (Corkwood), metasedimentary (Sherlock Bay, Mt Martin), and igneous (Elizabeth Hill) rocks.

Proterozoic orogenic belts, contain an abundance of these intrusions that have not been fully investigated. The Musgrave Province, Halls Creek Orogen, Albany–Fraser Orogen, Arunta Block, and western parts of the Yilgarn, Pilbara and Gawler cratons are considered the more prospective provinces. The major exploration challenges for finding basal Ni–Cu–Co sulphide deposits are to determine the predeformational geometries and younging directions of the intrusions, and to locate under cover, favourable environments (e.g., structural irregularities and depressions in basal contacts and feeder conduits) that concentrate the economically important massive sulphides (figure 3).

Hydrothermal-remobilised nickel sulphide deposits have diverse geological settings and metal associations that reflect the different compositions of the source rocks and fluids. Typically, most hydrothermal deposits are small tonnage and of low economic importance. The unusual Avebury deposit in western Tasmania has increased awareness of hydrothermal-type targets in Phanerozoic provinces that were previously considered to have low prospectivity.

Australia has large areas of Archaean to Phanerozoic continental flood basalts, but no 'Noril'sk-type' Ni–Cu–PGE deposits associated with these rocks have yet been discovered. Hence, there is also some potential for these underexplored deposits in large igneous provinces, such as the late Archaean Fortescue Group basalts of the Pilbara Craton, Palaeoproterozoic Hart Dolerite–Carson Volcanics of the Kimberley Basin, and Mesoproterozoic Warakurna dolerites/intrusions and Cambrian Kalkarindji basalts of western and northern Australia.

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Related websites/articles

Nickel sulfide deposits in Australia: characteristics, resources and potential will appear in Ore Geology Reviews, volume 29, No. 3–4, October 2006

link www.sciencedirect.com

AusGeo News 79

Nickel sulphide metallogenic provinces: resources and potential

link www.ga.gov.au

Resources

Australia's nickel endowment (PDF)

link www.ga.gov.au

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Australian Government
Geoscience Australia
AUSGEO news
ISSUE 83 Sept 2006

METALLOGENESIS *of intrusive rocks of Victoria*

New datasets target gold and base-metal mineralisation

David Champion

Geoscience Australia has been compiling and synthesising datasets of various metallogenic parameters for intrusive and country rock units of the Tasmanides (or Tasman Orogenic Zone—the younger eastern part of Australia, which is joined to the continent's Proterozoic and older core along the Tasman Line) of eastern Australia.

The work is part of the Felsic Igneous Rocks of Australia project to assist the exploration industry in the search for intrusion-related mineralisation systems (see, for example, Champion & Blevin 2005). As reported in *AusGeo News 74* and *79*, this project is being undertaken as regional modules. Datasets for north Queensland are currently being prepared for release, and datasets for Tasmania are now completed and released as a joint Mineral Resources Tasmania–Geoscience Australia product.

In collaboration with Geoscience Victoria, the project is now extending into the Tasman Fold Belt of Victoria and is currently synthesising metallogenic data for that state. Products of this study, which will include downloadable data tables for Victorian rock units (linked to Geoscience Australia's National Map digital geology) will be released in early 2007.

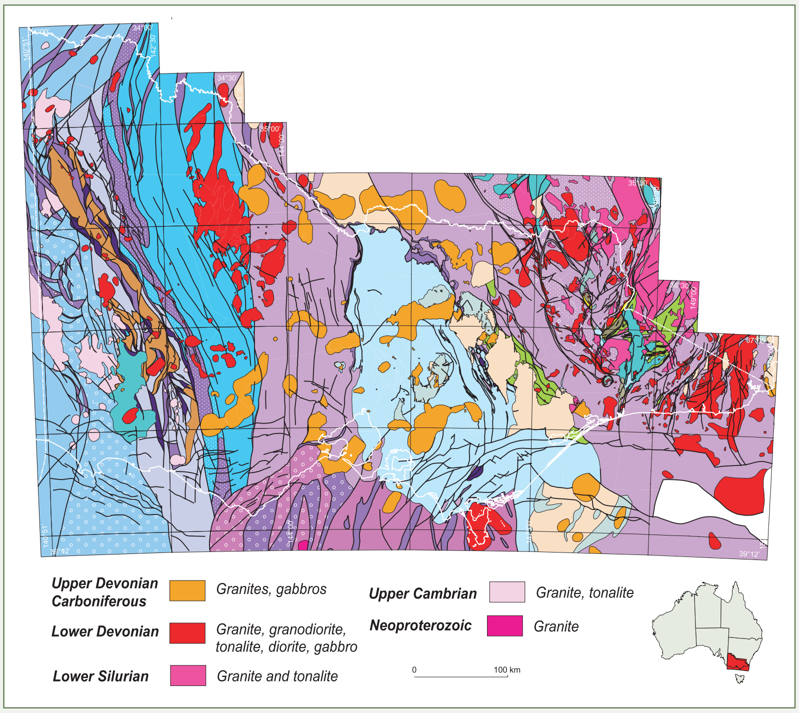

Figure 1. Simplified pre-Permian geology of Victoria. Geology map courtesy of Geoscience Victoria.

Preliminary implications for intrusion-related mineralisation

Granites comprise a significant part of the Lachlan Fold Belt in Victoria (up to 20% by surface area; figure 1). They are dominantly Silurian to Devonian, ranging from about 430 Ma to 350 Ma. Mineralisation associated with these granites includes a range of commodities, including tungsten, tin, molybdenum, copper and gold.

One of the project's primary aims is the compilation and interpretation of chemical-based metallogenic parameters for the granites, using the characteristics identified by Blevin and other workers (for example, Blevin 2004; see summary in Champion & Blevin 2005). The simplest first-pass regional approach has been to use the granite data to calculate parameters of oxidation state and degree of evolution. These parameters can then be used as defined by Blevin (2004)

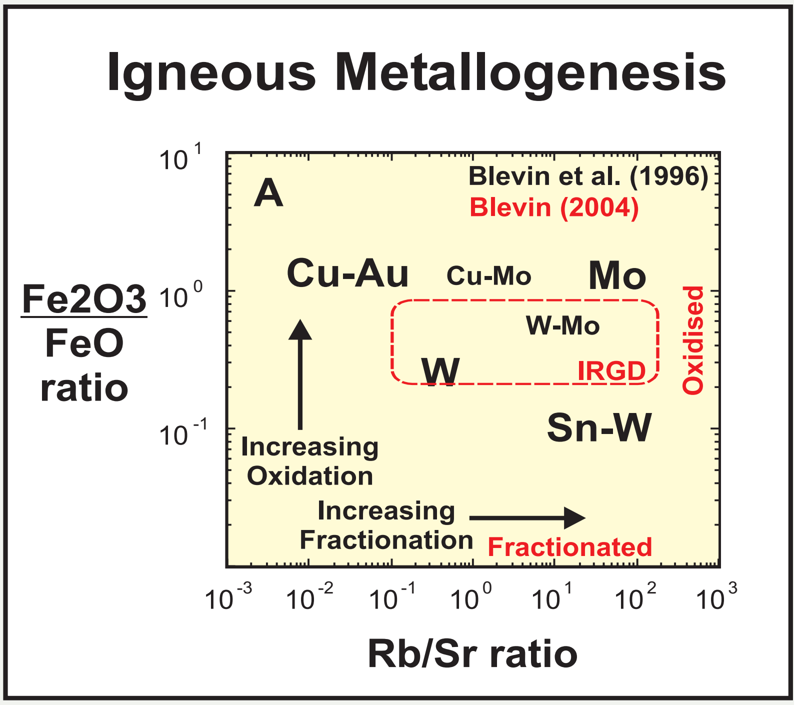

Figure 2. A. Relationship between the oxidation state (calculated using total rock Fe_2O_3/FeO ratio), and the degree of compositional evolution (calculated using total rock Rb/Sr ratio) of granites, and related metallogenic associations, as documented by Blevin et al (1996) and Blevin (2004).

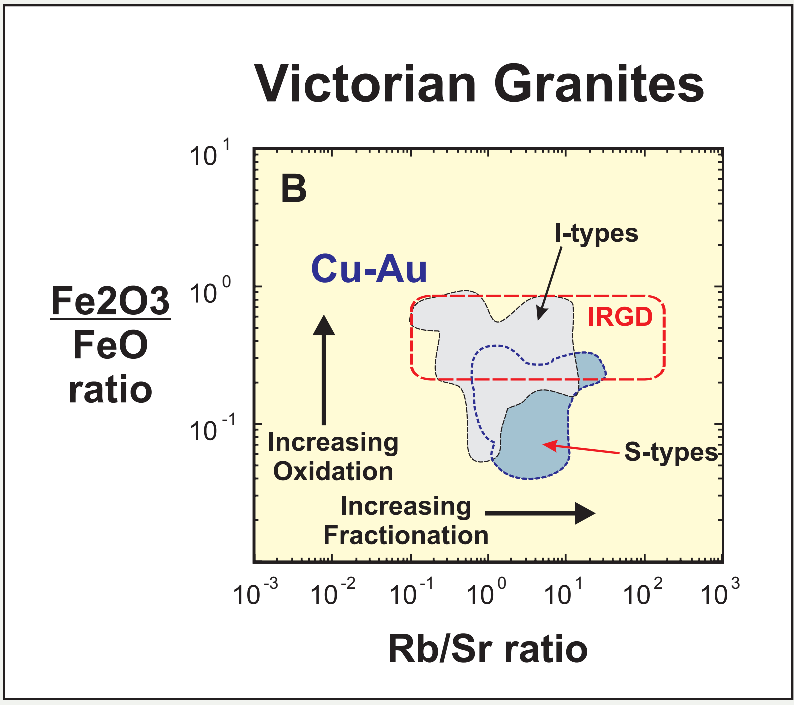

Figure 2. B. Oxidation – compositional evolution plot, contoured using available geochemical data for Victorian granites. The bulk of the geochemical data for the I-type granites (grey field) strongly overlaps with the suggested field (Blevin 2004) for intrusion-related gold.

to highlight mineral potential (figure 2).

Use of this technique is relevant for regional application to new exploration models, and particularly for intrusion-related gold systems (Thompson et al 1999, Blevin 2005), given that Bierlein & McKnight (2005) have recently documented several examples of intrusion-related gold mineralisation in western Victoria, and raised the possibility of additional, as yet undiscovered, mineralisation of similar styles elsewhere in the state.

Geoscience Australia has access to public and confidential geochemical data for over 200 Victorian granite units. A preliminary classification of this geochemical data, plotted (contoured) on the oxidation–fractionation diagram of Blevin (2004; figure 2), illustrates a number of points.

First, it is evident that the granites collectively span a range of compositions, encompassing various metallogenic associations, consistent with known mineral occurrences for the state. Second, it is apparent that only a few of the granites (for which we have data) have characteristics considered prospective for the granite-related porphyry copper–gold class of deposits (such as those associated with Ordovician magmatism in New South Wales, for example Cadia). Third, it is clear that the majority of Victorian I-type granites have chemical characteristics similar to those of granites known to be associated with intrusion-related gold mineralisation (figure 2). This does not necessarily indicate these granites will have associated gold mineralisation, but does show that much of Victoria has the potential for such mineralisation, consistent with the suggestions of Bierlein & McKnight (2005).

General models for intrusion-related gold systems also highlight the importance of continental sedimentary assemblages as host rocks, especially those with carbonaceous or carbonate-bearing units (see the compilation table in *AusGeo News 79*). These and other parameters are currently being compiled for all pre-Mesozoic Victorian country rock units. All synthesised data will be linked to Geoscience Australia's National Map digital geology. This linkage will allow integrated use of the country rock and granite data in a spatial environment, and will help to refine area selection for intrusion-related gold and other commodities in Victoria.

More information

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Related websites/articles

AusGeo News 74
Granite hosts focus of new minerals project
link

AusGeo News 79
Prospects look good for gold in north Queensland
link

Geoscience Australia's Felsic Igneous Rocks of Australia project
link

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Seabed Minerals Map — a world first for Australia

Figure 1. Minister for Industry, Tourism and Resources, the Hon. Ian Macfarlane and the Minister for Education, Science and Training, the Hon. Julie Bishop, following the launch of the Australian Offshore Mineral Locations map at Parliament House on 10 August 2006.

A world-first map showing known offshore mineral occurrences and deposits for Australia's vast marine jurisdiction was launched in August by the Minister for Industry, Tourism and Resources, The Hon. Ian Macfarlane, MP and the Minister for Education, Science and Training, The Hon. Julie Bishop, MP.

The Australian Offshore Mineral Locations map was developed by Geoscience Australia and CSIRO's Wealth from Oceans Flagship and Division of Exploration and Mining in collaboration with the state and Northern Territory Geological Surveys.

Minister Macfarlane said the map's documentation of known mineralisation in the huge expanse of Australia's seabed was an important instrument for encouraging future exploration and scientific study of the water column. 'Australia has one of the largest marine jurisdictions in the world, but very little is known about its make-up or resource potential,' Mr Macfarlane said.

He also pointed out that the gap between onshore exploration and mining, and seafloor exploration is enormous. The total expenditure for exploration in Commonwealth waters totals only $17 million, compared with Australia's annual mineral exploration expenditure of more than $800 million.

Minister Bishop commented that the data collected during compilation of the map would help researchers better understand the seafloor environment in Australian waters. 'We can expect the map to act as a catalyst for future surveys and exploration of Australia's offshore region which will help in the longer term development of strategic resource planning,' she said.

It is anticipated that the map will promote interest in exploring for marine minerals, particularly minerals located in readily accessible shallow waters, such as those illustrated by the drilling of seafloor sulphides in New Zealand and Papua New Guinea Territorial waters.

The map in portable document format can be accessed through Geoscience Australia's website and is available from the Geoscience Australia Sales Centre on Freecall 1800 800 173 (within Australia) or +61 2 6249 9966 (email mapsales@ga.gov.au).

Related articles/websites

Australian Offshore Mineral Locations map
www.ga.gov.au/minerals/exploration/offshore/
link

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Reducing natural hazard risk to remote Indigenous communities

Western Australia has 283 remote Indigenous communities which are populated by approximately 17 000 Aboriginal people. Though many communities are located in areas subject to flood, tropical cyclone, bushfire and tsunami, little is known about the risk posed to them by such hazards.

Many factors link the vulnerability of remote Indigenous communities to natural hazard risk. Some of these relate to hazards, however, there are many other complex factors involved, such as isolation, inadequate infrastructure, transient populations and cultural beliefs. All these factors need to be analysed and are equally important when determining risk. Consequently remote Indigenous communities have diverse and complex emergency risk management needs.

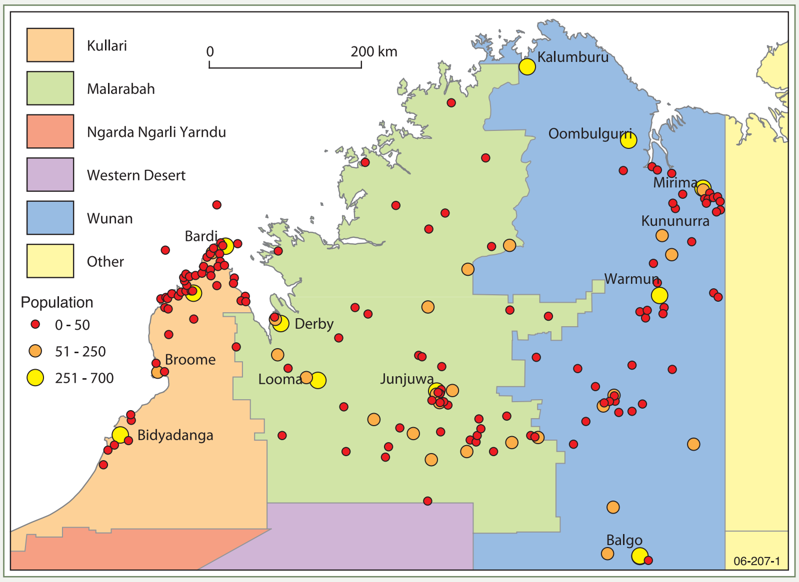

Figure 1. Remote Indigenous communities of the Kimberley.

Geoscience Australia and the Fire and Emergency Services Authority (FESA) of Western Australia are currently collaborating on a demonstrator project which aims to support decision-makers involved in natural disaster mitigation and emergency risk management reduce natural hazard risks facing remote Indigenous communities.

In bringing together key risk data in a mapping environment, the project fulfils two strategic objectives.

Firstly, since it will assist FESA develop a much clearer understanding of the level of natural hazard risk faced by these Indigenous communities, the information will assist in the prioritisation and delivery of emergency risk management activities.

Secondly, the project involves examining existing data collection systems at the state level and how these can be replicated and modified to facilitate the collection of consistent data for a national risk assessment. It is one of three demonstrator projects currently being undertaken by Geoscience Australia as part of meeting Reform Commitment 2 of the Council of Australian Governments (COAG) Report *Natural Disasters in Australia*.

To date, Geoscience Australia and FESA have held several meetings and workshops with Western Australian emergency managers, including operational services officers who work closely with remote Indigenous communities.

As a result key indicators of risk are being developed in a geographic information systems (GIS) environment with the final data and information due to be released in an ArcReader format in September 2006. Decision-makers who are unfamiliar with GIS will be able to use this format to view information on all remote Indigenous communities in Western Australia and examine issues relating to natural hazard risk.

Some of the key indicators of risk incorporated into the GIS environment to date include: remoteness, bushfire/cyclone exposure, language (traditional or English), airstrip access, community evacuation plans, petrol-sniffing programs and population size. When these and other indicators are combined they create a more complete picture of the natural hazard risk in particular communities which will enable emergency managers to make better informed decisions.

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in brief

International award assists inversion modelling development

Geophysical inversion methods form an integral part of Geoscience Australia's ongoing program to develop predictive 3D models of subsurface geology. Consequently Nick Williams, a Minerals Division geoscientist, is undertaking a Ph.D. in Geophysics at The University of British Columbia (UBC) in Vancouver, Canada. His project is focussed on developing and improving the techniques for integrating geology, geophysics and rock properties into 3D models through the use of geophysical inversion software developed by UBC Geophysical Inversion Facility.

Having commenced with Geoscience Australia in 2001 as part of the organisation's Graduate Program, he is currently working on problems associated with regional 3D mapping, nickel targeting and exploration in the Agnew-Wiluna greenstone belt of the Eastern Goldfields in Western Australia's Yilgarn Craton. His project is supported by Geoscience Australia, the Predictive Mineral Discovery CRC, the UBC Mineral Deposit Research Unit, the UBC Geophysical Inversion Facility, and BHP Billiton.

In April 2006, Nick was awarded a US$4000 Hugo Dummett Mineral Discovery Fund grant to support his research by the Society for Economic Geologists, an international organisation with over 3000 members in more than 70 countries. The competitive fund 'supports applied economic geology research, including the development of new exploration technology and techniques, and the dissemination of related results'. The grant is being used to cover costs associated with the analysis of density and magnetic properties of samples

Figure 1. Nick Williams.

Nick collected during field work around Leinster and the Perseverance Ni deposit in 2005.

The knowledge gained from this analysis will help clarify the relationship between the expected geology and the observed gravity and magnetic responses in the region. This in turn will allow the inclusion of geological constraints into the geophysical inversions to provide more reliable 3D models of subsurface geology.

in brief

Earthquake Engineering Conference AEES2006

In November this year, Geoscience Australia will host the annual conference of the Australian Earthquake Engineering Society (AEES). This is an opportunity for earthquake engineers, engineering seismologists, emergency managers, code writers, insurance actuaries and others to discuss measures aimed at reducing earthquake risk in Australia.

During the 20th century earthquakes caused, on average, 10 000 deaths per year with about 10 times that number of people suffering severe injuries as a result of building collapse.

Keynote speakers from the United States and New Zealand have accepted invitations to address the conference, which is being held between 24 and 26 November. The organisers are planning a program with a mixture of oral presentations and poster sessions.

The AEES is affiliated with the International Association of Earthquake Engineers through its linkage as a professional society of Engineers Australia and it draws a significant membership from the geoscience community and people interested in earthquakes and their impacts.

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in brief

Map producers working together

With an area covering more than 7 650 000 square kilometres, the revision of Australia's topographic maps is a major challenge that governments cannot tackle alone. For many years private map publishers as well as members of the public have provided information which has contributed to the updating of Geoscience Australia's maps and data sets. This information has come from a variety of sources including dedicated field revision, anecdotal comments, and formal feedback, as well as distribution of topographic maps to local organisations and rural property owners/managers for review.

This collaboration between map publishers and Geoscience Australia has gone a step further toward the main goal of increasing the value of data acquired whilst reducing the costs for participating organisations.

During August, mapping staff from Geoscience Australia joined one of Australia's largest commercial map publishers, Hema Maps, to undertake field revision work in the Douglas/Daly, Katherine, Daly Waters, and Roper River regions in the Northern Territory.

During the month, the Hema Map Patrol vehicle and its combined crew from Hema Maps and Geoscience Australia travelled more than 6000 kilometres of roads and tracks, noting and recording locations of numerous man-made and natural terrain features. The crew used differential GPS navigation systems coupled to laptop computers and GIS software to record this information.

Hema Maps General Manager Rob Boegheim considered that the joint initiative succeeded for a number of reasons. 'Working with Geoscience Australia allowed us to acquire data that is useful to both organisations. Hema Maps use a lot of Geoscience Australia data to produce our extensive range of maps and by sharing many of the costs and resources involved in acquiring data we can fast track our map development and update program'.

Figure 1. Cameron Corner to Moomba Rd—Hema Map Patrol vehicle.

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in brief

Spatial information scientist receives 2006 Fulbright Scholarship

Figure 1. Dr Alan Forghani.

A spatial information scientist with Geoscience Australia is one of 21 Australians to receive a Fulbright Scholarship worth up to $40 000 to study and conduct research in the United States.

Dr Alan Forghani left Australia in early August to take up the scholarship and carry out research on remote sensing applications at the Geographic Information Science Centre with the University of California Berkeley.

He will examine wind and bushfire assessment approaches used in the US, focusing on the integration of these models with remote sensing data and test its suitability for the Australian environment. He believes the work being conducted at the University of California Berkeley complements Australian research and will contribute to planning and designing safer communities.

Dr Forghani will also visit the Rocky Mountain Research Station's Missoula Fire Sciences Laboratory in Montana which developed the Wind Wizard system to engage with eminent bushfire scientists.

The 2006 Australian Fulbright scholarships are administered by the Australian-American Fulbright Commission and funded by the Australian and US Governments and a group of corporate partners.

GEODATA TOPO 250K

Series 3 released

The recently released *Series 3* of Geoscience Australia's 1:250,000 scale vector data has so far proved popular with map producers and GIS professionals.

GEODATA TOPO 250K Series 3 is a vector GIS representation of the major topographic features appearing on 1:250 000 scale NATMAP topographic maps. *Series 3* data is no more than five years old for the majority of locations and compliments the popular NATMAP Raster products and data released in 2005.

Significantly, map producers, emergency managers and the spatial industry now have access to low cost, high quality data that has been extensively updated since the release of *Series 2. GEODATA TOPO 250K Series 3* includes additional cartographic layers and symbology that allows production of high quality maps for minimal effort.

Series 3 data unlike its predecessor is provided as a seamless coverage of Australia arranged in ten themes – cartography, elevation, framework, habitation, hydrography, infrastructure, terrain, transport, utility and vegetation.

Customised 1:250 000 Scale (250K) GEODATA is also available where requirements are not met by these packaged products. The price will be determined after assessing individual client needs. Alternatively, requests for customised data may also be referred to a third party supplier.

Geoscience Australia is currently deploying *MapConnect*, an online mapping solution where users will be able to seamlessly extract and download data for selected areas (subject to download parameters), and in a number of different delivery formats.

GEODATA TOPO 250K Series 3 is available on DVD in Personal Geodatabase, ArcView Shapefile or MapInfo TAB file formats for only $99 (including GST) per package. Alternatively, individual map tiles can be accessed from the Free Downloads link on the Geoscience Australia website (www.ga.gov.au).

GEODATA TOPO 250K Series 3 Specifications

Themes:

• Cartography • Elevation • Framework • Habitation • Hydrography • Infrastructure • Terrain • Transport • Utility • Vegetation.

More information

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Coverage	National (power lines not available in South Australia)
Currency	Data currency is generally less than five years.
Coordinates	Geographical.
Datum	Geocentric Datum of Australia (GDA94).
Format	Personal Geodatabase, ArcView Shapefile and MapInfo TAB.
Medium	Packaged DVD ROM ($99 per package).
Previous Version	Replaces GEODATA TOPO 250K Series 2.
Release Date	26 June 2006.

product news

Alternative satellite imagery for Australia

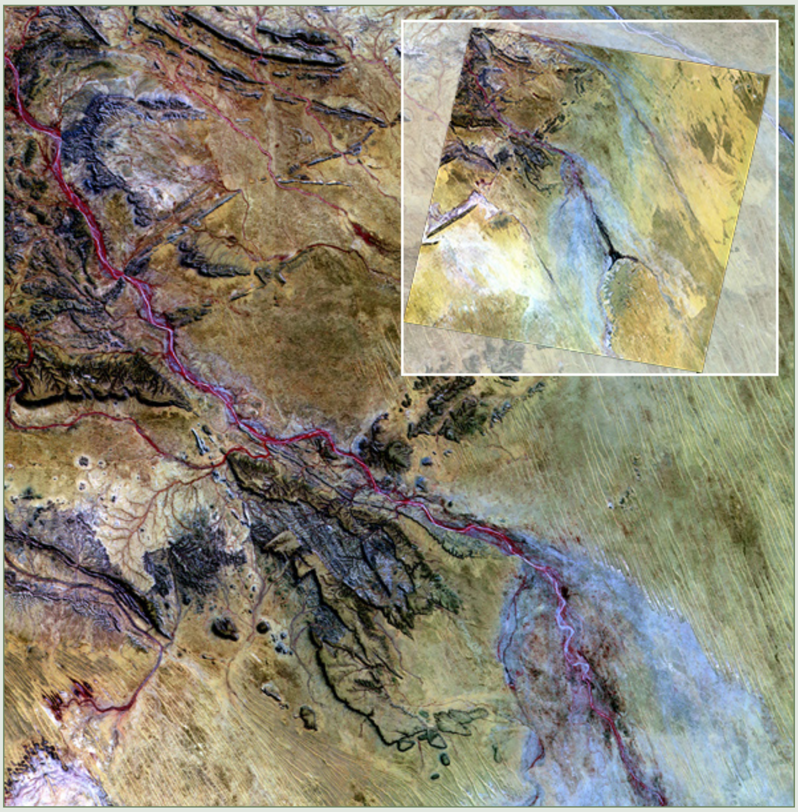

Figure 1. The first image from the China-Brazil Earth Resources Satellite (CBERS-2) acquired by Geoscience Australia on 7 April 2006 in cooperation with the China Center for Resource Satellite Data and Applications (CRESDA). The image area is located approximately 100 kilometres east of Alice Springs and the swath width is around 100 kilometres (Image centre: S 24:09:20 E 135:36:30).

Geoscience Australia has successfully received a test downlink of satellite images from the China-Brazil Earth Resources Satellite (CBERS-2) at its Alice Springs ground station. CBERS-2 provides images with a spatial resolution of approximately 20 metres with repeat coverage every 26 days. This test downlink is part of the contingency planning Geoscience Australia has been undertaking with the local user community and international satellite operators to secure access to alternative sources of data in case of a continuity gap in Landsat data.

Geoscience Australia is also evaluating data from the SPOT (Système Pour l'Observation de la Terre) satellites and investigating the potential for downlinks of ResourceSat-1 (also known as Indian Remote Sensing Satellite P6). Geoscience Australia's consultations aim to identify alternative sources of imagery for applications that require access to images spanning a period of time.

The Australian Centre for Remote Sensing (ACRES) has been acquiring images from the Landsat series of satellites since 1979. Landsat data have proved invaluable to government and industry for a range of applications including environmental monitoring, agriculture, mapping and emergency management. As the current Landsat satellites age, Australian users have become concerned about the continuing availability of reliable and cost effective satellite imagery.

This test downlink also demonstrates the flexibility provided by the multi-satellite capability of Geoscience Australia's receiving station in Alice Springs. The receiving station can easily be reconfigured to enable quick and easy access to new sources of satellite remote sensing data.

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product news

MapConnect: online delivery of maps and spatial information

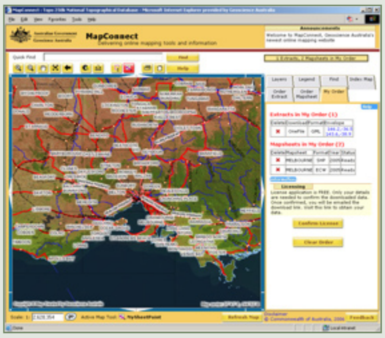
Geoscience Australia's National Mapping & Information Group is deploying the next generation of online mapping applications. 'MapConnect' enables users to select and download maps and spatial datasets from a standard web browser without the need for any additional software. Its map-based interface accesses the most recent available data using areas, themes and formats determined by the user thus enabling mainstream access to spatial data and maps by the wider community.

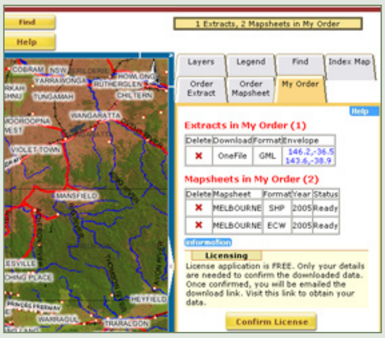
MapConnect will be useful for a wide range of applications including tourism, business, emergency management, education, agriculture, and public administration. It is a user-friendly way to directly access the most current data and maps. After locating an area of interest by entering its name and zooming in, users can then download a PDF version of a map covering that area for printing on a standard printer, as well as digital data in a variety of formats, to create a customised map.

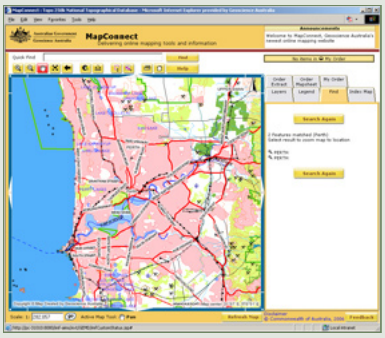
The available formats include:

- PDF maps – cartographic maps, including legends and scales, that can be used in the field by field crew, or incorporated into publications and reports. These maps are in a vector format that allows them to be printed at high resolution or enlarged without loss of quality.
- image formats – ideal for use with GPS navigation systems in vehicle mounted or handheld devices.
- GIS formats – current data with attributes and symbology (pGDB, ShapeFile, TAB & GML formats) for input into software packages which are useful for analysis and advanced map production. Data can be selected by theme or as a single file before being compressed for download.
- screen based images – can be simply printed from the map window for use by the general public.

All downloads are registered and licensed with the Office of Spatial Data Management (OSDM) before being downloaded from the Geoscience Australia website.







More information

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MapConnect@ga.gov.au

New geophysical datasets for Mount Isa, Paterson, East Arunta and Bowen-Surat regions

Datasets from seven new geophysical surveys which will be a valuable tool in assessing the mineral potential of their respective regions were released in August 2006. They included four new airborne magnetic and radiometric surveys in the Mount Isa and Bowen-Surat regions in Queensland and Paterson Province in Western Australia as well as new gravity surveys covering the East Arunta region in the Northern Territory and Queensland's Mt Isa and Bowen-Surat region.

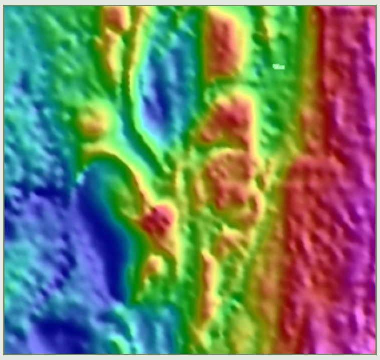

Figure 1. Mount Isa Area A gravity

The data were acquired in surveys conducted in 2005 and 2006 which were managed by Geoscience Australia on behalf of the Geological Surveys of Queensland, Western Australia and the Northern Territory.

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

Table 1. Details of the gravity surveys.

Survey name	Survey Type	Date of Acquisition	1:250 000 Map Sheets	Station spacing/ orientation	Stations	Contractor
East Arunta (NT)	Gravity	June – July 2006	Huckitta, Tobermory, Illogwa Creek, Hay River	2.0 x 2.0 km east – west	5 500	Daishsat Geodetic Surveyors
Mount Isa Area A (Qld)	Gravity	April – June 2006	Cloncurry, Mount Isa	2.0 x 2.0 km east – west	6 700	Daishsat Geodetic Surveyors
Bowen – Surat (Qld)	Gravity	Nov 2005 – April 2006	Taroom, Roma, Surat, Baralaba, Springsure, Eddystone, Mitchell, Homeboin, Dirranbandi, St George	4.0 x 4.0 km	5 200	Daishsat Geodetic Surveyors

Table 2. Details of the airborne surveys.

Survey	Survey Type	Date	1:250 000 Map Sheets	Line Spacing/ terrain clearance /orientation	Line km	Contractor
Bowen–Surat South (Qld)	Magnetic, Radiometric	January – April 2006	Homeboin, Surat, Dalby, Ipswich, St George and Goondiwindi	400 m, 80 m, east – west	154 000	Fugro Airborne Surveys
Mount Isa West (Qld)	Magnetic, Radiometric	February – April 2006	Mount Isa (western 20%), Urandangi (western 20%), Glenormiston (two-thirds), Mount Whelan (northern 20%)	400 m, 80 m, east – west and north – south (north of -21.56°)	63 000	Fugro Airborne Surveys
Paterson Central	Magnetic, Radiometric	June 2005 – April 2006	Nullagine, Paterson Range, Rudall	400 m, 60 m, east – west	94 300	UTS Geophysics
Paterson South - East	Magnetic, Radiometric	April – June 2006	Rudall, Tabletop	400 m, 60 m, east – west	28 400	UTS Geophysics

product news

More information

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Related websites/articles

AusGeo News 81
SMART exploration gets Geoscience Australia support
link www.ga.gov.au

2006 East Arunta Gravity Survey
link kakadu.nt.gov.au

Geological Survey of Western Australia
link www.doir.wa.gov.au

events calendar

EVENTS 2006

Mining 2006 — **1–3 November** — 1

Hilton Brisbane
Mining 2005, PO Box 1153, Subiaco WA 6904
phone +61 8 9388 2222
fax +61 8 9381 9222
e-mail info@verticalevents.com.au
www.verticalevents.com.au

AAPG International Conference and Exhibition — **5–8 November** — 2

American Association of Petroleum Geologists
Perth Convention and Exhibition Centre
AAPG Convention Department, PO Box 979, Tulsa Oklahoma 74101-0979 USA
phone +1 918 560 2617
fax +1 918 560 2684
e-mail convene2@aapg.org
www.aapg.org

13 ARSPC — **20–24 November** — 3

13th Australasian Remote Sensing and Photogrammetry Conference
National Convention Centre, Canberra
ICMS Pty Ltd, GPO Box 2200, Canberra ACT 2601
phone +61 2 6257 3299
fax +61 2 6257 3256
e-mail arspc@icms.com.au
www.arspc.org/

AEES2006 — **24–26 November** — 4

Australian Earthquake Engineering Society
Geoscience Australia, Canberra
Kevin McCue, ASC, PO Box 324, Jamison Centre, ACT 2614
e-mail mccue.kevin@gmail.com
www.aees.org.au

events calendar

EVENTS 2006 (CONT'D)

Computational Modelling and Decision Support in the Solid Earth and Environmental Community — **30 November – 1 December**

5

CSIRO Discovery Centre, Canberra
CSIRO Exploration & Mining
phone +61 8 6436 8625
fax +61 8 6436 8555
e-mail petra.bowling@csiro.au
www.seegrid.csiro.au

NAPE Expo 2007 –North American Prospects Exhibition — **1–2 February**

6

American Association of Professional Landmen
AAPL, 4100 Fossil Creek Boulevard, Fort Worth, Texas 76137 USA
phone +1 817 847 7700
fax +1 817 847 7703
e-mail nape@landman.org
www.napeonline.com

PDAC International Convention & Trade Show — **4–7 March**

7

Prospectors and Developers Association of Canada
Metro Toronto Convention Centre, PDAC, 34 King Street East Suite 900, Toronto, Ontario M5C 2
phone +1 416 362 1969
fax +1 416 362 0101
e-mail info@pdac.ca
www.pdac.ca

APPEA Conference and Exhibition — **15–18 April**

8

Australian Petroleum Production and Exploration Association
Adelaide Convention Centre
Vicki O'Gorman, APPEA Limited, GPO Box 2201, Canberra ACT 2601
phone +61 2 6247 0906
fax +61 2 6247 0548
e-mail vogorman@appea.com.au
www.appea.com.au