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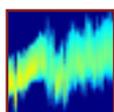
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# CEO comment



**Chris Pigram** – CEO Geoscience Australia



This issue of *AusGeo News* features several reports on Geoscience Australia’s research to assist mineral and energy resource explorers as well as our contributions to natural resource management and the alleviation of the effects of climate change on Australia’s coastal zone.

Our first article outlines the geophysical techniques used to map the 3D signatures of ore deposits in the Cobar region of New South Wales. The maps utilise geophysical inversions of gravity and magnetic data to produce 3D models of density and magnetic susceptibility (see *AusGeo News* 96). The application of the technique in a sample area showed that it is apparent that the major deposits of the region lie within the changes between alteration types.

This issue includes details of a recent study by Geoscience Australia scientists which has integrated and modelled national geoscientific datasets to generate a weathering intensity index for the Australian continent. Weathering intensity is a fundamental characteristic of the regolith which is the layer of weathered bedrock and sediments that overlies fresh bedrock at depth. The index has broad applications for a range of natural resource management, environmental and mineral exploration issues.

Australia’s coastal zone includes major cities and supports major industries such as agriculture, fisheries and tourism and has more than 80 per cent of Australians living within it. Our article outlines Geoscience Australia’s contribution to the National Coastal Vulnerability Assessment, which was commissioned by the former Department of Climate Change, and examined the vulnerability of coastal communities to rising sea-levels. The study utilised two nation-wide consistent databases managed by Geoscience Australia; NEXIS which describes Australia’s infrastructure and Smartline which outlines coastal geomorphology (or landforms).

I am pleased to report the outcome of additional research and reprocessing of data from the airborne electromagnetic survey over the Kombolgie section of the Pine Creek region in the Northern Territory. There has been a significant improvement to the mapping of conductivity and identifying features, such as unconformities and major structures, at much greater depths than has previously been published.

This issue also includes a report on a seabed mapping survey off northern Australia and an update on the Geothermal Energy Project. New products include geophysical datasets covering the Pine Creek region in the Northern Territory and the Paterson region in Western Australia.

I wish to congratulate Geoscience Australia’s recently retired Chief Scientist, Lynton Jaques, who was awarded a Public Service Medal in the recent Australia Day honours. Lynton managed and coordinated the development of the *Australian Energy Resource Assessment* (see *AusGeo News* 98) which provides an authoritative base for debate and policy development on Australia’s future energy directions. It was a significant culmination to the contribution Lynton has made to Geoscience Australia and its predecessors over the past 38 years and we wish him well in his retirement.

As always we welcome your feedback and encourage you to use the email address at the end of each article.

# Mapping the footprint of ore deposits in 3D using geophysical data

*Potential field data provides alteration signatures*

*Richard Chopping and Simon van der Wielen*



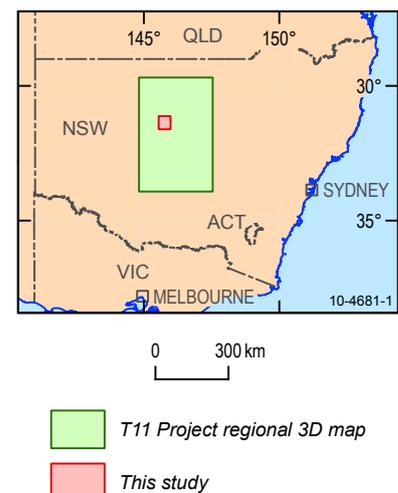
Geologists identify rocks mainly through identifying the minerals they contain. These might include the minerals which make up the majority of rocks we see at the Earth's surface, such as quartz or feldspars. They could also be minerals which are more commonly associated with ore deposits, such as pyrite (fool's gold), pyrrhotite or magnetite. Geologists identify these minerals by their unique properties such as hardness, colour, crystal form and cleavage, streak, how heavy the mineral is, or how magnetic it is. The latter two properties are termed 'physical properties', namely density and magnetic susceptibility.

Recent developments in technology allow for the mapping of the distribution of physical properties derived from geophysical data in 3D. These developments, which utilise geophysical inversions of gravity and magnetic data (Williams et al 2009), have produced 3D models of density and magnetic susceptibility. In a project conducted between 2006 and 2008 for the Predictive Mineral Discovery Co-operative Research Centre (*pmd*\**CRC*), the authors examined the 3D signatures of ore deposits in the Cobar region of New South Wales (NSW; figure 1).

**“This link between mineralogy, physical properties and geophysical responses is the key to mapping the signatures of ore deposits using geophysics.”**

## Linking geology and geophysical data

The physical properties of geological materials are the link between geology and geophysics. A high density area of the Earth will produce a gravity high; a low density area will produce a gravity low. Likewise, an area with high magnetic susceptibility will produce a magnetic high. These geophysical responses are linked to the minerals contained within the rocks in those areas; an area of rock which contains more dense minerals has a higher density and will thus produce a gravity high. This link between mineralogy, physical properties and geophysical responses is the key to mapping the signatures of ore deposits using geophysics. Often the processes which form a mineral deposit will produce minerals which have vastly different physical properties to the minerals already formed in the host rocks. These differing physical properties resulting from the processes of mineralisation can produce a geophysical response.



**Figure 1.** Location of the study area used for alteration mapping and the study area for the *pmd*\**CRC* Cobar Project T11 in the Lachlan Subprovince and Cobar Basin.

## The study area

The Cobar region has a rich mining history spanning more than 100 years (Glen 1987). The area has mainly been mined for copper, gold, silver, lead and zinc, at mines such as CSA, Great Cobar and Peak. Significantly for this study, geophysical responses due to mineralisation are known in the Cobar region. Studies of these responses have focussed predominantly on the magnetic and gravity responses, although there are also anomalies in other geophysical data (such as electromagnetic data). The focus of this study was to map the alteration mineralogy in 3D utilising geophysical techniques.

## Chemical alteration in 3D

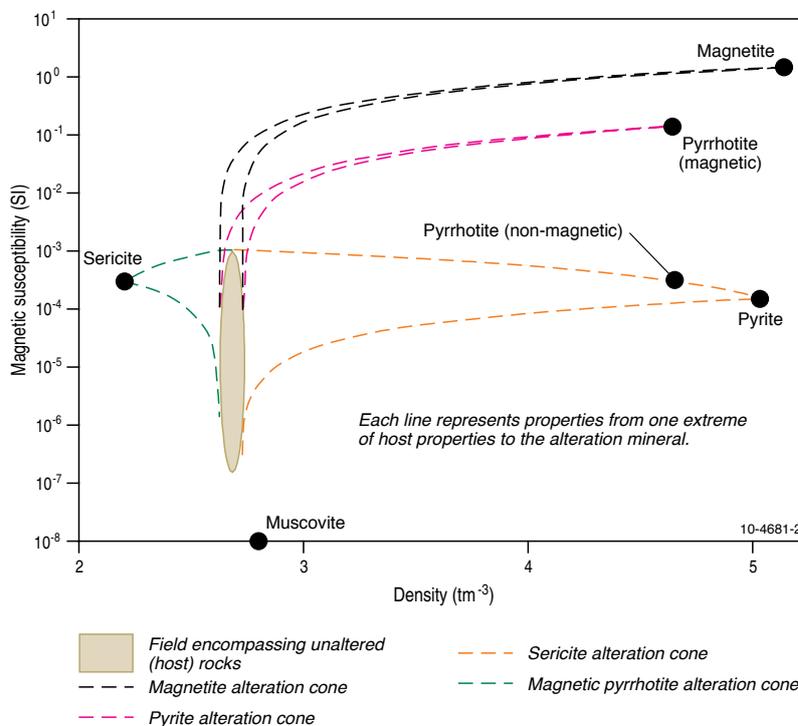
To understand the method by which the changes resulting from the formation of ore deposits (termed chemical alteration) can be mapped in 3D requires some elaboration of the concept.

Chemical alteration is defined here as the change in the original (termed primary) mineralogy of a rock that results from fluids and/or heat from the mineralising system interacting with the rocks through which they pass. The physical properties of rocks that host ore deposits are controlled, predominantly, by the mineralogy of the rock (Carmichael 1989). Consequently alteration minerals which

have properties that differ by a considerable amount to the primary minerals in a rock will produce a rock which has properties which differ from the original rock hosting the alteration.

However, it should be noted that chemical alteration does not result in a completely altered rock. Many rocks remain a mixture of primary and alteration minerals. As an example, a rock may contain 40 per cent primary minerals and 60 per cent alteration minerals. In this case, the density of the rock will be 40 per cent of the density of the primary minerals and 60 per cent of the density of the alteration minerals. For magnetic susceptibility, the relationship is more complex, but many authors suggest that it can be assumed to be linear for concentrations of magnetite less than 20 per cent (Carmichael 1989).

Because of variations in mineralogy and other factors, any host rock in a mineral system will not have a single, definitive set of physical properties. When plotted on a graph of physical properties, the variability in properties of a host rock can be defined by a limited field (shaded polygon; figure 2). This limited field implies that rocks altered to an assemblage of alteration minerals will be contained by a field which converges around the physical properties of that assemblage. This is a feature we term the 'alteration cone'



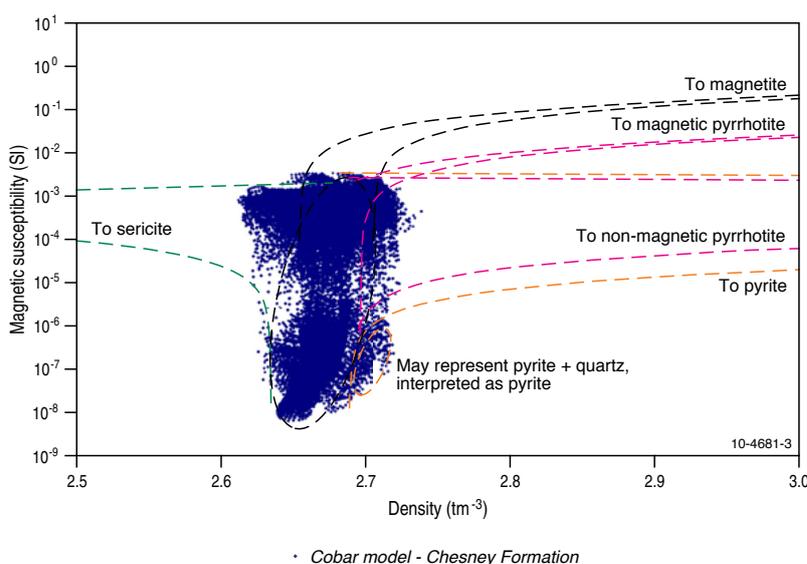
**Figure 2.** Magnetic susceptibility versus density plot showing a hypothetical location for a distribution of host rock properties and the location of some alteration minerals. The dashed lines indicate paths that progressively altered samples will take on this scatter plot. Any samples that plot within the field defined by these dashed lines (the 'alteration cone') can be inferred to be altered to the property shown at the apex of the alteration cone.

(Chopping 2007; figure 2). Samples plotting outside the field of expected properties for a given host lithology, but within an alteration cone, are inferred to be altered to the alteration product which is located at the apex of the alteration cone.

### 3D inversion of geophysical data

The concept of the alteration cone can be used to interpret the results of potential field 3D inversions. The gravity and magnetic inversion programs—GRAV3D and MAG3D—used for this study were developed by The University of British Columbia-Geophysical Inversion Facility. The programs produced volumes of density contrast and magnetic susceptibility. These contrast with a background (reference) density or magnetic susceptibility which can be converted to an absolute density or magnetic susceptibility by adding the reference density or magnetic susceptibility for that cell. For this study an area 40 kilometres east-west, 50 kilometres north-south and 16 kilometres deep was constructed, and this model was divided into cubic cells of side length 250 metres. The density and magnetic susceptibility for each of these cells was derived using GRAV3D and MAG3D and the geological lithology for each cell was obtained from a 3D geological map constructed for the Cobar region (van der Wielen and Korsch 2007). The property distribution for each individual lithology, which was derived from the potential field inversions, can be queried for signatures of alteration by applying the alteration cone methodology discussed above.

Queries for alteration to magnetite, pyrrhotite, pyrite (potentially non-magnetic pyrrhotite) and sericite were undertaken. These are the

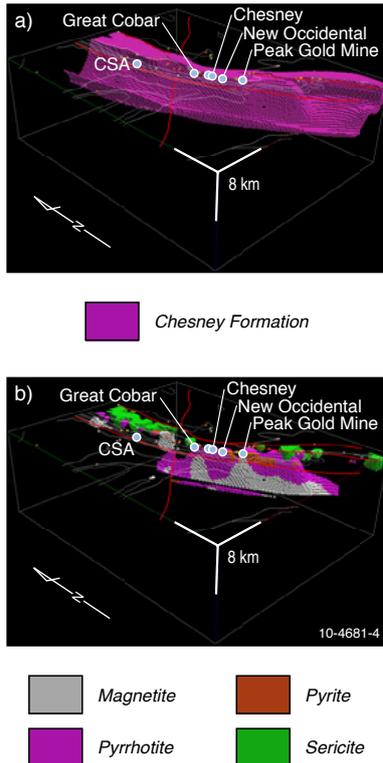


**Figure 3.** Magnetic susceptibility versus density plot for each cell of the Chesney Formation. Properties are derived from a 3D potential field inversion of magnetic and gravity data in the Cobar region.

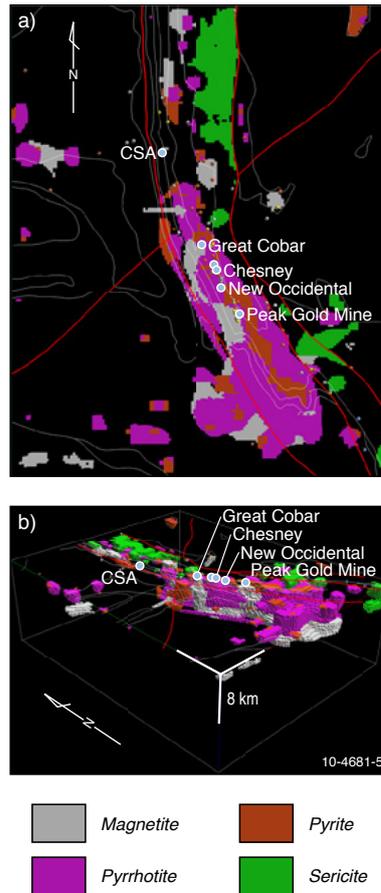
simplest alteration assemblages that can explain the physical property trends observed in the inversion results. These are not the only alteration types anticipated in the Cobar region, but these alteration minerals have the most significant density and magnetic susceptibility contrasts when compared to the host rocks. They are also likely to occur in sufficient quantities within the inversion cells to be detected by the inversions. Some previous studies in the region indicate that there may be alteration zones up to 30 metres wide containing 80 per cent sulphides; this would correspond to one or two per cent sulphides in a cell of 250 cubic metres.

### Changes in alteration types

A good illustration of the use of this technique is the Chesney Formation. This formation hosts a significant quantity of base metals in the region (Cook et al 1996). Its physical properties, derived from the potential field inversions, show a fairly typical trend, with the majority of cells clustered together (figure 3). The alteration cones encompass almost all of the samples that appear to be anomalous in their inverted properties. Some samples appear to show densities and magnetic susceptibilities that would be more akin to alteration to pyrite and quartz, however, these are interpreted to be pyrite in the final results to remain in our



**Figure 4.** a) 3D distribution of the Chesney Formation; b) distribution of cells according to alteration type which was obtained by querying the 3D model for all cells of the Chesney Formation with properties interpreted from the alteration cones (figure 3).



**Figure 5.** 3D distribution of alteration for all lithologies in the Cobar region, viewed from a) above and b) the same perspective as for figure 4. Areas shown in black indicate that the geological units show normal host rock physical properties.

simple alteration classification (figure 3). The results, when viewed in their true 3D context, show that there appears to be magnetite pipes, representing zones of more oxidised alteration, cutting into pyrrhotite or pyrite, which may represent zones of more reduced alteration (figure 4).

When viewing the alteration results for all lithologies in the study region (figure 5), it is apparent that the major deposits of the region lie within the changes between alteration types. These changes are either from magnetite-dominant alteration to pyrrhotite-dominant alteration or from pyrrhotite-dominant alteration to pyrite-dominant alteration. The overall pattern of magnetite, pyrrhotite and pyrite-dominant alteration zones is consistent with previous alteration studies in the region (Cook et al 1996; Lawrie and Hinman 1998; Stegman 2001).

The location of the known deposits in the Cobar region, located on the change from one alteration type to another, was entirely expected based on our knowledge of the mineral systems operating in the Cobar region. The change in alteration type corresponds to the conditions that promote maximum deposition of base metals (Cook et al 1996; van der Wielen and Korsch 2007). The change from magnetite-dominant to pyrrhotite-dominant reflects a change in the redox state. The change from pyrrhotite-dominant to pyrite-dominant may also represent a change in the redox state, a change in the availability of iron (Shi 1992), or possibly a temperature effect if the pyrite-dominant alteration actually represents non-magnetic pyrrhotite-dominant alteration. Pyrite and non-magnetic pyrrhotite cannot be distinguished on their densities and magnetic susceptibilities alone, as these properties are virtually identical for both minerals. A higher temperature allows the non-magnetic hexagonal crystal symmetry form of pyrrhotite to be stable, whereas, at a lower temperature, the magnetic monoclinic crystal symmetry form of pyrrhotite is stable (Dekkers 1989).

## Conclusions

This technique has allowed us to attribute anomalies in physical properties, with respect



to the 'normal' host properties, with an expected alteration type. The technique is particularly applicable in the Cobar region because there is limited physical property contrast between host units and alteration is the predominant cause of geophysical anomalies. The technique is also applicable in regions that are under significant cover. As with any geophysical technique, the exact results will depend on the property contrast from host to altered product. A strong host-to-host property contrast will require a more detailed geological model to obtain the best results, but mapping of gross alteration trends should still be possible with only a very simple inversion reference model.

### **Acknowledgements**

The research that underpins this article was conducted as part of the Predictive Mineral Discovery Cooperative Research Centre (*pmd*\*CRC) Project T11 in the Cobar region of New South Wales (NSW). The Project involved the collaboration of Geoscience Australia, the NSW Department of Primary Industries, and five mining companies in the region: CBH Resources Ltd, Cobar Management Pty Ltd, Peak Gold Mines, Triako Resources Ltd and Tritton Resources Ltd. This article was greatly improved by the contributions of colleagues at Geoscience Australia: Russell Korsch and Anthony Schofield who provided constructive feedback for the original presentation and Natalie Kositcin who edited the draft article.

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[www.ga.gov.au/ausgeonews/ausgeonews200912/surface.jsp](http://www.ga.gov.au/ausgeonews/ausgeonews200912/surface.jsp)

### **The authors**

Richard Chopping and Simon van der Wielen were Distinguished Geoscience Australia Lecturers (DGAL) for 2008 and this article is based on material from their DGAL presentation. It is also closely based on a presentation at the 2009 Australian Society of Exploration Geophysicists (ASEG) conference in Adelaide. The extended abstract for the presentation was awarded 'Best Written Paper' during the conference.

### **Related websites/articles**

Predictive Mineral Discovery Co-operative Research Centre (*pmd*\*CRC)

[www.pmdcrc.com.au](http://www.pmdcrc.com.au)

University of British Columbia-Geophysical Inversion Facility

[www.eos.ubc.ca/ubcgif/](http://www.eos.ubc.ca/ubcgif/)

*AusGeo News* 96: Expanding our knowledge of North Queensland

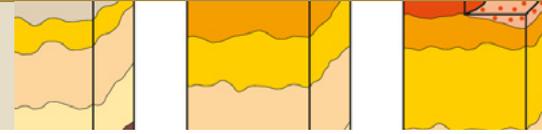
[www.ga.gov.au/ausgeonews/ausgeonews200912/northqld.jsp](http://www.ga.gov.au/ausgeonews/ausgeonews200912/northqld.jsp)



# Weathering intensity map of the Australian continent

*New framework provides new insights into an old continent*

*John Wilford*



A recent study by Geoscience Australia scientists has integrated and modelled geoscientific datasets to generate a weathering intensity index for the Australian continent. Weathering intensity is a fundamental characteristic of the regolith, the often discontinuous and highly variable layer of weathered bedrock and sediments that overlies fresh bedrock at depth. The weathering intensity index has broad applications for a range of natural resource management, environmental, mineral exploration and engineering issues.

Regolith materials cover over 85 per cent of the Australian continent and range from thin, skeletal, soils over slightly weathered bedrock through to very highly weathered bedrock at depths of more than 100 metres below the surface. Important geological and biochemical cycles operate within the regolith zone, including groundwater systems and nutrient cycles involving carbon, nitrogen, oxygen, phosphorus and sulfur, and all elements necessary for life and the biomass. Biogeochemical cycles within this zone are complex and occur across diverse spatial and temporal scales. Northern hemisphere researchers use the term ‘critical zone’ to describe this life-sustaining environment. Critical zone research involves integrated studies of water with soil, air and biota in the near-surface terrestrial environment (Lin 2010).

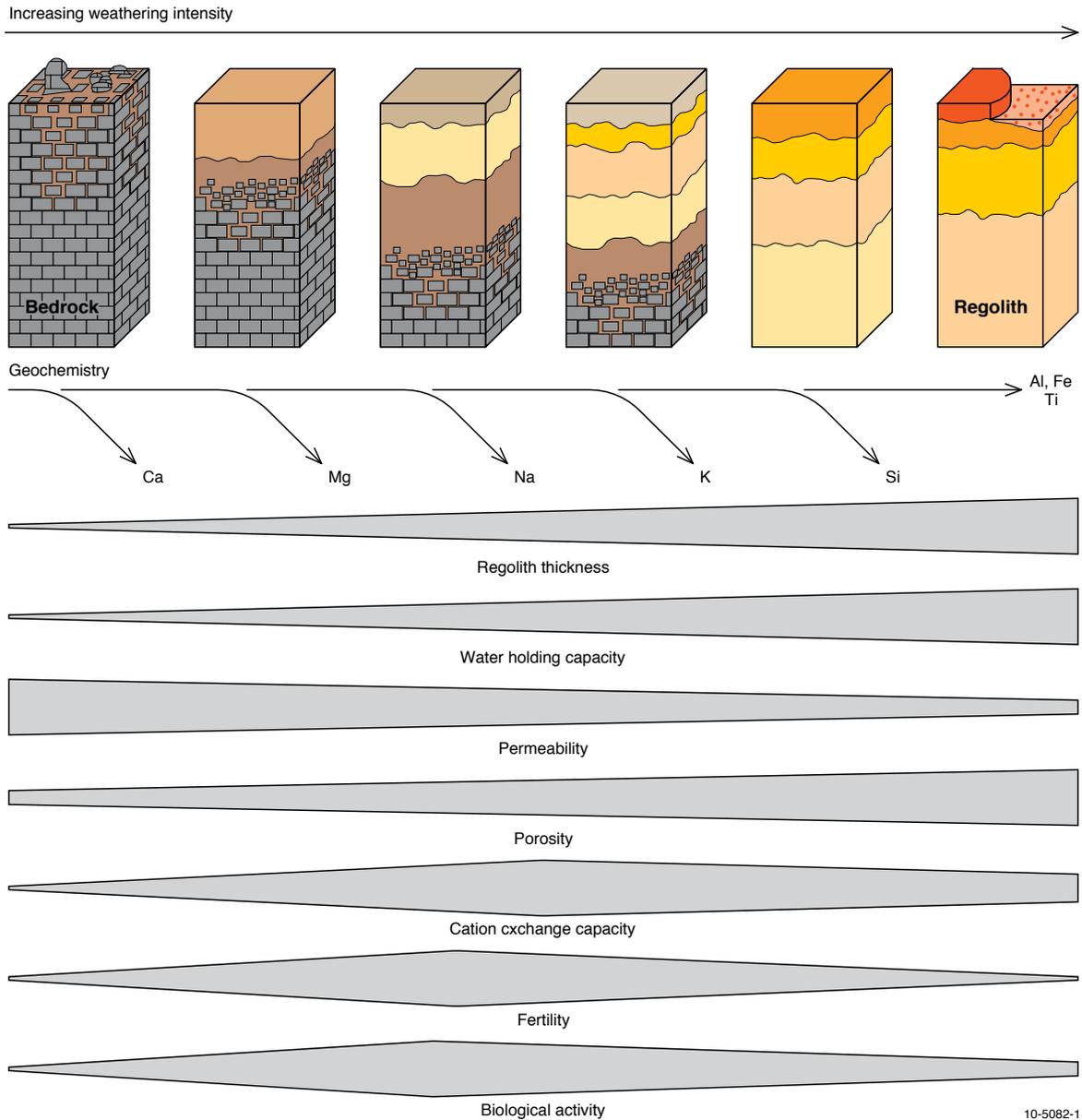
**“The weathering intensity index has broad applications for a range of natural resource management, environmental, mineral exploration and engineering issues.”**

## **The regolith and weathering intensity**

The degree to which the regolith is weathered (or its weathering intensity) is intrinsically linked to the factors involved in soil formation including parent material, climate, topography, biota and time. These processes operate within, and are characteristic of, the critical zone. Typically there is a correlation between the degree of

weathering intensity and the degree of soil development. With changes in weathering intensity we see changes in the geochemical and physical features of rocks, ranging from essentially unweathered parent materials through to intensely weathered and leached regolith where all traits of the original protolith (original unweathered rock) is overprinted or lost altogether. These relationships are summarized in figure 1. An example of these changes is the generation of clays; depending on the parent material and climatic conditions, clays are formed by combining alumina, hydroxide ions and silica. Generally, the amount of clay produced increases as weathering intensity increases and two-layer clays transition to more stable one-layer clays. Since clays have an extremely high surface area and are able to retain water, minerals and nutrients, they are favoured sites for chemical reactions and biological activity in soil.

Geochemical indices have been used to quantify and measure the degree of weathering intensity based on the relative proportions of stable versus mobile elements measured from regolith samples



**Figure 1.** Physical, chemical and biological changes associated with increasing weathering intensity. The trends (shown left to right) are generalised and will change in response to bedrock type and climate. Evolving regolith materials are stylistic and shown in warm hues.

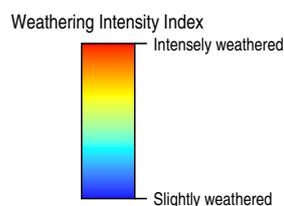
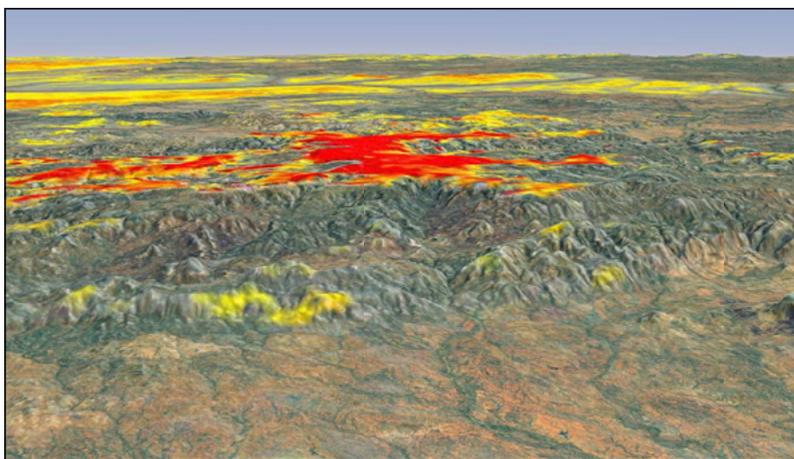
that have been collected down a weathering profile. As weathering intensity increases, soluble elements such as potassium, sodium and calcium are lost in solution while the more stable oxides and resistate minerals (such as zircon) are retained in the regolith. However, a limitation of this approach is that they are single-point/single profile measurements and consequently do not inform on spatial weathering variations across a landscape. This limitation has been addressed in the new study which integrates and models two national geoscientific datasets to generate a prediction of weathering intensity across the surface of the continent as a whole.

## Building a weathering intensity model for Australia

The national weathering intensity prediction has been developed using airborne gamma-ray spectrometric data from Geoscience Australia's Radiometric Map of Australia

and NASA's 90 metre resolution Shuttle Radar Topography Mission (SRTM) elevation data (see Related articles/websites). Airborne gamma-ray spectrometry effectively measures the distribution of three radioelements—potassium, thorium and uranium—in surface bedrock and soil. Most gamma-rays measured at airborne survey heights emanate from the uppermost 30 to 40 centimetres of soil and rock. Variations in concentrations of these radioelements largely relate to changes in the mineralogy and geochemistry of rock and regolith materials. Distributions of these elements change as the primary minerals in the rock weather to secondary components including clay minerals and oxides. Potassium abundance is measured directly as gamma-rays emitted when potassium ( $^{40}\text{K}$ ) decays to argon ( $^{40}\text{Ar}$ ). Uranium and thorium abundances are derived indirectly by measuring gamma-ray emissions associated with the daughter radionuclides bismuth ( $^{214}\text{Bi}$ ) and thallium ( $^{208}\text{Tl}$ ) respectively. As a result they are expressed as equivalent concentrations of uranium and thorium.

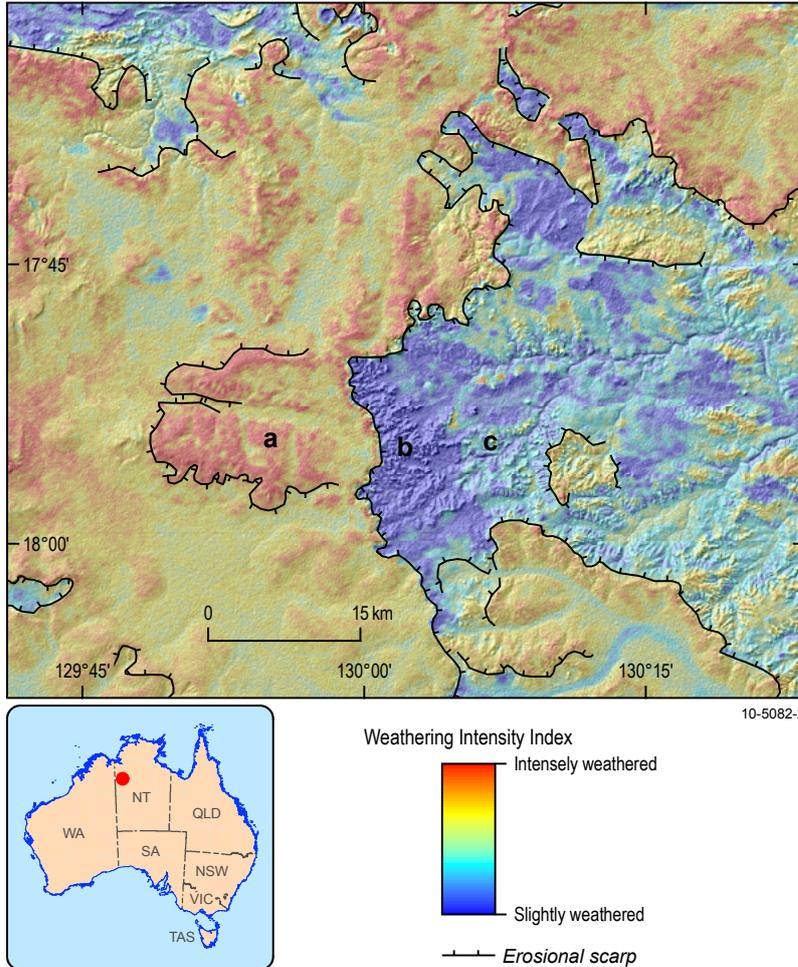
The SRTM elevation data provide digital terrain attributes, such as slope or relief, which are useful because they can indicate geomorphic processes. Areas where bedrock outcrops are relatively unweathered and uneroded can be conspicuous, whilst in other areas, the relative rates of soil removal versus accumulation (that is, denudation balance) can be depicted.



**Figure 2.** Weathering intensity model from a 3D landscape perspective, showing highly weathered Proterozoic granites and Jurassic sandstones over the southern half of the Mt Isa Inlier. Only moderately to highly weathered bedrock is shown.

For generation of the national weathering intensity index, the degree of bedrock weathering was assessed using a six-level, field-based classification scheme. Level 1 describes largely unweathered landscapes with a high proportion of fresh bedrock exposed at the surface, whilst level 6 relates to areas where bedrock is completely weathered to secondary minerals (such as clays and oxides: see figure 1). Over 300 classified field sites were used to establish regression model relationships between the degree of weathering intensity and the environmental covariates (the total count of the three radioelements) and a terrain relief image derived from the elevation model data. A forward stepwise regression model approach resulted in a strong correlation ( $r^2 = .86$ ) between the environmental covariates and weathering intensity observed in the field.

Some rock types contain few or no gamma-emitting radioelements, for example, highly siliceous sandstones or ultramafic rock. Where such materials are exposed at the landscape surface the radioelement distribution obviously cannot be used to predict the degree of weathering. In these cases, a terrain attribute such as relief is used to estimate weathering intensity based on the assumption that those landscapes with high relief are likely to have or maintain thin soil and slightly weathered bedrock. In contrast,



**Figure 3.** The weathering intensity index has the potential to encapsulate landscape evolution in the context of surface age, weathering, and geomorphic processes, and the associated physical and chemical characteristics of the regolith. In this example landscape denudation is largely controlled through a series of retreating erosional scarps. The oldest surface and more intensely weathered regolith occur above the scarp (a) and least weathered materials are exposed at the base of the scarp (b). Surface age increases down-slope and away of the edge of the scarp (c).

low relief landscapes are likely to accumulate and preserve weathered materials (that is, paleo-surfaces) with correspondingly higher weathering intensities. Rocks and sediments with low radioelement emissions are identified using the total count or dose channel of the gamma-ray dataset. For materials emitting low levels of gamma-rays a second regression model has been generated with predictions based solely on terrain relief. The two regression models were subsequently combined to generate the final weathering intensity prediction. Details of the approach are provided in Wilford (2011).

### The index and soil property predictions

The weathering intensity index has broad application in understanding weathering and geomorphic processes across a range of spatial and temporal landscape scales (figure 2). The index can

pinpoint highly weathered paleo-surfaces, assess chemical and physical denudation processes, and map the relative rates of regolith formation and its removal through erosion across different landscapes (figure 3). Calibration of, or linking the weathering intensity model with observed physical, chemical and biological changes within the regolith has the potential to improve our understanding of biogeochemical processes within the critical zone and across large areas, including soil-water interactions and nutrient cycling. The index also has the potential to be used in combination with other environmental covariates in a range of soil property predictions including texture, chemical composition, depth, fertility, pH, porosity and permeability. The latter two properties are important for understanding the way in which solutes move through groundwater and the interflow pathways within the regolith and the consequent hydrogeological processes and characteristics within different landscapes. The weathering intensity index is currently being integrated with other datasets to develop an improved hydrogeological framework to assist in improved salinity and groundwater management (*AusGeo News* 97). Correlations are expected when using the weathering index for broad-scale ecological studies where biological processes are underpinned by soil fertility and water availability. The index



is therefore likely to be useful in mapping and modelling plant types and/or for predicting the distribution of plant communities as well as assisting a more general understanding of the interrelationships between regolith, climate (present and paleo) and vegetation at local, regional or continental scales.

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# Australia's coastline: adapting to climate change

## *Assessing infrastructure vulnerability to rising sea-levels*

*Bob Cechet, Paul Taylor, Christina Griffin and Martyn Hazelwood*

Australia's coastal zone includes major cities and supports major industries such as agriculture, fisheries, and tourism. The zone also includes coastal wetlands and estuaries, mangroves and other coastal vegetation, coral reefs, heritage areas and threatened species or habitats.

All of Australia's major cities (except Canberra) will potentially be affected by rising sea-levels, higher tides and more frequent storms. Perth, Adelaide, Melbourne, Sydney, Brisbane, Darwin and Cairns all include low-lying areas and critically important commercial precincts, infrastructure, and very large numbers of residential properties (figure 1). Much of the residential and commercial infrastructure located near the coastal areas of these cities was built around the port facility which was, historically, the focal point of activity within the community. Most of the road and rail network dates from the early 20th century, and was built around the need for good harbour access both from the sea and the land.

Since the release of the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment in 2007 a considerable body of new data and observation has been compiled. In March 2009 a major climate conference was convened in Copenhagen by the International Alliance of Research Universities. The Conference *Synthesis Report* made a number of significant points, but had one over-riding message: *'key climate indicators are already moving beyond the patterns of natural variability within which contemporary society and economy have developed and thrived'*.

In 2008, researchers told the Parliamentary Inquiry into climate change and environmental impacts on coastal communities



**Figure 1.** Aerial view of Gold Coast skyline (image courtesy of Wikipedia.org).



**Figure 2.** Coastal erosion at Wamberal beach, New South Wales, in 1978.

(Commonwealth of Australia 2009) that Australia's coastline is especially vulnerable which echoed the sentiments expressed in the National Climate Change Adaptation Framework (NCCAF 2007). Adaptation to sea-level rise is therefore a key challenge, and includes coastal modification (erosion control measures), engineering solutions (barrages and weirs), or even re-location of communities.

Geoscience Australia has recently completed the 'First-Pass' Australian National Coastal Vulnerability Assessment (NCVA; Cechet et al 2011), which was commissioned by the Australian Government Department of Climate Change to assess the vulnerability of coastal communities to rising sea-levels. This first-pass national assessment includes an evaluation of the exposure of infrastructure (residential and commercial buildings, as well as roads and major infrastructure such as airports) to sea-level rise and storm tide.

## The threat

More than 80 per cent of Australians live within the coastal zone. Chen & McAneney (2006) estimate that approximately six per cent of Australian addresses are within three kilometres of the shoreline and in areas less than five metres above mean sea-level (about 700 000 residences; Commonwealth of Australia 2009). In addition, a significant number of Australia's ports, harbours and airports would be under threat. A number of important environmental, biological and heritage sites are situated within the coastal zone, and tourism is a major industry.

### Causes and effects of rising sea-levels

**Tides and storm surges:** Climate change will not be a simple, uniform warming process, but will vary from region to region. Changing climate will bring changing weather, with associated changes to wind strength and direction affecting storm tides riding on raised sea-levels.

**Ocean currents:** Currents on the Australian west and east coasts will strengthen as more heat is transported from the tropics to the mid-latitudes resulting in impacts on coastal ecosystems.

**Inundation:** Even if the sea were totally calm, significant areas of Australia's coastline will be flooded if sea-levels rise as predicted.

**Erosion:** Soft coastlines are potentially mobile because of rising sea level.

**Salinisation:** Groundwater, estuaries, lakes and rivers will be 'invaded' by salty sea water, altering and causing massive changes to coastal ecosystems.

## Assessing coastal vulnerability at the national scale

Adapting to climate change and coastal variation will be a major challenge for communities and governments in the 21st century. The first requirement for meeting this challenge is accurate knowledge of the coastal zone and its properties as well as knowledge of the infrastructure (that is, a comprehensive national set of underpinning data).

As data collection is usually based within local and state jurisdictional boundaries, Geoscience Australia has managed the development of two nationally consistent databases describing Australia's infrastructure assets and coastal geomorphology. These databases (NEXIS and Smartline) contain information collected from local and state government agencies, scientific institutions and the private sector which has been reformatted into a consistent standard to allow national-scale assessments.

## The National Exposure Information System

The *National Exposure Information System* (NEXIS) is a significant national initiative being developed at Geoscience Australia. The system is capable of providing the necessary information about infrastructure exposure for risk assessments by supplying comprehensive and nationally consistent data. It has been categorised into residential, business (commercial and industrial), institutions and transport infrastructure (roads; highways, local roads and unsealed roads; rail, ports and airports). This information has been collated at the local level and has been applied at the national scale using reasonable and logical assumptions and expressions.

NEXIS is derived primarily from reliable and publicly available datasets, and maintains information that spatially locates buildings and infrastructure and their attributes and is compatible with multi-hazard vulnerability assessment models. NEXIS also provides nationally consistent generic infrastructure exposure information (at building level) derived from statistical sampling of data-rich regions and supplies the output nationally through a set of rules and assumptions. The information has already been applied for a range of threats anywhere along Australia's coast, including sea-level rise, extreme weather, and other threats to communities and infrastructure.

## Smartline

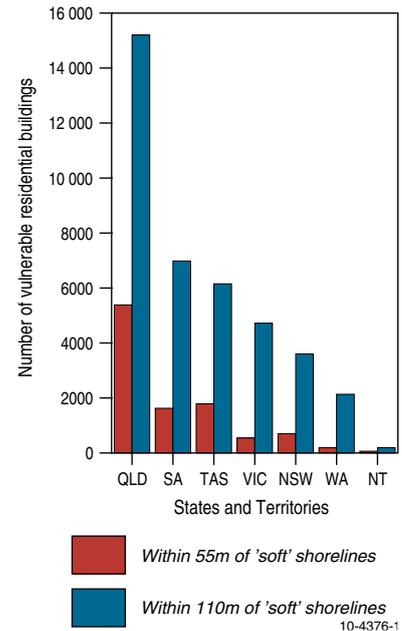
The National Coastal Landform and Stability Mapping Tool (Smartline) was created by a team of specialists at the University of Tasmania and is managed by Geoscience Australia. Smartline is an accurate representation of the high-water mark around the coast. Information is embedded in a line map in detailed segments so that the landform type, bedrock geology and exposure of the coast to wave action can be identified. The line classifies the backshore, intertidal and subtidal zones, and is segmented each time a change in the coastal environment attributes occurs.

As part of the NCVA, Smartline has been used to classify coastal zones that are potentially unstable (based on the geomorphology), and therefore more susceptible to the effects of sea-level rise, including coastal erosion and recession. One of the expected impacts from climate change is accelerated coastal recession due to rising sea-levels, although rates and location of recession are highly dependent on several factors. These include the inherent susceptibility of differing coastal landform types, regional variations in the processes driving erosion/recession or instability (for example, sea-level rise and wave climate), and local factors such as topography and sediment budgets. An example of the impact of coastal erosion on residential infrastructure is shown in figure 2. In 1974 and 1978, the Wamberal beach region of central New South Wales suffered significant coastal erosion because of wave energy associated with severe Tasman Sea storm events.

Smartline has been used to determine the length of each landform stability class in Australia. Approximately 63 per cent of the Australian coast is composed of either sandy or muddy shores. The remainder is composed of 'soft' rock or 'hard' rock shores. Approximately 47 per cent of sandy and muddy shores are backed by soft sediments (as opposed to bedrock) and are therefore potentially mobile. This is a significant statistic as it encompasses shores which are both unimpeded by human structures and those in more built-up areas where migration of 'soft' shorelines will generate planning and management issues for communities. Sandy shores make up 30 per cent of the 'free-moving', unimpeded shores while the remaining 17 per cent are muddy shores. The identification of potentially mobile shores is significant for the implementation of successful coastal planning for climate change adaptation.

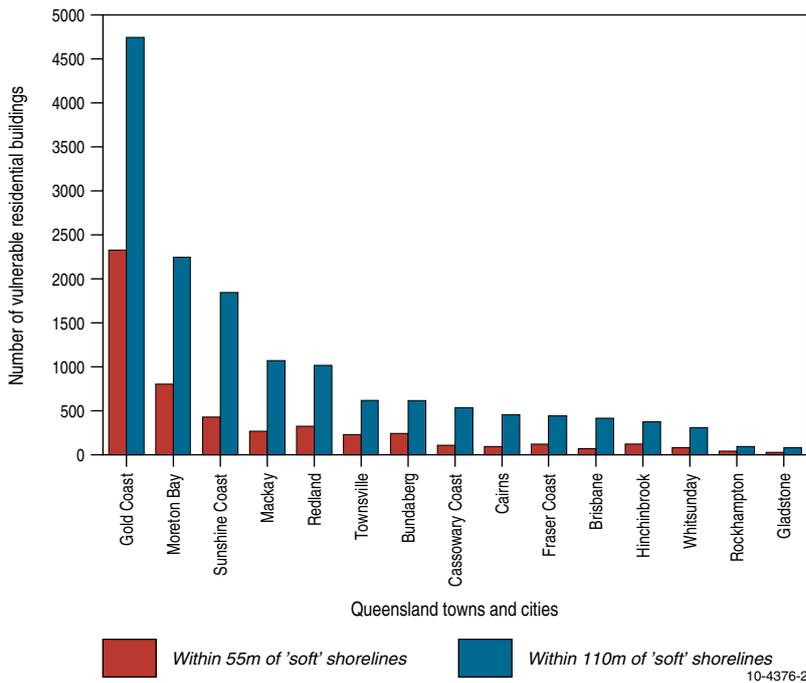
## Residential infrastructure vulnerable to erosion

By identifying soft and potentially erodible shores the Smartline was used to develop *Zones of Potential Instability* (ZPI). Using the sea-level rise scenario outlined on page 4, the ZPIs were used to generate a new potential shoreline position. This shoreline position was integrated



**Figure 3.** Number of residential buildings (by state and territory) located within 55 and 110 metres of 'soft' shorelines (simulating the average and maximum extents of coastal recession by 2100).

with NEXIS to determine the number of buildings which would be vulnerable to recession. Utilising the simple Bruun Rule (Bruun 1962) for recession (that is, recession distance equals 100 times the sea-level rise height) as the risk-averse scenario and half this distance as the risk-tolerant scenario and based on a sea level rise of 1.1 metres by 2100, we assumed that 'soft' shorelines could recede between 110 and 55 metres inland respectively. Figure 3 shows the number of residential buildings (by state or territory) located within 55 and 110 metres of 'soft' shorelines. The number of residential buildings in Queensland (by local government area or LGA) located within 55 and 110 metres of 'soft' shorelines is shown in figure 4. Across Australia, nearly 39 000



**Figure 4.** Number of residential buildings in Queensland (by LGA) located within 55 and 110 metres of 'soft' shorelines (simulating the average and maximum extents of coastal recession by 2100).

residential buildings are located within 110 metres of potentially erodible shorelines, with nearly 40 per cent of those buildings located in Queensland. There was no consideration of any existing, planned or future protective structures associated with the estimates of buildings at risk by 2100. Local sediment processes, such as accretion, were not considered.

### Inundation mapping

An assessment of the vulnerability of the coast to inundation requires an accurate understanding of coastal elevation. A Digital Elevation Model (DEM), which represents in a national-scale map the height above sea-level for each grid cell, was a key dataset for a national assessment of potential coastal inundation. Elevation data and modelling options were assessed by the Spatial Information Council and the Cooperative Research Centre for Spatial Information (CRCSI). The Australian Government decided to invest in a mid-resolution DEM covering the entire coast derived from SPOT *High Resolution Stereoscopic Reference3D* satellite imagery.

The SPOT DEM has a horizontal resolution of approximately 30 metres (that is, 30 metres by 30 metres elevation grid) and a vertical height resolution of one metre (that is, elevation of the surface is in intervals of one metre in height). Limited localised comparisons with high resolution LiDAR (*Light Detection and Ranging*) elevation data (approximately 10 to 15 centimetres vertical

accuracy and a horizontal resolution in the order of metres) indicated that the SPOT DEM generally provided an adequate representation of the shape of coastal elevation. This applied even if the SPOT DEM heights were not exactly correct, however relative patterns of inundation could be obtained. For a whole of continent 'first-pass' national analysis the SPOT data was assessed as 'fit-for-purpose'.

The core data elements of the inundation mapping were:

- *Sea-level rise* (SLR) estimated as a maximum of 1.1 metres by the year 2100 was selected for this assessment. This was based on the plausible range of sea-level rise values from research since the IPCC Fourth Assessment Report and because nearly all of the uncertainties in sea-level rise projections operate to increase rather than lower estimates of sea-level rise (Department of Climate Change 2009). This should be considered a high-range estimate of SLR suitable for long-term planning purposes.
- *Storm tide* was estimated from models using observations from tide gauges, global tide data and wind models. Storm tides data for one in 100 year events were provided for Victoria, Tasmania and New South Wales (McInnes et al 2009A). Storm tide values are the estimated current climate 'one in 100 year storm surge' value combined with the

normal tidal component. McInnes et al (2009B) considered the frequency of extreme events in south-eastern Australia and found that storm surges, which occur once in 100 years at present, could now be expected on average once every 40 years by 2030. The impact of climate change on storm tide is not being considered in this first-pass study.

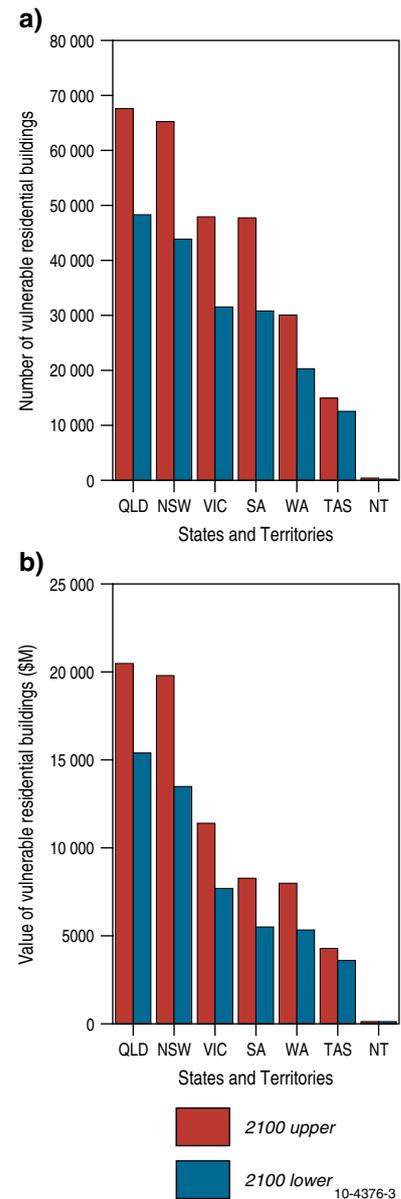
- *Mean High Water Level and observed/recorded storm tide.* For remaining areas (Northern Territory, Queensland, South Australia and Western Australia), tidal heights were obtained from continent-wide tidal height predictions (essentially modelled Mean High Water Level values) from the National Tidal Centre at the Bureau of Meteorology.

### Modelling coastal vulnerability

The assessment methodology involved modelling the area of coastal inundation by projecting inland an undisturbed and level seawater surface ('bath tub approach') which utilised the previously described data inputs and the SPOT DEM. The resulting coastal inundation polygons were integrated with NEXIS to provide an analysis of vulnerability, in terms of potentially affected property and infrastructure and the cost of replacement. Counts of the number of residential and commercial buildings located within the inundation polygons and their replacement value were provided as well as the lengths of road and rail infrastructure and their values. Building counts/values and road/rail lengths/values were assessed at local government area (LGA) for an upper and lower end estimate of vulnerability. These were derived by undertaking comparisons of inundation footprints generated using the higher vertical/horizontal resolution LiDAR elevation data (where available) with those derived using the SPOT DEM to capture uncertainty in the estimates.

The Zones of Potential Instability were then integrated with the coastal inundation polygons to estimate the combined impact of inundation and potential recession. This analysis does not include the potential impacts of inland flooding converging with coastal (ocean) inundation. Convergence of inland flooding and coastal inundation could greatly increase the areas potentially inundated.

Table 1 shows the vulnerability of residential infrastructure (by state or territory) considering inundation and erosion impacts both separately and when combined. Queensland and New South Wales have the greatest vulnerability when considering both the value of the infrastructure and also the number of buildings affected. Figure 5 shows the number and replacement value of potentially vulnerable residential buildings (by state and territory) considering the combined impacts of both inundation and recession. Nationally, residential buildings valued at \$64 billion are vulnerable to inundation, and this



**Figure 5.** Number (a) and value (b) of potentially vulnerable residential buildings (by state and territory) considering the combined impacts of both inundation (1.1 metre sea level rise (SLR) and storm tide) and recession (Bruun rule; 100 times SLR). Values are based on the 'upper' and 'lower' estimates derived by localised validation/comparison utilising LiDAR elevation data.

value increases to \$72 billion when considering the combined vulnerability to both inundation and recession. Figure 6 shows the length (in kilometres) of

**Table 1.** Number and value of residential buildings vulnerable to the impacts of coastal inundation, recession and the combination of inundation and recession for all states and the Northern Territory. The values consider a sea-level rise of 1.1 metres by 2100 in combination with a sea-level increase from a one in a 100 year return-period storm surge event (for New South Wales, Victoria and Tasmania) and the spring high-water tide for all other states. Values are based on the ‘upper’ estimates derived by localised validation/comparison with LiDAR elevation data.

State	‘Inundation’ only		‘Recession’ only (Zone of Potential Instability)		Inundation + Recession (Zone of Potential Instability)	
	Number	Value (\$mil)	Number	Value (\$mil)	Number	Value (\$mil)
New South Wales	62 400	19 000	3 600	1 260	65 200	19 800
Northern Territory	200	60	200	80	400	130
Queensland	56 900	16 000	15 200	5 800	67 700	20 500
South Australia	43 000	7 400	7 000	1 300	47 800	8 300
Tasmania	11 600	3 300	6 100	1 800	14 900	4 300
Victoria	44 700	10 300	4 700	1 450	48 000	11 400
Western Australia	28 900	7 700	2 100	600	30 000	8 000
<b>AUSTRALIA</b>	<b>247 700</b>	<b>63 760</b>	<b>38 900</b>	<b>12 290</b>	<b>274 000</b>	<b>72 430</b>

vulnerable roads and railway (by state or territory) considering the combined impacts of both inundation and recession. The more populous states of Queensland, New South Wales and Victoria figure prominently with regard to vulnerability. For figures 5 and 6, the values are based on the ‘upper’ and ‘lower’ estimates derived by localised validation/comparison utilising LiDAR elevation data.

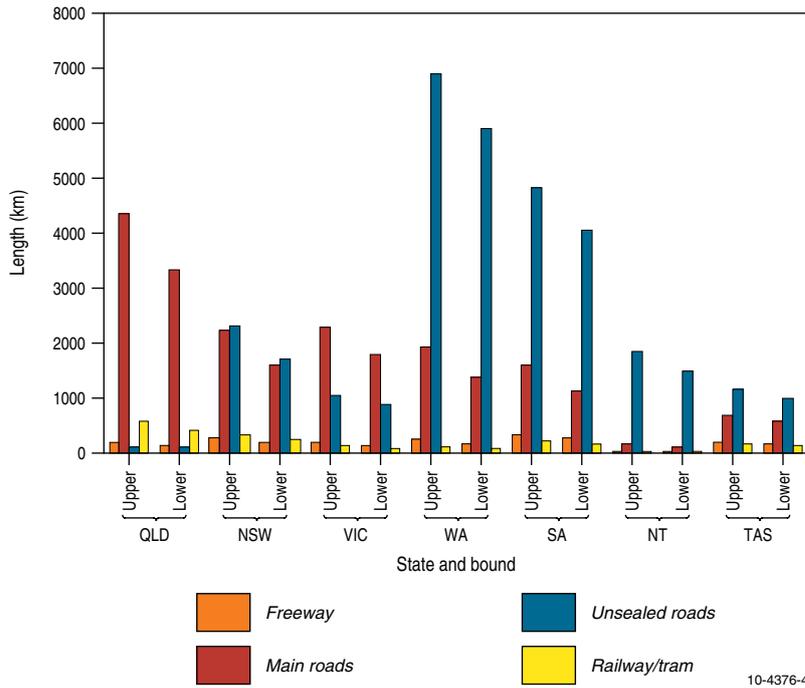
### Impact of population pressures on vulnerability to inundation/recession

The Australian Bureau of Statistics (ABS 2009) suggests that Australia’s population will increase to between 30.9 and 42.5 million people by 2056, and between 33.7 and 62.2 million people by 2101. It is predicted that a large percentage of this increased population will live in the coastal zone (as at present), particularly if climatic predictions of higher inland temperatures are correct. Along the eastern seaboard in particular, the coastline is developed for residential use and is heavily populated. Increased population will put greater pressure on the coastal zone, and this gives a particular urgency to the need for adaptation to rising sea-levels.

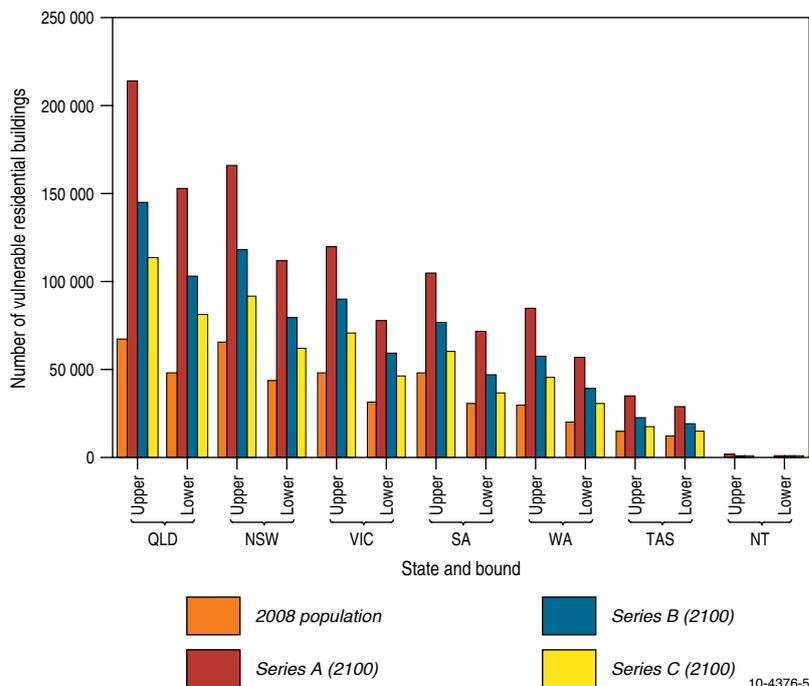
The ABS population projections simply illustrate the growth and change in population that would occur if certain scenarios about future levels of fertility, mortality, internal migration and overseas migration were to prevail over the period of the projection (that is, in a similar way to the climate projections/scenarios). These assumptions incorporate recent trends which indicate increasing levels of fertility and net overseas migration to Australia. Three main series of projections—the ABS’s Series A, B and C—are utilised. Series

B largely reflects current trends in fertility, life expectancy at birth, net overseas migration and net interstate migration, whereas Series A and Series C are based on the high and low assumptions for each of these variables respectively. As Australia is considered by the rest of the world to be a sparsely populated continent, the combination of global climate change and global population pressures could lead to acceptance of more overseas migration. This would make projections at the higher end of the range (Series A) more likely.

Considerable research has been carried out by Geoscience Australia and others investigating levels of occupancy, housing construction methods, and household income, with a view to compiling a nationwide measure of the cost of replacement of assets. Existing commercial property databases (such as CityScope) covering the



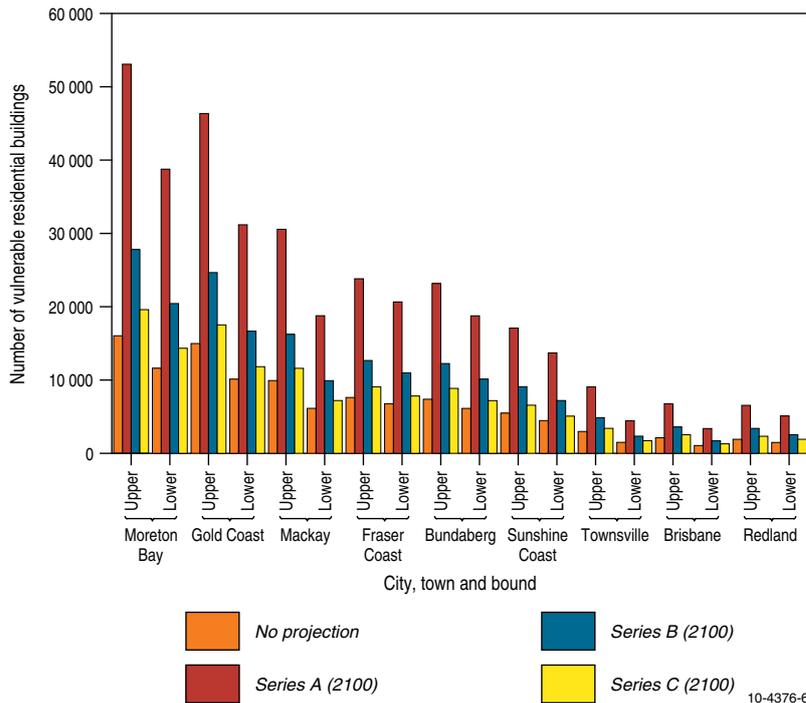
**Figure 6.** Length (in kilometres) of vulnerable roads/railway (by state and territory) considering the combined impacts of both inundation (1.1 metre SLR and storm tide) and recession (Bruun rule; 100 times SLR). Values are based on the 'upper' and 'lower' estimates derived by localised validation/ comparison with utilising elevation data.



**Figure 7.** Number of vulnerable residential buildings (from inundation and recession) under 2100 sea-level using the current (2008) population and also the ABS Series A, B and C population projections.

main urban centres have been supplemented by Geoscience Australia's research. For this study we have used the Series A, B and C population projections to illustrate the change in exposure with respect to residential structures. Projections of residential infrastructure exposure (within NEXIS) maintain the current ratio of people (occupants) per building within each statistical local area (1500 plus regions across Australia). In addition, for the period post-2056, we have maintained the ratio of local to national change in order to maintain the 2056 local trend (for each series) up to the end of the 21st century. The current ratio of people per building has been gradually reducing over the past four decades; however for this task we have maintained it at current levels. We believe this is a realistic assumption as it is counteracted by the recent trend of increasing medium density (multi-storey) developments, which have a lower vulnerability to inundation.

Figure 7 shows the number of vulnerable residential buildings (from inundation and recession) under the 2100 projected sea-level and current (2008) population as well as the ABS Series A, B and C population projections. Potential vulnerability is significantly increased by the ABS Series A and B population projections. In fact for the Series A projection the increase in sea-level has a smaller impact on the vulnerability compared to



**Figure 8.** Number of vulnerable residential buildings (from inundation and recession) in Queensland (by LGA) under 2100 sea-level using the current (2008) population as well as the ABS Series A, B and C population projections.

the increase in population (see figure 7; note the additional part of the bar above the level for 2100 sea-level and 2008 population). For the Queensland region, Figure 8 shows the number of vulnerable residential buildings (from inundation and erosion) for the most impacted LGAs (considering the 2100 sea-level with the 2008 population, and also ABS Series A, B and C population projections). The south-east corner of Queensland where most of the vulnerability for residential infrastructure is located (see figure 8), is currently experiencing large population growth and an associated building boom. All along the entire eastern seaboard, including South East Queensland, adaptation to rising sea-levels is becoming a priority for local councils battling to implement sound controls as increased population puts greater pressure on the coastal zone.

### Summary and Conclusions

The Australian Government has developed a three-part response to climate change:

- helping to shape a global conclusion
- reducing Australia’s greenhouse gas emissions
- adapting to unavoidable climate change.

Adaptation recognises that, whatever policy decisions are made at present, some degree of climate change has become inevitable, and therefore some adaptation to this is equally inevitable. Australia’s long coastal zone is particularly vulnerable, and the capacity to adapt will be of critical importance.

The National Coastal Vulnerability Assessment (NCVA), which is part of the government’s adaptation plan, has provided an assessment of the future implications of climate change for Australia’s coastal zone, with a particular focus on coastal infrastructure and settlements. Further information on the study, including a breakdown of results for each state and territory by LGA with regards to the residential, commercial and road/rail vulnerability, can be found on the NCVA webpage which is located on Geoscience Australia’s *OzCoasts* website. The NCVA will inform the Australian Government’s consideration of national priorities for adaptation to reduce climate change risk in the coastal zone. The NCVA has:

- Provided an initial assessment of the implications of climate change for nationally significant aspects of Australia’s coastal regions (national overview and for key regions).
- Identified national priority regions to support effective adaptation policy responses in the coastal zone.



- Identified key elements of a nationally coordinated approach to reducing climate vulnerability and risk in the coastal zone.
- Located and begun the process of remedying shortfalls in research, as well as creating a national standard for comparison.

In collaboration with state and local governments and private industry, this assessment will provide information for application to policy decisions for, inter alia, land use, building codes, emergency management and insurance applications.

### **For more information**

email [ausgeo@ga.gov.au](mailto:ausgeo@ga.gov.au)

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NCCAF. 2007. National Climate Change Adaptation Framework. Available at:

[www.coag.gov.au/coag\\_meeting\\_outcomes/2007-04-13/docs/national\\_climate\\_change\\_adaption\\_framework.pdf](http://www.coag.gov.au/coag_meeting_outcomes/2007-04-13/docs/national_climate_change_adaption_framework.pdf)

### **Related websites/articles**

International Alliance of Research Universities. The Synthesis Report of the Conference [climatecongress.ku.dk/pdf/synthesisreport](http://climatecongress.ku.dk/pdf/synthesisreport)

For more information on sea-level rise please visit

[www.cmar.csiro.au/sealevel/sl\\_hist\\_intro.html](http://www.cmar.csiro.au/sealevel/sl_hist_intro.html)

OzCoasts (accessible through the Geoscience Australia website)

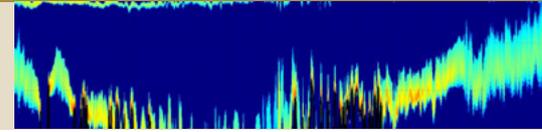
[www.ozcoasts.org.au/climate/index.jsp](http://www.ozcoasts.org.au/climate/index.jsp)



# Onshore Energy Security Program update

*Delivering data and improved scientific understanding*

*Marina Costelloe, Ross Brodie and Jenny Maher*



Geoscience Australia's Onshore Energy Security Program (OESP) is a five-year program announced in August 2006 designed to reduce risk in exploration and support development of Australia's onshore energy resources.

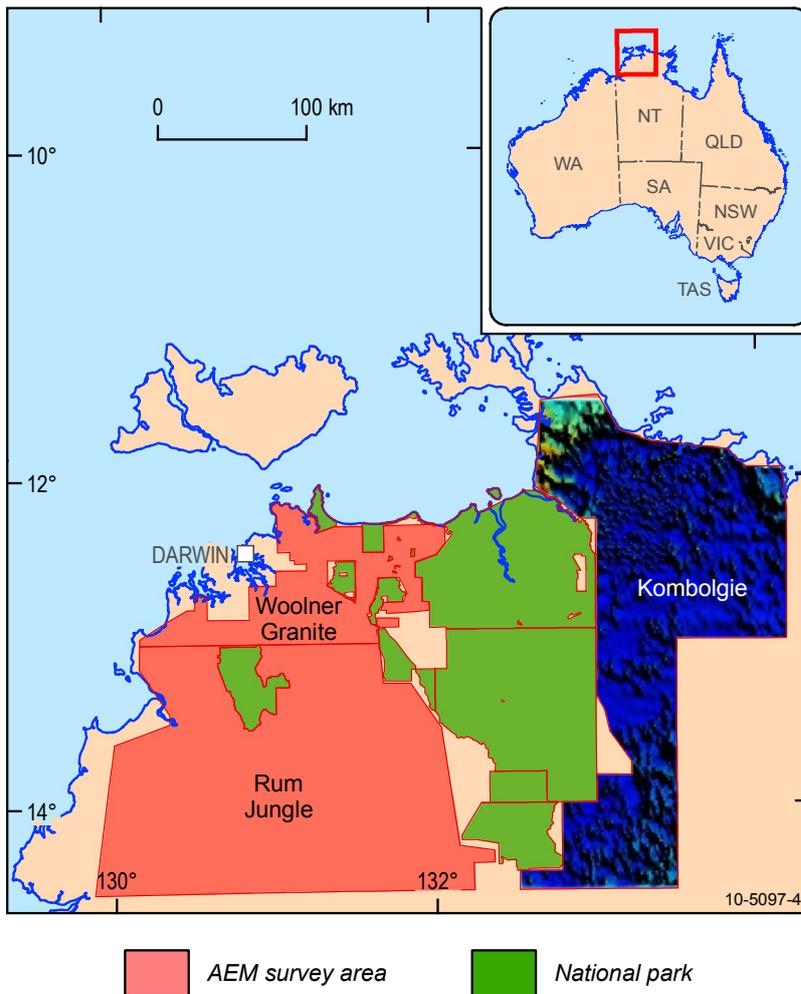
A full description of OESP projects can be found on the Geoscience Australia website and new data releases and updates are announced through Geoscience Australia's monthly newsletter *Minerals Alert*.

## Kombolgie airborne electromagnetic survey goes deeper

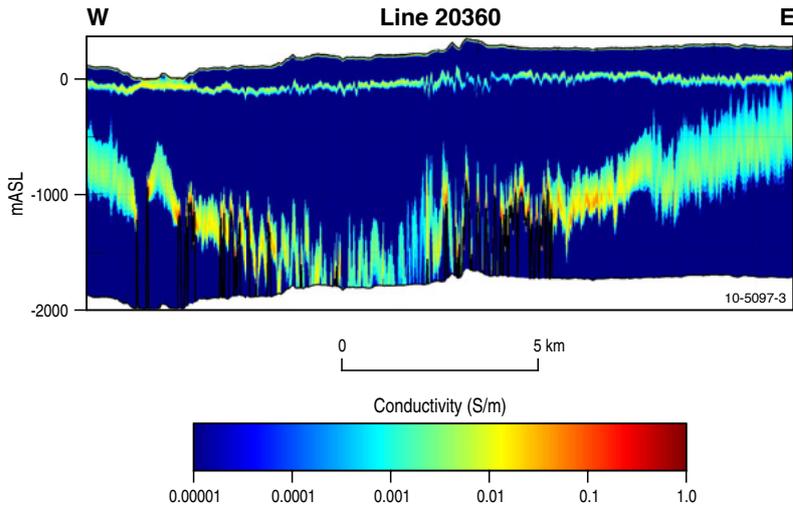
Geoscience Australia's Onshore Energy Security Program (OESP) has acquired airborne electromagnetic (AEM) data in areas considered to have potential for uranium or thorium mineralisation. These surveys, which are managed and interpreted by scientists at Geoscience Australia, are designed to reveal new geological information at a regional scale rather than deposit-scale.

The Pine Creek AEM survey area (figure 1) is comprised of three survey areas: Woolner Granite, Rum Jungle and Kombolgie. The TEMPEST™ AEM system was used for the Woolner Granite and Rum Jungle surveys whilst the Versatile Time Domain Electromagnetics (VTEM™) system was used for the Kombolgie survey.

The main geological target in the Kombolgie survey area, which contains the Nabarlek uranium deposit, was the Paleoproterozoic Katherine River Group metasediment unconformity. The survey covered sections of the Alligator River, Cobourg Peninsula, Junction Bay, Katherine, Milingimbi and



**Figure 1.** Pine Creek Survey boundary locations. The Kombolgie Survey area is highlighted with an image of the estimated conductance to 2000 metres. Geoscience Australia funded 5000 metre line spacing across the entire Kombolgie survey and an infill area at 1666 metre line spacing.



**Figure 2.** Conductivity for a portion of Kombolgie survey line 20360 section showing a coherent conductivity feature to 2000 metres.

Mount Evelyn 1:250 000 map sheets (Costelloe et al 2009). In the Kombolgie survey, flown during 2008, 8800 line kilometres of VTEM™ data were acquired, covering an area of 32 000 square kilometres.

In 2009 the processed response data and conductivity estimates to 600 metres depth were produced by the survey contractor Geotech Airborne using commercial version (3.30) of EM Flow™ (Macnae et al 1998; Stolz and Macnae 1998), The Phase-1 Kombolgie conductivity estimates were made available through the Geoscience Australia Sales Centre.

Further research was carried out in order to extract additional value from the electromagnetic data. In this process, Richard Lane of Geoscience Australia and Professor James Macnae of the Royal Melbourne Institute of Technology, discovered that in parts of the survey area geologically plausible conductivity estimates could be generated to depths exceeding 1500 metres (figure 2).

Consequently, reprocessing of the Kombolgie AEM data by Geoscience Australia, using a more recent version (5.23-13) of EM Flow™, has produced an enhanced set of conductivity estimates. These reveal new geological information including subsurface geological features that are associated with unconformity-related as well as sandstone-hosted Westmoreland-type and Vein-type uranium mineralisation. The datasets are also suitable for interpretation focussed on other commodities including metals and potable water as well as for landscape evolution studies. The improved understanding of the regional geology to depths greater than 1500 metres in selected areas will be of considerable benefit to mining and mineral exploration companies.

Full results and interpretation from the Pine Creek Airborne Electromagnetic Project, including the Kombolgie VTEM™ Survey, will be presented at an industry workshop immediately after the

Northern Territory Geological Survey's Annual Geoscience Exploration Seminar to be held in Alice Springs on 24 March 2010. A one-day workshop for industry and other stakeholders will be held in Perth on 7 June.

The new conductivity sections are now available through the Geoscience Australia website free of charge.

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### Related websites/articles

Enhanced set of conductivity estimates for the Kombolgie region within the Pine Creek survey area

[www.ga.gov.au/products/servlet/controller?event=GEOCAT\\_DETAILS&catno=71371](http://www.ga.gov.au/products/servlet/controller?event=GEOCAT_DETAILS&catno=71371)

Kombolgie Phase-1 VTEM™ data and processing report.

[www.ga.gov.au/products/servlet/controller?event=GEOCAT\\_DETAILS&catno=71372](http://www.ga.gov.au/products/servlet/controller?event=GEOCAT_DETAILS&catno=71372)

The Versatile Time Domain Electromagnetics (VTEM™) system operated by Geotech

[www.geotech.ca/index.php?option=com\\_content&task=view&id=2&Itemid=53](http://www.geotech.ca/index.php?option=com_content&task=view&id=2&Itemid=53)

Geoscience Australia's Onshore Energy Security Program

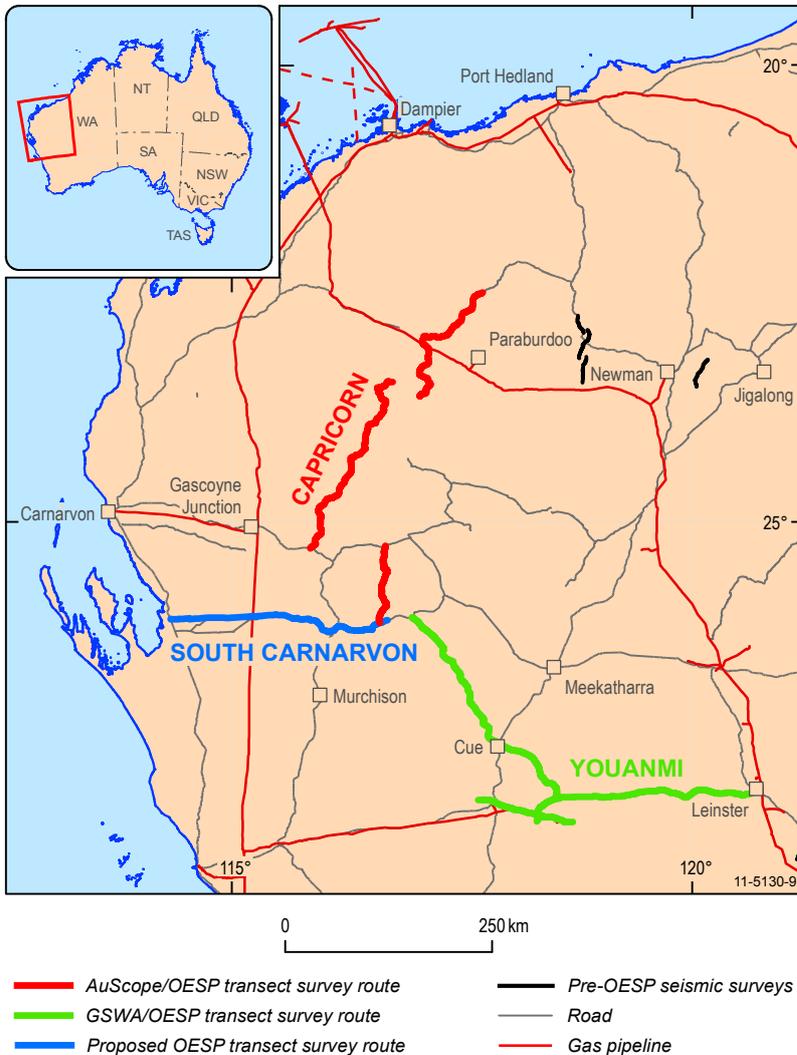
[www.ga.gov.au/energy/energy-security-program/onshore-energy-security.html](http://www.ga.gov.au/energy/energy-security-program/onshore-energy-security.html)

### Onshore seismic program

Regional scale, deep crustal seismic surveys have been a major component of the Onshore Energy Security Program (OESP). To date, thirteen seismic surveys have been conducted as part of the Program and the datasets and products from these surveys are being released progressively as processing and interpretation is completed. These data are accessible via the Geoscience Australia website.

A major survey was proposed to image the Kidson Sub-basin, an under-explored depocentre of the Canning Basin in Western Australia, as the final seismic acquisition under the OESP (see *AusGeo News* 97). However this survey had to be deferred because it was not certain that land access negotiations could be completed for the data acquisition to commence before the end of the OESP.

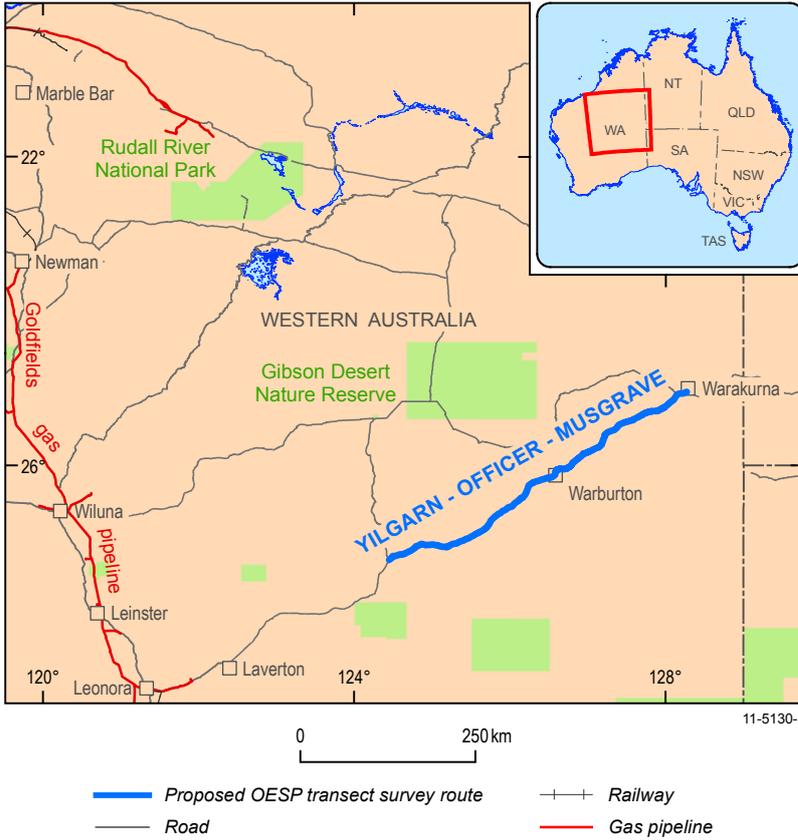
Instead seismic data will now be acquired over the South Carnarvon Basin and the Officer Basin in Western Australia. The South Carnarvon survey aims to image the Byro Sub-basin, an under-explored depocentre with both hydrocarbon and geothermal energy potential. The sub-basin is in the onshore section of the Carnarvon Basin, Australia's premier petroleum producing province (figure 3). The acquisition phase of this survey is scheduled to commence in April 2011 and the resulting datasets will link with data acquired by Geoscience Australia during the offshore Southwest Frontiers Project in late 2008 and early 2009.



**Figure 3.** Location map for the planned South Carnarvon Basin seismic survey in Western Australia (in blue). The Capricorn Seismic Line (in red) and the Youanmi Seismic Line (in green) were acquired in 2010.



**Figure 4.** Seismic trucks during the Capricorn seismic survey in WA.



**Figure 5.** Location map for the planned Yilgarn–Officer–Musgrave seismic survey in Western Australia.

The Yilgarn–Officer–Musgrave survey aims to image the western Officer Basin, another of Australia’s under-explored sedimentary basins with hydrocarbon potential (figure 5). The survey data will

also build on the geoscientific knowledge of the architecture of Australia’s crust and the region’s relationship with the western Yilgarn and central Musgrave cratons.

Acquisition of seismic data in this area is planned to commence in May 2011.

**For more information**

email [ausgeo@ga.gov.au](mailto:ausgeo@ga.gov.au)

**Related websites/articles**

Seismic Acquisition & Processing.

[www.ga.gov.au/minerals/projects/current-projects/seismic-acquisition-processing.html](http://www.ga.gov.au/minerals/projects/current-projects/seismic-acquisition-processing.html)

*AusGeo News 97:* Onshore Energy Security Program maintains momentum

[www.ga.gov.au/ausgeonews/ausgeonews201003/oesp.jsp](http://www.ga.gov.au/ausgeonews/ausgeonews201003/oesp.jsp)

Southwest Frontiers Project

[www.ga.gov.au/energy/projects/southwest-frontiers.html](http://www.ga.gov.au/energy/projects/southwest-frontiers.html)



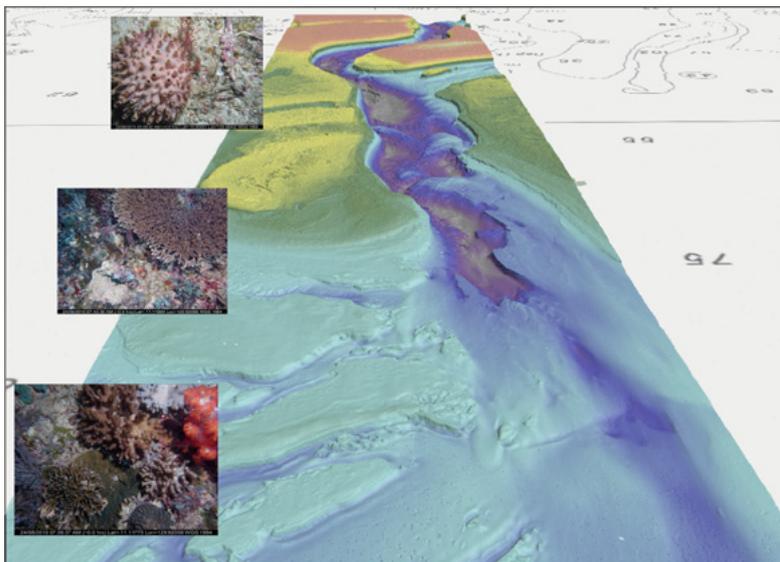
## Seabed mapping off northern Australia

Nine Geoscience Australia scientists participated in a month-long seabed mapping survey to the Van Diemen Rise, eastern Timor Sea, off the coast of the Northern Territory. The survey, which ran from 30 July to 26 August 2010, was the second survey in the area following an initial survey to the region in 2009 (*AusGeo News* 97).

This second survey added more detail to the 2009 survey results and addressed specific research questions posed by Australia's offshore oil and gas industry regarding the distribution of unique and sensitive seabed habitats and potential geohazards such as petroleum seeps in the region.

More than 600 square kilometres of additional seabed environments were mapped. Initial findings show shallow carbonate banks that are partially covered by a hard crust that supports luxurious sponge and coral gardens. The deeper channels are characterised by strong tidal currents with floors covered by muddy sands that contain abundant animals. Conversely, the sediment plains are characterised by muddy sands and relatively sparse biota. Large areas of the seabed on the soft sediment plains and on the floor and sides of the channels contain pock marks up to two metres deep and 20 metres in diameter. Abundant branching coral debris was also observed at one location on the outer shelf indicating that hard corals were once more extensive than at present. Several new species have already been identified from the 2009 survey, and more discoveries are likely from the new samples.

Data from the survey will be used to more fully characterise seabed environments in Northern Australia; namely, shallow (less than 200 metres) carbonate banks, deeper intervening channels, and flat sediment plains.



**Figure 1.** A 3D perspective of new bathymetry data and seabed biota collected on the Van Diemen Rise, Timor Sea off northern Australia.

This survey was part of a three-year collaboration between Geoscience Australia and the Australian Institute of Marine Science (AIMS) involving marine surveys off northern Australia using Geoscience Australia's shallow multibeam sonar system and AIMS' research vessel *Solander*. In addition to nine researchers from Geoscience Australia, the survey included researchers from the Australian Hydrographic Office, Museum and Art Gallery of Northern Territory, and Geological Survey of Canada.

It is planned that the major analyses and interpretations from this survey will be completed by mid-2011. These data will be incorporated with other regional data to produce reports and maps that describe and show the location of different seabed environments and geohazards. They will provide pre-competitive information and data for Australia's offshore oil and gas industry as well as support environmental regulation for planned infrastructure development in the region.

### **For more information**

email [ausgeo@ga.gov.au](mailto:ausgeo@ga.gov.au)

### **Related websites/articles**

*AusGeo News* 97: Researchers collaborate on marine survey in Northern Australia

[www.ga.gov.au/ausgeonews/ausgeonews201003/inbrief.jsp#inbrief1](http://www.ga.gov.au/ausgeonews/ausgeonews201003/inbrief.jsp#inbrief1)

## Geothermal Project update

Geoscience Australia's Geothermal Energy Project has been collecting precompetitive data to support the emerging geothermal industry as part of the agency's Onshore Energy Security Program. This has included field work to record temperature logs in existing boreholes across Australia as well as collecting drillcore samples for laboratory analysis at Geoscience Australia's headquarters.

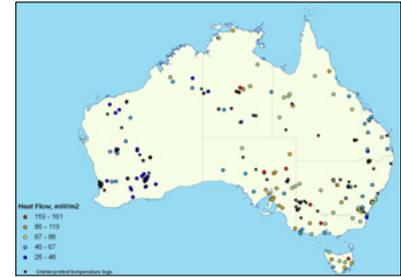
The data and samples are used to calculate the heat flow, or the amount of heat energy passing through the Earth at any point, which provides an indicator of geothermal potential at each sample location. Heat flow is calculated as the product of the change in temperature with depth (thermal gradient) and the thermal conductivity of the rock. Thermal conductivity varies as a result of a range of factors such as rock type and grain size. Samples taken from the boreholes are measured using a divided bar thermal conductivity instrument in the Geoscience Australia laboratory.

Thermal conductivity analysis and the calculation of the heatflow at each geographic location for a large number of samples are currently underway. Because of the time involved in these processes, Geoscience Australia has recently released the first in a planned series of reports of heatflow determinations. The first report contains data from eleven wells in New South Wales, Queensland and Western Australia.

Currently heat flow data are very sparse with data for only about 150 sample points publicly available through open databases (figure 1). Geoscience Australia plans to significantly increase the number and distribution of heat flow determinations across Australia.

The Geothermal Energy Project has recently released an update to the crustal temperature image, *OzTemp*. The image is an interpretation of the temperature at five kilometres depth below the surface of Earth and provides an indication of geothermal potential across Australia. It also shows the large-scale variations in the temperature field in different parts of the continent. This release marks the first time since 1994 that an interpretation of temperature at five kilometres depth has been published by the agency.

The image is available for download through the Geoscience Australia website in a number of formats including a spatially located version for use in GIS programs. The temperature data from which the *OzTemp* image was derived is also available for download. This database includes 17 000 onshore and offshore temperature records. Approximately 5300 of these records were used in the interpretation of Australia's crustal temperature.



**Figure 1.** Distribution of publicly available heat flow data which is shown as coloured circles while those holes for which Geoscience Australia has released heat flow data are shown as coloured stars. The new holes logged by Geoscience Australia awaiting heat flow determinations are shown as black stars.

The ongoing release of new temperature and heat flow data aims to support the emerging industry and encourage the development of a new low emission power generation technology.

### For more information

email [geothermal@ga.gov.au](mailto:geothermal@ga.gov.au)

### Related websites/articles

OzTemp-Interpreted Temperature at 5km Depth Image

[https://www.ga.gov.au/products/servlet/controller?event=GEOCAT\\_DETAILS&catno=71143](https://www.ga.gov.au/products/servlet/controller?event=GEOCAT_DETAILS&catno=71143)

Heat flow interpretations for the Australian continent: Release 1

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Geoscience Australia's Geothermal Energy Project

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## Geological and energy implications of the Paterson Province airborne electromagnetic survey

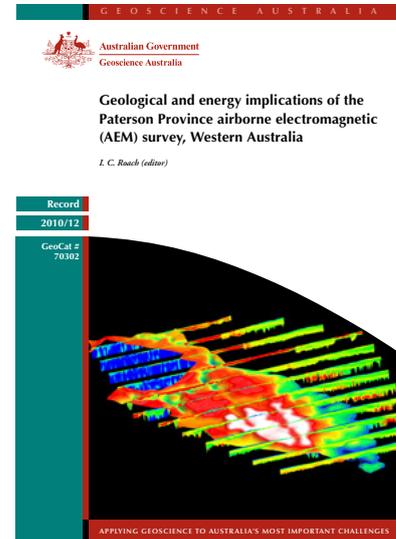
The Paterson airborne electromagnetic (AEM) survey was the first regional AEM survey flown in Australia. It was conducted between September 2007 and October 2008 over the Paterson region of northwestern Western Australia as part of Geoscience Australia's Onshore Energy Security Program. The survey was flown by Fugro Airborne Surveys Pty. Ltd. using the Fugro TEMPEST™ time-domain AEM system. The survey included a total of 28 200 line kilometres flown at various line spacings (six kilometres, two kilometres, one kilometre, and 200 metres) and covered an area of approximately 47 600 square kilometres.

The Paterson AEM survey was designed to deliver reliable, pre-competitive AEM data to promote exploration for uranium, uranium-copper, copper-gold, base metals and manganese minerals in the under-explored Paterson region. The survey area includes the working mines of Woodie Woodie (manganese), Nifty (copper) and Telfer (gold-copper) and the deposits at Kintyre (uranium) and Magnum (copper). All of the known deposits or prospects occur in Archean or Proterozoic rocks that outcrop within the surrounding Permian, Mesozoic and Quaternary cover; the cover comprises about 84 per cent of the survey area.

Airborne electromagnetic data were subjected to quality assurance and quality control procedures before being inverted using sample-by-sample Geoscience Australia layered earth inversion (GA-LEI) software. The GA-LEI data were validated using confidential and public-domain drill hole conductivity data collected during field trips to the region, and public-domain drill hole lithological data compiled during the data processing phase of the survey.

Interpretation of the GA-LEI data reveals new information for uranium prospectivity in potential unconformity-related, sandstone (roll-front and tabular) and valley calcrete uranium systems. The AEM data imaged the important Coolbro Sandstone-Rudall Complex unconformity near the Kintyre uranium deposit. The data also highlighted other areas where this unconformity, or others assessed as having moderate to high potential for uranium mineralisation, may occur. The AEM data are particularly effective for mapping carbonaceous and pyritic metasedimentary rocks at depth. These may be important reductants for reacting with uranium-bearing hydrothermal fluids.

The AEM data also provided new interpretations for the extent of Permian palaeovalley systems, the extent of and inter-relationships between Archean and Proterozoic bedrocks and Permian and Mesozoic cover in the Canning Basin and the extent of potential



redox fronts near salt lakes and playas associated with valley calcretes occupying palaeodrainage channels within the survey area.

The potential for gold and base metal mineralisation within the survey area has been reassessed in light of collated knowledge regarding the Miles mineral system, and the O'Callaghans mineral system. The Miles mineral system is the most prevalent and formed during the inversion of the Yeneena Basin. This mineral system dissolved uranium and copper and deposited them at redox boundaries near major faults. The O'Callaghans mineral system operated during and after intrusion of the O'Callaghans granite suite.

The AEM data have greatly improved understanding of the basement-cover relationships

in the area, particularly between Proterozoic rocks of the Yeneena Basin and Rudall Complex and the overlying Paleozoic-Mesozoic rocks of the Canning Basin. A number of the units within the Permian and Mesozoic cover are weakly to moderately conductive, due to contained clays, saline groundwater, or a combination of both and are well imaged within the data. The AEM data and the drill hole data base have also allowed the 3D stratigraphy of the Canning Basin to be interpreted over a broad area, revealing a number of large-scale sedimentary structures that were previously unknown. The data also reveal new information regarding the 3D structure of Permian palaeovalley systems around the Rudall Complex, especially those near the Kintyre uranium deposit.

**For more information**

email [ausgeo@ga.gov.au](mailto:ausgeo@ga.gov.au)

**Related websites/articles**

Geological and energy implications of the Paterson Province airborne electromagnetic (AEM) survey, Western Australia (Geoscience Australia Record 2010/12)

[https://www.ga.gov.au/products/servlet/controller?event=GEOCAT\\_DETAILS&catno=70302](https://www.ga.gov.au/products/servlet/controller?event=GEOCAT_DETAILS&catno=70302)

A drill hole database for the Paterson airborne electromagnetic (AEM) survey, western Australia. (Geoscience Australia Record 2009/31)

[https://www.ga.gov.au/products/servlet/controller?event=GEOCAT\\_DETAILS&catno=69505](https://www.ga.gov.au/products/servlet/controller?event=GEOCAT_DETAILS&catno=69505)

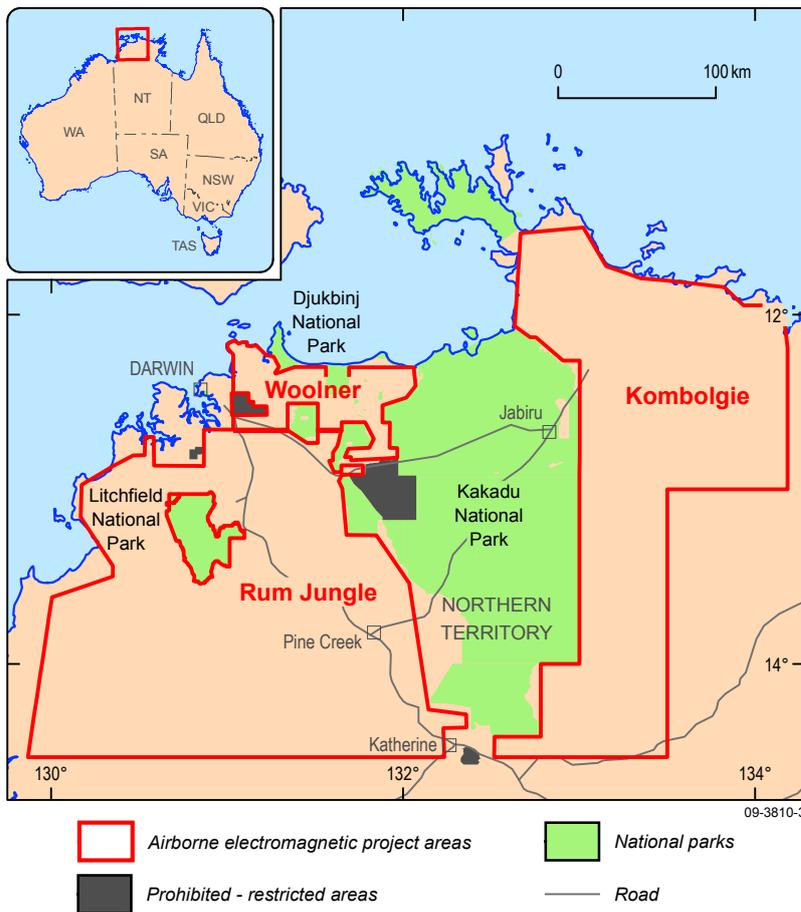
**New geophysical datasets released**

Airborne electromagnetic datasets covering the Pine Creek region of the Northern Territory and the Paterson region in Western Australia have been acquired by Geoscience Australia. These areas

are considered to have potential for uranium or thorium mineralisation and the surveys were conducted as part of the Onshore Energy Security Program.

To support the interpretation of these datasets Geoscience Australia also collected downhole conductivity logs for a number of drillholes in each area. Data from these logs are now available through the Geoscience Australia website.

Conductivity logs were acquired from twenty four boreholes during two field campaigns in April and October 2008 in support of the Pine Creek AEM survey. The Pine Creek AEM survey comprises three areas: Kombolgie to the east of Kakadu National Park; Woolner Granite near Darwin; and Rum Jungle to the west of Kakadu National Park (figure 1). In the Paterson region conductivity logs were



**Figure 1.** The Pine Creek airborne electromagnetic survey boundary locations showing the Kombolgie, Woolner and Rum Jungle areas.

acquired from nineteen boreholes during September 2008. The survey covers a total area of 49 000 square kilometres. These products are available for free download through the Geoscience Australia website.

Two areas of previously confidential infill AEM data and inversion products from the Rum Jungle TEMPEST™ survey in the Pine Creek area have also been released. The first is Phase-2 data, that is, Geoscience Australia layered earth inversion data and derived products, for the Woolner Granite and Rum Jungle surveys. Final data including Infill areas K1, K2 and K3 for the Pine Creek–Kombolgie AEM survey, that is, the area east of Kakadu National Park are also available. The data for the Rum Jungle survey are available for download through the Geoscience Australia website whilst the Pine Creek products are only available on DVD through the Geoscience Australia Sales Centre.

**Table 1.** Details of the airborne electromagnetic survey data.

Survey	Completed	Area	AEM system	Line kilometres	Contractor
Rum Jungle NT	24 May 2009	34 900 square kilometres	TEMPEST	14 200	Fugro Airborne Surveys Pty Ltd
Kombolgie NT	27 April 2009	30 500 square kilometres	VTEM	8800	Geotech Airborne Pty Ltd

### For more information

**email** [ausgeo@ga.gov.au](mailto:ausgeo@ga.gov.au)

### Related websites

Free Data Downloads facility (Geoscience Australia)

[https://www.ga.gov.au/products/servlet/controller?event=DEFINE\\_PRODUCTS](https://www.ga.gov.au/products/servlet/controller?event=DEFINE_PRODUCTS)

Pine Creek–Kombolgie AEM survey final data (DVD only)

[https://www.ga.gov.au/products/servlet/controller?event=GEOCAT\\_DETAILS&catno=71372](https://www.ga.gov.au/products/servlet/controller?event=GEOCAT_DETAILS&catno=71372)

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