ABSOLUTE DESTRUCTION

Fire swept through a key site for measuring absolute gravity in Australia when the January 18 bushfires destroyed Geoscience Australia's Satellite Laser Ranging and GPS facilities at Mount Stromlo.

The absolute gravity site was in the basement of the administration building.

At this site the force of gravity (or absolute value of gravity) has been measured at various times by CSIRO and visiting overseas organisations to develop a time series of gravity changes.

These precise measurements of changes in the Earth's gravity field are used to determine vertical crustal movement and changes in absolute sea level.

The question is whether the redistribution of mass above the site has had any measurable effect on the gravity field as a result of the fire.

Prior to rebuilding, Geoscience Australia and the Research School of Earth Sciences (Australian National University) are conducting a microgravity survey to determine any change. A relative gravity connection will also be done between Mount Stromlo and the absolute gravity site at Tidbinbilla outside Canberra. Measurements will be repeated after the administration building is rebuilt.

The Mount Stromlo absolute gravity site was established in 1996 in collaboration with the Geographical Survey Institute of Japan. The original measurements were taken by simultaneous observation using three, high-precision FG-5 absolute gravity meters. During this observation, absolute gravity was also measured at Tidbinbilla.

For more information phone Ray Tracey on +61 2 6249 9279 or e-mail ray.tracey@ga.gov.au

HOT ROCKS shed layers

Granite boulders in Canberra's burnt-out forests have been cracking and shedding layers of rock. This sort of 'onion-skin' weathering normally takes hundreds of years. But it seems that extreme heat during January's bushfires has sped up the natural process.

The peeling boulders are on hilltops, on well-drained slopes and in valleys. Canberra was in drought, so water did not cause this rapid breakdown.

Combustion in the eucalypt and pine forests would have generated temperatures greater than 1000 degrees Celsius. Burning trees and leaf litter heated the rock surfaces to at least 500 degrees.

The outsides of these coarse-grained granite boulders became hotter than their interiors, and the various minerals that comprise the rocks, such as feldspars and quartz, expanded at different rates.

With sustained heating, the boulders' interior temperatures would also have risen. But as the fires died, the surface cooled quickly and at a much faster rate than the inside.

These different rates of expansion and contraction cracked and peeled the boulders.

The insides of the fallen rock fragments and the newly exposed boulder surfaces are fresh or only slightly blackened, suggesting that the boulders probably disintegrated in the late stages of the fire.

These types of granite boulders are found in paddocks and on hills all over Australia. Because Australia is bushfire-prone, maybe this process has been more important than previously thought for shaping the landscape over the past several million years.

OPEN ALL HOURS for *seismic action*

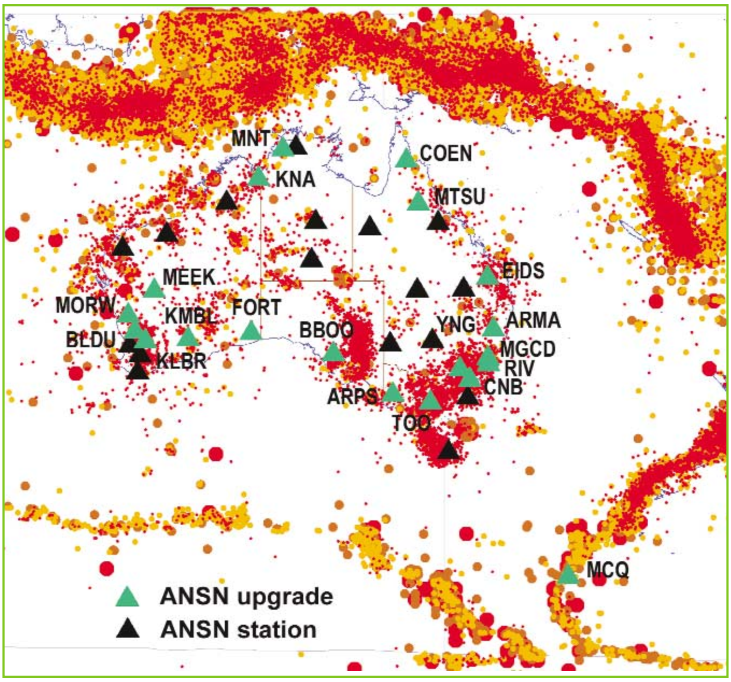


Figure 1. Australian National Seismograph Network (ANSN) stations where the black triangles represent current stations and the green triangles show the stations proposed for data-quality upgrades. The orange and gold dots show earthquake locations and magnitudes.

Mine blasts, factory explosions, earthquakes and kangaroos are all in a day's recording if the action is within range of a station in the Australian National Seismograph Network (ANSN) operated by Geoscience Australia.

The network of 37 real-time seismographic stations never shuts down. It continuously monitors earthquakes and other seismic events in Australia, Indonesia and the south-west Pacific, and large earthquakes worldwide. Some stations are also part of a global network that monitors nuclear explosions.

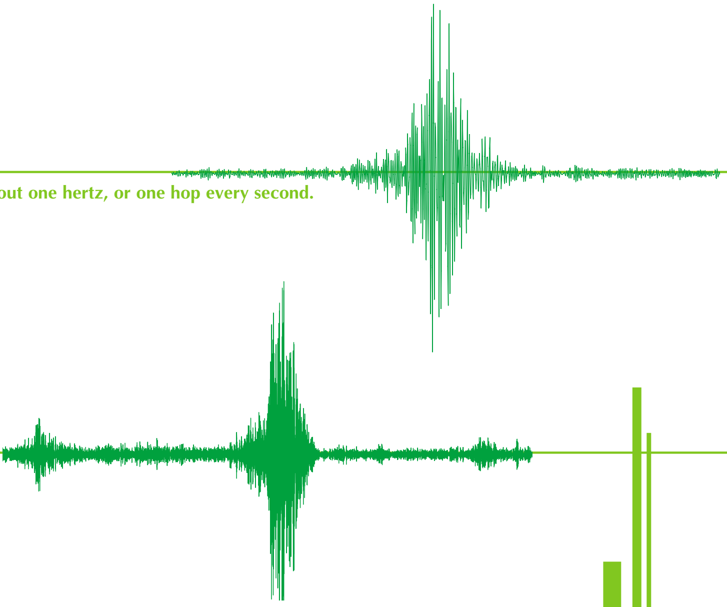
Because of the network's range and equipment sensitivity, seismographs record all earthquakes greater than magnitude 3.5 in the Australian region and all events near stations including a kangaroo bounding by.

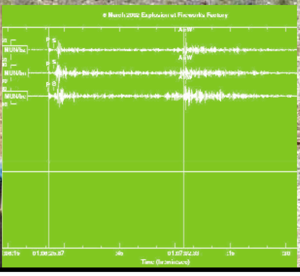
There are 34 stations throughout Australia, two stations in Antarctica and one on Macquarie Island (figure 1).

On alert

Data from the network are telemetered in near-real time to Geoscience Australia, which operates a 24-hour, seven-day-a-week earthquake alert system. When a seismic event is detected, the system automatically locates it and estimates the magnitude.

Kangaroo bounces are about one hertz, or one hop every second.





This rapid action is crucial when earthquakes are large or have the potential to cause a tsunami that would devastate coastal communities.

If an earthquake is potentially damaging, the system alerts the on-call duty seismologist at Geoscience Australia, who verifies the event and then notifies Emergency Management Australia (EMA). EMA relays the warning to the relevant local authorities in the state, territory, or neighbouring country.

Data use

Many people use the network's data—from the building, resource and insurance industries, to government agencies, the media, and the general public. The data are archived and used to develop earthquake hazard models. These models are important for estimating earthquake risk in Australian communities, and for providing advice on building codes.

Mining companies have been using the data to investigate seismic events in such mineral provinces as the goldfields of Western Australia and the base-metal deposits of Cobar and Broken Hill.

Essential data are provided to the earthquake research community and international agencies, such as the International Seismological Centre and the US Geological Survey. These agencies maintain comprehensive databases of global earthquake data and publish international bulletins of seismic activity.

E-access

Geoscience Australia's new earthquake database, designed around two worldwide standards (CSS 3.0 and ISC schemas), will be the national repository for earthquake data.

The database will be capable of linking possible locations and times for an event, magnitudes and source parameters, as well as ground shaking intensity maps for the event. Facilities will include automatic data entry and data delivery via the web.

A new web page 'Plot a seismogram of an earthquake' (www.ga.gov.au.urban/waveform) allows individuals to view current and past geophysical events. The page helps build awareness of seismological risk. It has a facility for user feedback.

Network expansion

Three new seismograph stations were added to the ANSN in November 2002. The new Queensland stations at Coen in Cape York, Mount Surprise west of Cairns, and Eidsvold west of Bundaberg filled a void. Earthquakes along the Queensland coast down to magnitude 3.5 can now be monitored.

In February this year the Warramunga seismic array operated by Australian National University was added to the network. The array improves the monitoring of central Australia by detecting earthquakes 0.5 smaller in magnitude than was previously possible. With the Alice Springs seismic array, it improves Australia's nuclear discrimination capability.

Network upgrade

The bandwidth and dynamic range of 19 onshore Australian stations are being upgraded (figure 1) to improve data quality. This will help research into the characteristics of earthquake ruptures and faults, and the propagation of seismic waves through the Australian continent. These characteristics must be known to estimate the ground shaking caused by earthquakes, and the potential damage to buildings and infrastructure.

Manton Dam in the Northern Territory, one of the seismic stations to be upgraded, also houses a geodetic station for the Australian Regional GPS Network (ARGN). This station is one of Geoscience Australia's first steps in integrating seismic and geodetic data acquisitions systems.

Geoscience Australia provides real-time data to the Incorporated Research Institutions for Seismology. There are plans to upgrade the Macquarie Island and Casey (Antarctica) seismic stations to provide the consortium with even better data.

For more information phone Andrew Owen on +61 2 6249 9276 or e-mail andrew.owen@ga.gov.au

Update on geomagnetic *directions*

Picking up magnetic disturbances of the Earth and its atmosphere for navigation and space communication, and providing data to calibrate compasses are among the tasks of the Australian geomagnetic observatory network operated by Geoscience Australia.

Geoscience Australia recently combined this network with its seismic and geodetic operations to create the Geoscience Australia Earth Monitoring group.

The geomagnetic observatory network comprises nine permanent observatories and 15 super repeat stations that monitor approximately an eighth of the Earth's surface.

Observatories on continental Australia are at Canberra, Charters Towers, Alice Springs, Kakadu, Gnangara and Learmonth. The other observatories are at Mawson and Casey in Antarctica and Macquarie Island.

Usually seven repeat stations are 're-occupied' each year to survey and update geomagnetic data for Australia, Papua New Guinea, and islands in the south-west Pacific.

Recent miniaturisation of survey equipment has been of considerable benefit, especially for stations that are accessible only by air. The three-component fluxgate variometer, proton magnetometer and newly designed data acquisition unit can be run from either mains power or 12-volt batteries with solar-powered charging.

Software now loads the geomagnetic data into a database as soon as it is transmitted to Geoscience Australia's headquarters. This new data and archived data, which is slowly being added to the database, can be accessed via the web.

One-minute time resolution data from all Geoscience Australia's magnetic observatories can be displayed graphically or downloaded in blocks of up to seven days. The latest Australian Geomagnetic Reference Field model is also available on-line. It indicates the strength and direction of the magnetic field at any selected site and time.

Geomagnetic indices have been developed to characterise aspects of magnetic disturbances over time. The most commonly used of these is the three-hour quasi-logarithmic K-index.

The International Association of Geomagnetism and Aeronomy has approved a number of computer algorithms to generate K-indices from magnetic observatory data. But none adequately imitates the results of manual scaling of Australian magnetograms. Geoscience Australia therefore has developed a computer-assisted method of manual scaling.

The graphic-user interface of Geoscience Australia's database uses one of the standard algorithms to produce the daily magnetogram on screen, and an estimate of the underlying regular or diurnal variation. The regular curve can then be manipulated on screen as if it were being scaled manually. The resulting regular variation is subtracted from the magnetic record to leave the disturbance component that is subsequently scaled automatically.

A magnetometer calibration facility was added to the Canberra Magnetic Observatory about four years ago to increase the accuracy of data from Australian observatories and to eliminate the need to carry out a series of absolute observations to calibrate observatory magnetometers. The calibration facility was a joint initiative of Geoscience Australia and the Defence Science and Technology Organisation.

As Geoscience Australia's capabilities are unique and unrivaled within Australia, it regularly calibrates compasses and compass-theodolites for defence, navigation and other calibration service providers.

Geoscience Australia also supports Indonesia's geomagnetism program.

For more information phone Andrew Lewis on +61 2 6249 9764 or e-mail andrew.lewis@ga.gov.au

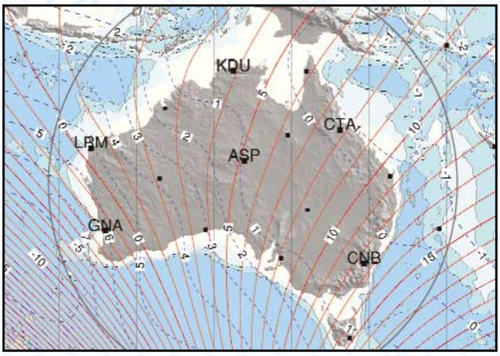
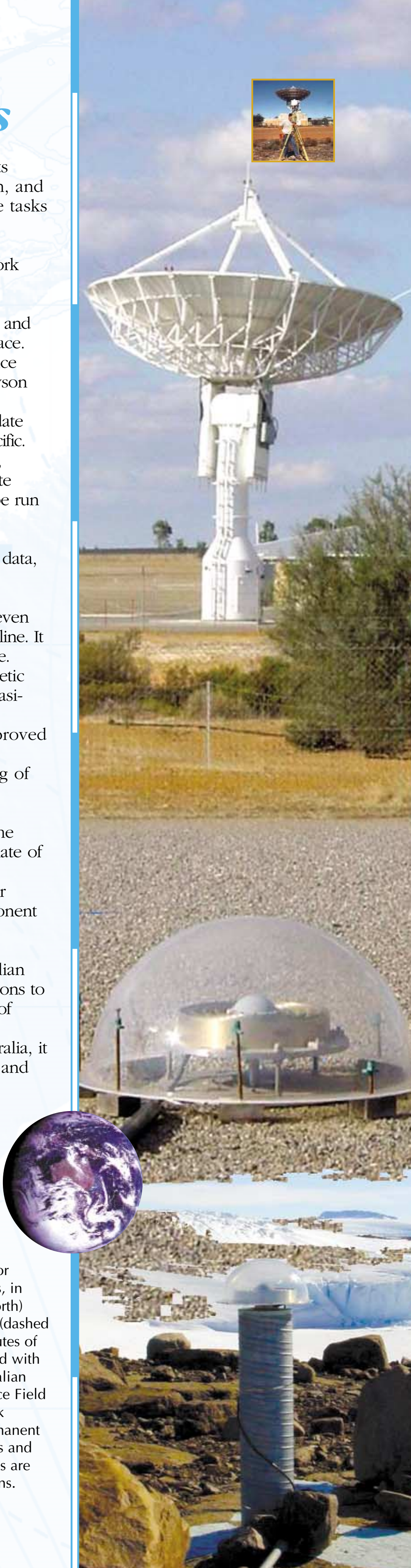


Figure 1. Contours of magnetic declination or variation (red contours, in degrees east of true north) and its rate of change (dashed blue contours, in minutes of arc per year) calculated with the Epoch 2000 Australian Geomagnetic Reference Field model. The large black squares show the permanent magnetic observatories and the small black squares are the super repeat stations.



Slightest **movement noted by GPS network**

When the earth moves in Australia, the Australian Regional GPS Network (ARGN) can tell us in which direction and by how much, even if it is only a few centimetres.

ARGN consists of 16 permanent, geodetic-quality GPS receivers on geologically stable marks in Australia and its territories (figure 1).

It provides reference points for spatial data that are used to map the Australian region, as well as data for research into sea-level changes and the dynamics of the Earth's crust.

ARGN also contributes data to global geodesy programs.

Not just any site is suitable for stations in this network. ARGN site selection (table 1) is based on such criteria as:

- located on geologically stable ground;
- have a clear 360° horizon above 15° elevation;
- free of any significant signal interference or multipath reflection;
- can access 240 volt power, telephone or the internet;
- be more than 10 kilometres from the coast (preferably) to minimise tidal loading;
- be in a secure, government-owned property (ideally).

Figure 1. The Australian Regional GPS Network. In January this year, Melbourne was added to the network and a bushfire destroyed the Mount Stromlo facility.

Each station has a geodetic-type GPS receiver and antenna. The GPS antenna is secured to bedrock or at least base material.

The raw GPS data are transferred from the receiver to an on-site computer with a Linux operating system. Data are stored on site and regularly transferred to Geoscience Australia via the internet or a modem.

Most ARGN sites have two GPS receivers in place—one as a back up. This policy was instigated for the most remote sites (Antarctica, and Macquarie and Cocos islands), but will gradually apply to all sites. The back-up or redundancy procedure also includes computers, power and communication equipment.

All GPS stations are monitored for vertical and horizontal movement by a local tie survey.

For survey purposes, each station has at least three reference marks (stainless-steel rods) placed around the antenna monument. The rods are equally spaced on a circle with a radius approximately 25 metres from the monument, and driven to refusal or fixed to bedrock material.

High-precision electronic surveying equipment is used to measure movement to within one-millimetre accuracy.

For more information phone Bob Twilley on +61 2 6201 4346 or e-mail bobtwilley@auslig.gov.au

Location	ID	Date installed	Latitude deg.	Longitude deg.	Communications
Alice Springs	ALIC	Aug 1992	-23.67	133.88	modems
Ceduna	CEDU	Sep 1993	-31.87	133.80	modems
Cocos Is	COCO	Jul 1992	-12.18	96.83	internet
Darwin	DARW	Aug 1992	-12.85	131.13	modems
Hobart	HOB2	Aug 1992	-42.80	147.43	internet
Jabiru	JAB1	Feb 1997	-12.67	132.90	modems
Karratha	KARR	Sep 1992	-20.98	117.08	modems
Melbourne	MOBS	Jan 2003	-37.83	144.98	internet
Mt Stromlo	STR1	Jun 1998	-35.30	149.02	internet
Tidbinbilla	TID1	May 1992	-35.40	148.98	internet
Townsville	TOW2	Jan 1995	-19.27	147.05	internet
Yaragadee	YAR2	Dec 1990	-29.05	115.35	modems
Casey	CAS1	Dec 1993	-66.28	110.52	internet
Davis	DAV1	Nov 1993	-68.58	77.97	internet
Macquarie Is	MAC1	Jun 1995	-54.50	158.93	internet
Mawson	MAW1	Jan 1993	-67.60	62.87	internet

Table 1. ARGN station information. The Mt Stromlo GPS station was destroyed in a bushfire on January 18. It should be operating again within 12 months.

GEOSCIENCE AUSTRALIA'S EARTHQUAKE HAZARD AND NEOTECTONICS PROJECT is putting its research on the map—the Australian Earthquake Hazard Map. The project is studying earthquake activity and building models that explain Australia's earthquakes. These models will be used to estimate and map where earthquakes are likely to occur.

Earthquakes MOVE ON but not without a *trace*

There are less than 100 years of instrumental recordings of Australian seismicity. So the first step in mapping earthquake hazard is to search the landscape for evidence of old seismic activity. This involves finding areas where earthquakes deformed the geology over the past 1.8 million years (the Quaternary), and analysing this data at a regional and continental scale.

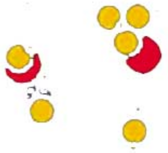
Large earthquakes can significantly modify the landscape. For example, earthquakes helped shape the fault-bounded Mount Lofty Ranges east of Adelaide, and the 1968 Meckering earthquake in south-west Western Australia produced a 37 kilometre long and 2.5 metre high scarp.

Big earthquakes can also divert drainage. The large bend in the Murray River at Echuca is related to movement on the Cadell Fault.

Regional geomorphology therefore provides the first important constraint on seismicity models.

Seismicity migrates

Observations in the south-west corner of Western Australia suggest that Quaternary deformation is distributed regionally among a group of favourably oriented faults and that seismicity is migratory over time. Relief on individual Quaternary faults tends to be subtle, with evidence of only one or two large Quaternary earthquake events preserved.



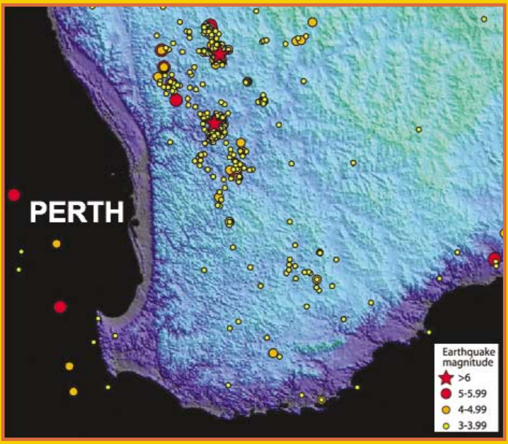


Figure 1. Digital elevation model over south-west Western Australia showing subdued relief associated with seismicity

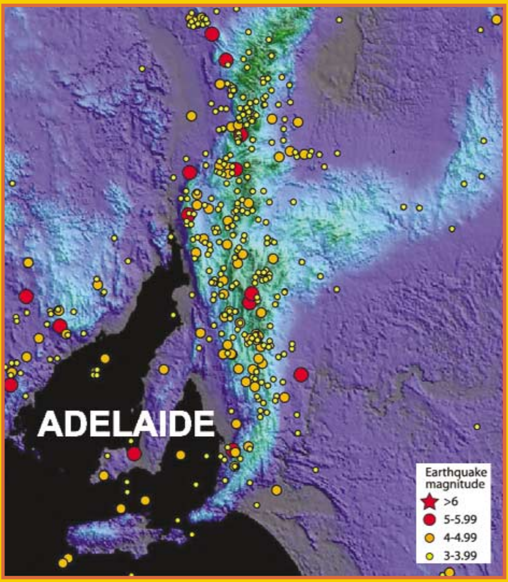


Figure 2. Digital elevation model over the Flinders and Mount Lofty ranges showing rugged, youthful relief bounded by a handful of major faults. The relief is associated with a significant concentration of earthquake epicentres.

A comparison of the Meckering fault scarp and new high-resolution aeromagnetic data[1] shows exceptional agreement. Virtually every element of the scarp surface correlates with a basement lineation mapped in the magnetics. It suggests that the surface rupture involved concurrent movement on faults belonging to a main north-west to south-east set and other faults trending at high angles.

Fault interaction could be important in shutting down activity on individual structures. Intersections could lock-up after one or two large events, causing seismicity to migrate elsewhere.

At Meckering, uplift is more distributed than if recurrent deformation was localised on a single large fault. Rates of erosion therefore can compete with rates of relief generation, and the landscape remains essentially flat (figure 1).

Recurrence questioned

At Meckering and in much of arid Australia, it is debatable whether a 'recurrence interval' on individual faults applies. If future research finds that the Meckering-style fault intersection is the norm, then large earthquakes might 'recur' on a fault only once.

For estimating seismic hazard, recurrence may be better applied to fault families because faults that don't preserve a history of activity, and are presently aseismic, could be the next to generate a damaging earthquake.

Styles differ

The highlands of south-eastern Australia and the rugged, youthful topography of the Mt Lofty–Flinders ranges of South Australia preserve evidence of a very different style of seismicity to central and Western Australia (figure 2). Here rates of uplift on a handful of controlling structures are far in excess of rates of erosion. Large offsets on individual structures are the sum of multiple movements.

Although individual events are typically of indeterminate magnitude and timing, time-averaged slip rates are recoverable elsewhere from strata, marine strandlines, riverine terraces, and drainage diversion. But the main faults, in this instance, are the most significant for hazard estimation purposes.

Database established

Not all evidence for deformation of the Australian continent is as dramatic as a fault scarp. Other indicators include tilted or folded strata, deformed shorelines of lakes, uplifted marine and fluvial terraces, and liquefaction deposits.

Geoscience Australia is compiling a database of all these geologic indicators. The database currently contains more than a hundred instances of Quaternary deformation, and continues to grow. As yet, very few have been investigated in detail.

To complement this work, two other avenues are being pursued: computer modelling of deformation at a continental scale, and analysis of the deformation associated with contemporary seismicity.

Computer modelling

Computer models can be used to estimate the rate at which the Australian plate is deforming internally. The faster the calculated rate of deformation in a region, the higher the rate of seismicity that might be expected over time.

Using the long-term deformation rate to estimate seismic hazard overcomes the problems associated with less than 100 years of recordings. It is also useful for estimating deformation rates in regions where there are no geological or seismic data.

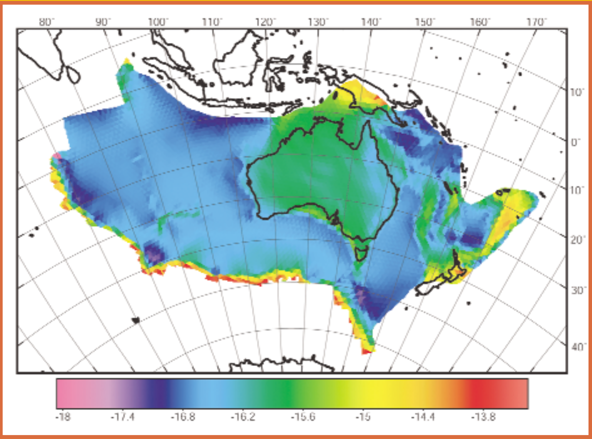
Computer models require making assumptions about the structure and composition of the Australian plate, and the forces acting on its boundaries. The estimate is restricted by what is known about the plate and forces imposed on it, the accuracy of the assumptions, and simplifications required for the modelling.

There are many ways of modelling plate deformation. One method, based on the computer model SHELLS[2], has been used at a global scale and at the regional scale in Alaska and New Zealand. It has not been used before to model the Australian plate in detail (figure 3).

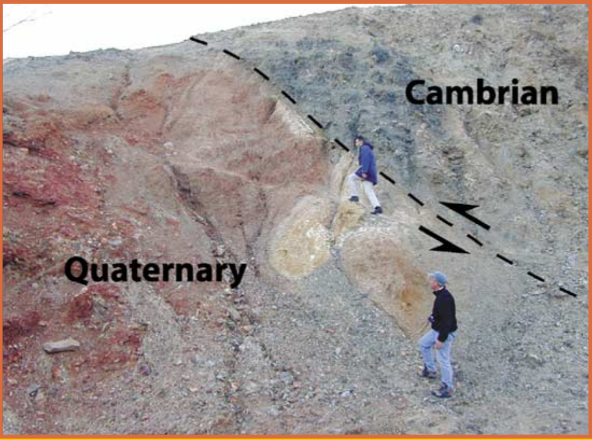
The realism of the model can be assessed by comparing the predicted surface deformation with that observed from geodetic benchmarks (i.e. GPS surveys), or from estimates of the spreading rate along mid-ocean ridges. The direction of the maximum stress produced in the model can also be compared with that estimated from geological data, earthquake data and from borehole data.

The model shown in figure 3 gives an example of the deformation rate across Australia. The surface velocity of the model is within a few millimetres per year of the observed values, and the direction of the maximum stress is within a few tens of degrees of observations.

Further modelling will be used to improve understanding of Australian seismicity at the regional scale and, for example, to explore theories on the mechanism for the Meckering earthquake.



▲ **Figure 3.** An example of the maximum deformation rate estimated by SHELLS for one particular model of the Australian plate. The scale at the bottom is in logarithmic units, so the variation in strain rate across the plate is several orders of magnitude (from about $10^{-13}s^{-1}$ to $10^{-18}s^{-1}$). The red regions have a high deformation rate (and high seismicity). The deformation rate is generally much higher at the plate boundaries than in the oceanic regions inside the plate.



▲ The Milendella Fault east of Adelaide is exposed in a creek bend.

▲ The eight-metre-high Cadell Fault scarp, adjacent to the large bend in the Murray River, forced the river to divert south.

Current events

The characteristics of contemporary seismicity provide ideas on how Australia is deforming and at what rate. Each earthquake event represents a finite amount of deformation. The magnitude of this deformation can be estimated from the amount of energy released during an earthquake. This is routinely calculated from seismograph data.

Calculations for southern Australia suggest about a millimetre of compression, probably east–west, across the whole continent each year (uncertainty of at least 50%).

The most intense seismic activity over the past 50 years has been in the south-west corner of Western Australia and in the Flinders and Mt Lofty ranges (figures 1 & 2). The earthquake energy released in these two regions suggests deformation rates of between 0.1 and 0.6 millimetres a year.

Long-term deformation measurements are being taken in these two areas to verify the estimates. They will be reconciled with computer-modelled and geologically derived deformation rates to determine how stationary seismic activity is over time.

Contemporary seismicity also helps researchers refine the location of Australian earthquakes and determine whether earthquakes in the various active regions occur on major structures (i.e. faults and fault zones), or are randomly distributed on many minor structures.

Work on earthquake sequences such as the Burakin earthquakes (see article in this issue) is producing 3-D images of earthquake faults, and characterising the stresses that led to failure. This research is particularly informative as deformation on geological structures can be inferred from small earthquake events even if they don't rupture the surface.

The work will capture patterns in the migration of seismicity over time and help estimate and map earthquake hazard in Australia.

For more information phone Dan Clark on +61 2 6249 9606 or e-mail dan.clark@ga.gov.au

[1] Collected in collaborative research with Professor Mike Dentith, University of Western Australia

[2] SHELLS was developed by Peter Bird (UCLA) and others.

Looking for the BIG QUAKES

The return period for the largest, most damaging earthquakes in Australia could be several thousand years. In the short time since European settlement, it is therefore unlikely that Australia has experienced the maximum-sized earthquakes possible in most regions.

To better understand the characteristics of large events, and the behaviour of the faults that host them, scientists look for records of prehistoric earthquakes in the landscape (e.g. fault scarps).

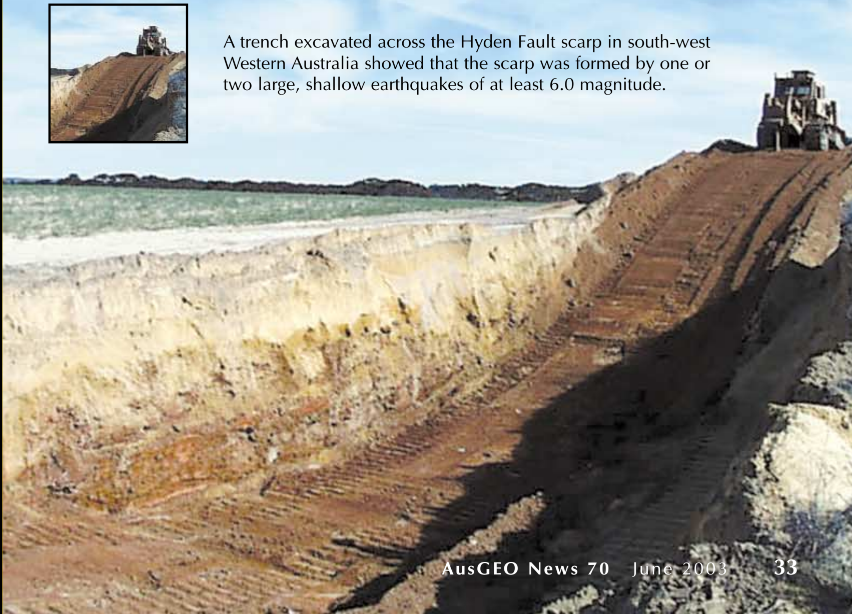
Palaeoseismology is the study of earthquakes that have occurred in the past, usually in prehistoric times. The field encompasses several subdisciplines, including Quaternary (1.8 million-year-old to present-day) geology.

Many faults in Australia are likely to have experienced Quaternary displacement because of large earthquake events. Few have been investigated in detail.

This year, Geoscience Australia's Earthquake and Neotectonics Project is conducting field research in three likely palaeoseismic areas:

1. Meckering in Western Australia, near the site of the 1968 surface-rupturing earthquake;
2. the Lake Edgar Fault in south-west Tasmania, which preserves evidence of several surface-rupturing earthquakes; and
3. the Cadell Fault on the New South Wales–Victorian border, that dammed and diverted the Murray River at various times in the Quaternary.

For details phone Dan Clark on +61 2 6249 9606 or e-mail dan.clark@ga.gov.au


A trench excavated across the Hyden Fault scarp in south-west Western Australia showed that the scarp was formed by one or two large, shallow earthquakes of at least 6.0 magnitude.

Palaeoliquefaction features formed during the 1897 Beachport earthquake

Old river soils probed for LAYER changes

Water-saturated, sandy soil rapidly losses its strength and stiffness and becomes liquid when the ground shakes severely. This process is called liquefaction, and the severe shaking is typically caused by earthquake-generated seismic waves.

Liquefaction-related phenomena are commonly associated with large earthquakes along plate margins, in such places as Japan and the western United States. They have also been observed in Australia. During the 1897 Beachport earthquake in South Australia, the ground slumped and water and sand spouted from newly opened fissures.

Liquefaction alters the soil profile. The disturbances in soil layering can be detected long after the earthquake happened.

It is possible to estimate the timing and frequency of large earthquakes in an area by dating liquefaction deposits from several events.

Geoscience Australia's Earthquake and Neotectonics Project carries out palaeoliquefaction research in Australia. This year the project will survey three areas with exposed soil profiles in the Murray and Perth basins:

1. near Robe in South Australia, where the 1897 earthquake caused liquefaction;
2. on the Goulburn River in northern Victoria, near the Cadell tilt block where large earthquakes may have occurred but there is no historical record; and
3. along the Swan and Canning rivers near Perth, Western Australia, which is near an active seismic zone.

For more information phone Dan Clark on +61 2 6249 9606 or e-mail dan.clark@ga.gov.au

ANSIR AUSTRALIAN NATIONAL SEISMIC IMAGING RESOURCE

Call for *research proposals* for EXPERIMENTS in 2004 & *beyond*

Submissions by AUGUST 11, 2003

The Australian National Seismic Imaging Resource (ANSIR), a major national research facility, seeks bids for research projects for experiments in 2003 and beyond.

ANSIR operates a pool of state-of-the-art seismic equipment suitable for experiments designed to investigate geological structures. ANSIR is operated jointly by Geoscience Australia and the Australian National University.

ANSIR equipment is available to all researchers on the basis of merit, as judged by an Access Committee.

Demand for broad-band equipment is very high. This should be taken into consideration in the design of experiments. ANSIR provides training in the use of its portable equipment, and a field crew to operate its seismic reflection profiling systems. Researchers have to meet project operating costs.

Applicants should consult the web (http://rses.anu.edu.au/seismology/ANSIR/ansir.html) for details of the equipment available, access costs, likely field project costs, and the procedure for submitting bids. This site also includes an indicative schedule of equipment for projects that arose from previous calls for proposals.

Researchers seeking to use ANSIR in 2004 should submit research proposals to the ANSIR Director by August 11, 2003.

Enquiries should be directed to:

- **Prof Brian Kennett, ANSIR Director, Research School of Earth Sciences, Australian National University, Canberra ACT 0200. Tel. +61 2 6215 4621 or e-mail ANSIR@anu.edu.au**

Risky business

Like the great mathematician Ptolemy, who used equations long before satellite technology to model the universe, Geoscience Australia has a team applying numerical solutions to natural hazard risk in Australia. And like Ptolemy, the Risk Modelling team accepts that dealing with uncertainty and many unknowns is risky business. Christopher Zoppou explains…

Hazard

The first step in estimating the risk from a natural hazard is establishing the frequency, magnitude and spatial extent or region of influence of a natural hazard.

This task was once performed with analog systems or the use of expensive, scale models. Nowadays computer models are replacing analog and physical models for risk analysis because they make it easier to investigate numerous scenarios.

A computer model involves a series of equations that are an approximation of a natural hazard, to which a numerical solution is applied. The equations are generally based on conservative physical laws or derived from empirical observations, and they mimic the important behavioural characteristics of a natural hazard. But the mathematical model is still a simplification of the real problem, and so it contains uncertainties.

The model requires recorded observations. This information is usually based on a specific historical event. Observations from each natural hazard are a single sample of an infinite number of possibilities and therefore measurement errors are likely.

Uncertainty associated with the observations and with the equations must be accounted for in risk analysis.

Exposure

If infrastructure and people are not exposed to a natural hazard, there is no risk. Therefore it is essential to establish what is exposed to a natural hazard. This step is the simplest component in risk analysis.

The ‘exposure’ information is often stored as large databases containing census data and spatial attributes of buildings, lifelines and infrastructure in the built environment. These data can be interrogated in a geographical information system (GIS).

Vulnerability

The next step in the risk analysis is to establish the impact of a natural hazard. To identify the local impact, the model needs to provide the hazard’s magnitude or severity in relation to frequency and region of influence (time and space). The local impact will depend on how vulnerable exposed elements are to the hazard. These elements include buildings, infrastructure, lifelines and people.

Vulnerability is the least developed and understood component in natural hazard risk analysis. It is the main source of knowledge uncertainty in risk analysis.

For buildings, infrastructure and lifelines, crude damage-impact relationships have been derived from insurance data and ad-hoc surveys of damage. But there are very few examples where data have been collected after an event specifically to develop accurate hazard-damage curves. This is primarily because it is expensive to collect this information and there are time constraints.

Using aggregated data such as insurance figures and a single attribute of a hazard (e.g. water depth) to produce damage curves is generally unrealistic.

For example, flood damage is often characterised by the depth of inundation only. Yet there are at least three major components of a flood that influence the possible damage. These are the depth of inundation, the momentum of the flow, and the duration of inundation.

The depth of inundation is important. But the momentum of the flow, which is a product of the water depth and velocity of the flow, can be devastating.

The duration of inundation also needs to be considered because it can have an impact on the recovery, and the deposition of sediments can cause significant damage.

Models traditionally used to produce flood inundation maps do not provide accurate estimates of the flow velocity and are not capable of calculating the duration of inundation.

Vulnerability of an individual is even more problematic. A person's vulnerability depends on tangible factors, including socio-economic indicators such as income, age, family status, and history of exposure to a natural hazard. Intangible factors such as a person's psychological and emotional state and his/her beliefs are also important in establishing vulnerability.

Outcomes

Risk analysis can be used to identify the range of possible outcomes and their likely occurrence, by using probability distributions to characterise natural variability and knowledge uncertainty. From the distribution of possible outcomes, it is possible to extract the most likely outcome and its confidence intervals.

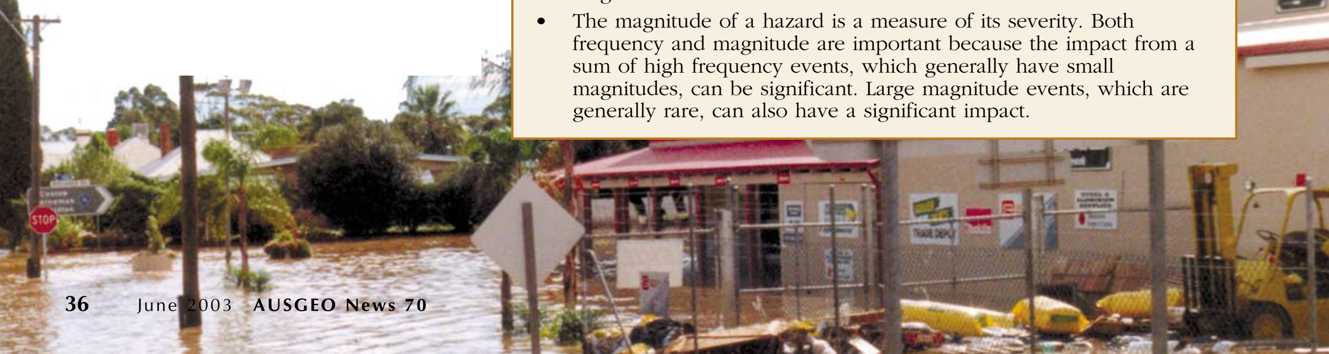
Undertaking a risk assessment requires a group with diverse skills in such areas as geology, geophysics, economics, engineering, social science, mathematics and statistics. Geoscience Australia has this unique group in its Risk Modelling Project.

Over the past two years, the project has been developing tools and models to assess a range of natural hazards. Other articles in this issue describe their applications.

For more information phone Christopher Zoppou on +61 2 6249 9812 or e-mail christopher.zoppou@ga.gov.au

GLOSSARY

- Risk assessment is the process used to establish the negative or positive impact from an uncertain event.
- Risk management is the process of managing threats and opportunities from an uncertain event.
- Risk is the integration of three factors: hazard, exposure and vulnerability (see flow diagram).
- A hazard is a natural event with the potential to cause harm. It is characterised by a certain probability of occurrence and a spatially variable intensity.
- Exposure refers to elements such as people, buildings and lifelines that are subject to the impact of a hazard.
- Vulnerability refers to the likelihood that these elements, when exposed to a hazard, will be affected by it.
- All natural hazards are associated with uncertainty in occurrence. But uncertainty in spatial location only applies to some natural hazards. For example, with earthquakes and cyclones both the location and likelihood are uncertain. With floods, the frequency is uncertain, but the spatial location is restricted to regions immediately adjacent to a watercourse.
- Frequency is the time interval between events of a particular magnitude.
- The magnitude of a hazard is a measure of its severity. Both frequency and magnitude are important because the impact from a sum of high frequency events, which generally have small magnitudes, can be significant. Large magnitude events, which are generally rare, can also have a significant impact.



Programming solutions for community risk

It has happened at last. A machine has been made to think, or at least make some decisions for us.

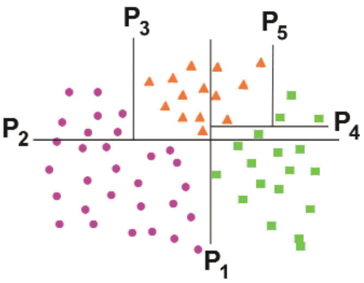
It all came about because of an overwhelming amount of data and limited time and money. Human ingenuity found a mathematical solution and programmed a computer to ‘see’ complex relationships in data.

When the computer is presented with new information, it predicts the outcomes, generates rules for the new data that can be read by humans, and ranks how important the attributes are for predicting the outcome.

For example, in a financial institution the computer might be ‘trained’ to determine customer risk. The computer can be presented with data about a new candidate for a home loan. After analysing the new factors and what it has ‘learnt’ from previous candidates, the computer indicates that the person is suitable for the loan and that in this case annual income is more important than the person’s age and gender (25 year-old female) when determining his/her loan suitability.

This technique for analysing data is called ‘decision-tree induction’. Decision trees are commonly used in the insurance and banking industries, but their popularity is on the rise. Decision-tree analysis is being applied in such diverse fields as medical diagnosis and human face recognition.

Geoscience Australia’s Risk Research Group also uses decision-tree analysis. Two applications for assessing community risk from natural hazards are outlined in the case studies.



▲ **Figure 1.** Orthogonal data splitting, where P_x is equal to the order of data partitioning.

Partitioning

Suppose we want to assess whether a customer should be given a loan based on previous customers’ records. The decision tree is generated by repeatedly partitioning the data until each partition consists dominantly of records with the same response value (e.g. ‘yes’ or ‘no’).

Each step of the partitioning is accomplished by selecting a splitting criterion (e.g. age <43, income <$2000), which determines how the data are to be partitioned at that point. Records satisfying each criterion then go into one partition and the rest into another, and so forth (figure 1).

The choice of criterion at each point is determined statistically to ensure that the partitioned data are as pure as possible. The partitioning continues until every partition contains records with the same response value. The resulting tree is called the ‘maximal tree’.

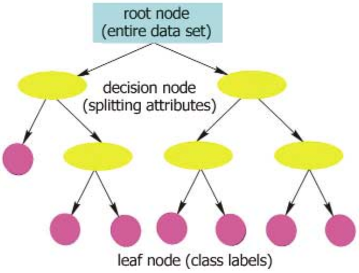


Figure 2. A basic outline of a decision tree showing some of the key components

Over-fitting

The maximal tree classifies exactly the data used to build it. But because it has been tailored to the idiosyncrasies of the data set on which it was trained, a maximal tree is unlikely to classify new data very well. Thus the tree loses the ability to model the general trend that the data are expected to describe.

Data sets also contain a certain amount of 'noise' from measuring errors. If a decision tree fits the data too closely, it may incorporate noise instead of revealing the underlying pattern. This phenomenon is known as over-fitting.

Pruning

A remedy for these problems is to use a separate test data set and to prune parts of the tree.

The training and test data sets normally contain similar errors or noise. The prediction error on the test set is calculated for every sub-tree (sharing the same root), and the sub-tree with the smallest error is selected for the final model (figure 2).

Once built, a decision tree can be used to classify new data by starting at the root node, then moving through it following the rules at each splitting point until a terminal node is encountered. The value assigned to each terminal node corresponds to the predicted outcome.

CASE STUDY 1:

LANDSLIDE ASSESSMENT

Much of south-east Queensland is prone to landslides because of heavy rainfall. Land is being cleared and developed for a burgeoning population, and certain physical factors make some areas prone to landslip, including:

- horizontal strata that directs ground water between porous and non-porous layers;
- accumulations of colluvial debris (loose soil and rock fragments found at the bottom of hillsides);
- the presence of clays; and
- beds of soft sediments.

Traditional methods of assessing landslide risk are not practical for such a large region because of constraints on site access, time and finances. But a decision-tree approach enables the environmental variables that influence slope stability to be analysed on a regional scale. Using a GIS and 'machine-learning' techniques are critical because modelling the many environmental variables at a high spatial resolution makes data sets very large.

Method

For landslides that occurred after the January 25–28, 1974 rainfall event in south-east Queensland, the following process was applied:

1. ascertain the environmental variables in the study region;
2. generate decision rules based on the landslides from this event; and
3. identify further areas of potential hazard.

A decision tree was constructed (using Quinlan's See5 algorithm) from 5592 mapped landslide training cases (three per landslide) and an equal number of cases randomly distributed outside the mapped area. A total of 107 decision rules were generated for the south-east Queensland study area (see table 1).

The entire rule-set was then brought into a GIS and individual rules were located spatially. As one rule can overlap another, rule-sets were ordered and spatially located by confidence from the highest (0. 997) to the lowest (0.601) value.

Rule 71

Geology = Marburg Formation
Slope (slope direction) = 37°–39°
Class (potential landslide) = Yes
Confidence = 0.929

Rule 69

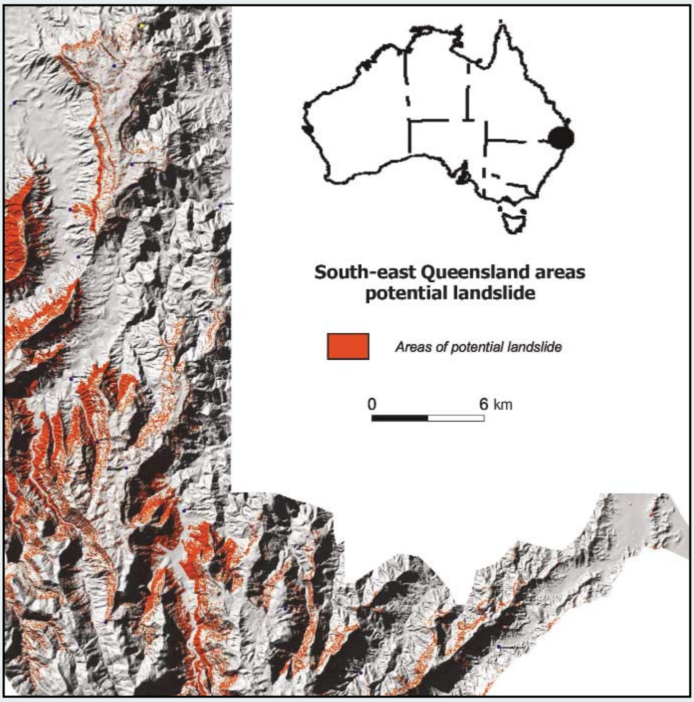
Aspect = 281°–300°
Slope = 7°–9°
Class = No
Confidence = 0.927

Rule 68

Geology = Marburg Formation
Slope = 40°–42°
Class = Yes
Confidence = 0.909

Table 1. A portion of the rule-set for landslides in south-east Queensland caused by the January 1974 rainfall event

Figure 3. Areas of potential landslide in south-east Queensland from the decision-tree analysis



Results

The decision-tree analysis shows that geological units are the primary controlling influence of landslide occurrence (figure 3). Field checking confirmed that it is an effective way of identifying further areas of potential landslide in the region.

Marburg Formation

In the Marburg Formation, landslides and debris slides tend to occur on slopes between 30° and 44° and on cleared slopes between 24° and 30°. They tend not to occur on slopes between 0° and 23° or between 45° and 75°.

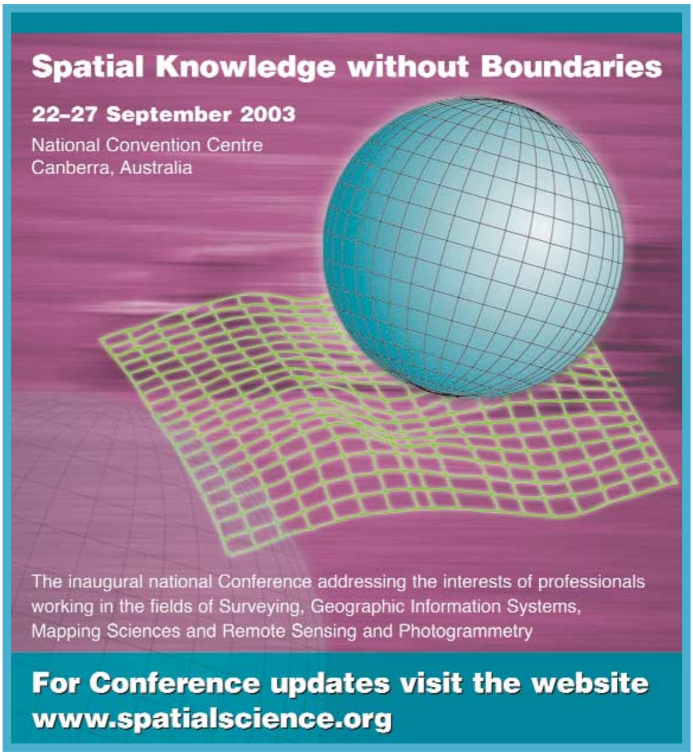
Tertiary colluvium

Where there is colluvium and the vegetation is cleared, landslides occur. If the colluvium is vegetated, landslides tend to occur on north-east and south-west facing slopes.

When morphology is a factor, ridge and planer features favour landslides. Landslides tend not to occur in concave landforms, but when curvature is a factor, concave features tend to promote landslide occurrence.

Beechmont Basalt

Landslides tend to occur on slopes between 12° and 41°, but more so on the edge of broad ridges with slopes of 6° to 11° and a southerly aspect. They tend not to occur on slopes between 0° and 3° or between 48° and 59°.



CASE STUDY 2:

SOCIAL VULNERABILITY

The impact of natural hazards on communities is a difficult, and at times almost impossible, assessment to make. Community vulnerability is not simple or static because personal and community circumstances continually change.

Measuring vulnerability has largely focused on qualitative assessment rather than quantitative risk modelling. Geoscience Australia's Risk Research Group is exploring the use of social indicators and decision-tree analysis to assess vulnerability.

Method

The 1996 Australian census data provided most values for the indicators of social vulnerability (figure 4). 'Typical individuals' in the Australian community were randomly generated from the data. A questionnaire was then developed, which asked participants to rank the vulnerability of these individuals to natural hazards. This provided a quantitative measure of the perception of vulnerability.

Decision-tree analysis was used to extract decision rules from the questionnaire results. The rules identified the different combinations of values that the participants thought contributed to social vulnerability.

The decision rules were applied to data from the Perth metropolitan area to identify potentially vulnerable individuals.

Vulnerability was integrated with hazard maps to generate a risk map for the Perth metropolitan area. The risk map identifies the districts with people considered most susceptible to natural hazards. This information is very useful for prioritising natural hazard mitigation, recovery and response strategies.

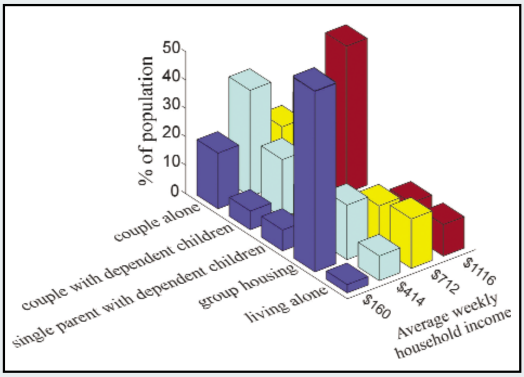
Results

The 1101 questionnaire responses were processed through CART (classification and regression trees), which is another implementation of decision-tree induction. The resulting tree generated 22 decision rules, where 11 were affirmative in regard to high vulnerability.

A person is considered vulnerable if one of the affirmative rules stated in figure 5 holds true.

The decision rules indicated that people thought personal injuries, residence damage, house insurance, income and age contributed to high vulnerability. The perceived high importance of residence damage and personal injuries was expected, and the importance of the other factors confirms current theories in disaster–risk research. But it was a surprise that gender, health insurance and disability were perceived to be of low importance.

For further information phone Anita Dwyer on +61 2 6249 9027 or e-mail anita.dwyer@ga.gov.au



▲ **Figure 4.** Australian Bureau of Statistics data used for the vulnerability indicator 'household type'

```
vulnerability = 'Low' # Default if no affirmative
                        rule is found
if INJURY_ PERSON > 3.5:
      vulnerability = 'High'          # rule = 1
else:
    if AGE > 46.5:
    if AGE > 60.5:
      vulnerability = 'High'          # rule = 2
else:
    if DAMAGE_BUILDING > 2.5:
      vulnerability = 'High'          # rule = 3
else:
    if DAMAGE_BUILDING > 3.5:
    if FAMILY_TYPE in [1,3,5]:
      vulnerability = 'High'          # rule = 4
else:
    if HOME_INS == 0:
      vulnerability = 'High'          # rule = 5
else:
    if DAMAGE_BUILDING > 3.5:
    if AGE > 43.5:
    if AGE > 66.5:
      vulnerability = 'High'          # rule = 6
else:
    if DAMAGE_BUILDING > 4.5:
    if AGE > 51.5:
    if INCOME <= 216.5:
      vulnerability = 'High'          # rule = 7
else:
      vulnerability = 'High'          # rule = 8
else:
    if HOME_INS == 0:
    if TENURE_TYPE in [1,4]:
      vulnerability = 'High'          # rule = 9
else:
    if AGE > 64.5:
    if TENURE_TYPE in [2,3]
      vulnerability = 'High'          # rule = 10
else:
    if AGE > 73.5:
    if FAMILY_TYPE in [4,5]:
      vulnerability = 'High'          # rule = 11
```

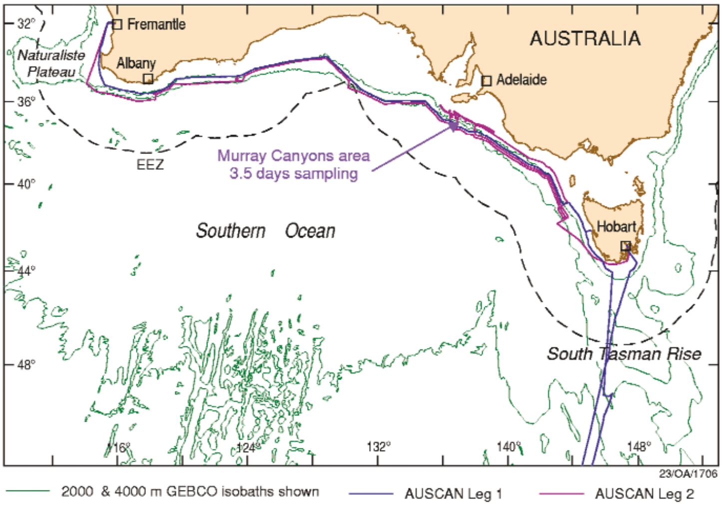
▲ **Figure 5.** The 11 decision rules for high social vulnerability

Australia is the flattest continent only reaching 2228 metres at its highest mainland peak, Mount Kosciuszko. But 150 kilometres off the coast from Adelaide is a different picture.

Almost 5000 metres beneath the ocean are underwater cliffs and valleys known as the Murray Canyons, which are deeper than America's Grand Canyon.

These canyons were some of the spectacular geological features mapped on a recent international research expedition (AUSCAN) involving Geoscience Australia.

Australia's GRAND CANYONS charted on research voyage



▲ **Figure 1.** Survey lines of the AUSCAN expedition that travelled 9000 kilometres and mapped approximately 70 000 square kilometres of sea-floor within three weeks.

AUSCAN expedition

The French ship, *Marion Dufresne* left Hobart on February 18 on the second leg of its three-week AUSCAN (AUStralian CANyons) expedition. It went west to explore Tasmanian submarine canyons and then north-west to the Murray Canyons (figure 1). It continued across the Great Australian Bight and along the south coast of Western Australia to Fremantle where it docked on March 5.

The ship travelled 9000 kilometres and mapped approximately 70 000 square kilometres of sea-floor.

Scientists had an idea of what would be found from earlier French–Australian work, such as the 1994 survey off west Tasmania and on the South Tasman Rise, the 1998 survey off south-west Western Australia, and a survey off southern Australia in 2000. But they were still excited by what they discovered.

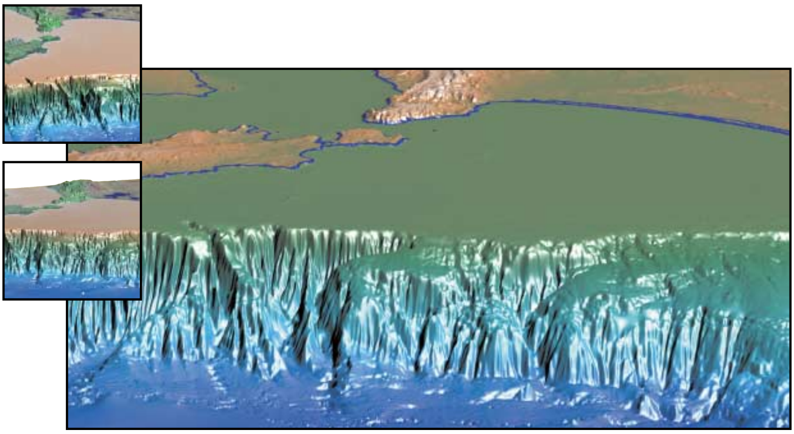


Figure 2. Images of the steep continental margin and spectacular Murray Canyons off South Australia

Murray Canyons

The continental slope south of Kangaroo Island formed when Australia split from Antarctica 65 million years ago. It is steeper and more rugged in this region than anywhere else on the Australian continental margin. Over a distance of only 40 kilometres it drops from 200-metres depth at the shelf edge to more than 5000 metres (figure 2).

The character of the canyons changes along the continental slope. Some are very rugged and steep, with cliffs up to two kilometres high dropping onto a flat abyssal plain. Others are linear and more than 100 kilometres long. The main canyon is 4600 metres deep.

For at least 30 million years the Murray–Darling River system has been shedding sediment into the canyons. The sediment has gouged large holes, a few hundred metres deep and several kilometres across, at the base of some of the steeper canyons.

Research program

AUSCAN's main objectives were to collect new data for marine environmental planning and management, to research the evolution of the margin and its canyons, and to find out more about environmental and climatic changes that affected the region during the late Quaternary.

The *Marion Dufresne* is equipped with multi-beam and sub-bottom profiler equipment, magnetic and gravity measuring instruments, and instruments to take temperature and salinity readings.

It also has a giant piston corer, 'Calypso' for sediment sampling. Calypso can take sediment cores up to 60 metres long from the deep ocean floor.

In deep water, the multi-beam system produces high-resolution 3-D images of the seabed in 20-kilometre-wide swaths at survey speeds of about 15 knots.

Giant cores

The highlight of the Murray Canyons sampling was the recovery of two giant piston cores, each more than 30 metres long from water depths of about 900 and 2450 metres.

The cores contain foraminiferal olive-grey silty clays with fine sands and shell fragments in some zones. These are a diary of geological, climatic and biological changes in Australia over the past 250 000 years.

Analysis of the cores should reveal sea-level and environmental changes that took place in the Murray–Darling Basin before and after human habitation. The presence of microfossils and pollen in some layers will reveal temperatures and vegetation types in different periods. Pine and vine pollen in particular will provide information about the arrival of Europeans to Australia.

Charcoal in the cores will indicate fire history, and dust and clay should show erosion history.

Data collection

AUSCAN collected data from the ocean and sea-floor at various depths, and acquired 3.5 kHz of sub-bottom profiler, gravity, magnetics and oceanographic data along the 9000 kilometres of survey lines. These data are currently being analysed at Geoscience Australia and other science institutions.

Geoscience Australia has already created a digital movie or 'fly through' from the 3-D images of the Murray Canyons.

The underwater terrain maps that it is producing from AUSCAN data will be a valuable resource for the navy, the fishing industry, petroleum companies, environmentalists and marine geologists.

Expedition team

The AUSCAN expedition involved 40 scientists and technicians from Australia, France, Germany and other European nations, as well as the United States. The Australian marine institutions involved were Geoscience Australia, National Oceans Office (NOO), Australian National University and the South Australian Research and Development Institute. NOO provided much of the Australian funding for the $1.5 million project, which Geoscience Australia manages.

The 120-metre *Marion Dufresne* belongs to the French Polar Institute and is the largest vessel in the French research fleet.

For more information phone Peter Hill on + 61 2 6249 9292 or e-mail peter.hill@ga.gov.au

Australia present at *major mineral exploration* show

The annual PDAC (Prospectors & Developers Association of Canada) Convention is the largest event of its type in the world. It provides an opportunity for Australian companies and government to mix with the global mineral exploration sector.

PDAC is traditionally held in Toronto, which is now the world's major mining finance centre. In 2002 the Toronto Stock Exchange (TSX) and TSX Venture Exchange raised $3580 million in mining equity finance, which is about 2.5 times that of any other major exchange.

PDAC 2003 held from March 9–13 had a record attendance of 8000 people from 74 countries. Australia was well represented.

Australian pavilion

Geoscience Australia coordinated the Australian governments' technical promotion in the Australian pavilion of the Trade Show. This year the Trade Show had exhibits from 280 companies and governments, while the adjacent Investors Exchange comprised trade booths from 225 exploration and mining companies.

Australia's government display showcased expertise in mineral exploration science, technology and information. This complemented the displays of non-government organisations and companies in the Australian pavilion including ENCOM Technology, Intrepid Geophysics, pmd*CRC, Gekko Systems, Australian Mineral Economics, and the legal firm Blakiston & Crabb.

Under the theme of 'Australia: More to explore' the government team promoted Australia's premier exploration provinces—the Curnamona, Gawler, Kimberley, Lachlan, Mount Isa–McArthur, Musgrave, Tanami–Arunta, and Yilgarn provinces, the Murray Basin, Tasmania, and the coal resources and coal-bed methane potential of the Bowen and Sydney basins.

Other drawcards for the Australian pavilion were a '3-D fly through' on a large plasma screen of Australia's magnetic, gravity and topography, and live demonstrations of on-line databases and the geoscience web portal—a single entry point to the geoscience web sites of all Australian government agencies.

The Australian pavilion was coordinated by GeoJag Australia and supported by the Austrade offices in Canada.

Industry visits

The Australian government team also visited a number of Toronto-based Canadian companies that have mineral exploration programs in Australia.

As well, prior to the convention Geoscience Australia gave a technical briefing on mineral exploration and exploration opportunities in Australia to invited companies, resource analysts, and resources media. These presentations, supported by the states and Northern Territory, emphasised Australia's mineral endowment, its potential for further world-class mineral deposits, and its high-quality, pre-competitive geoscientific information base.

Technical program

The PDAC technical program comprised 107 papers in 16 themes. Dominant themes were commodity prices and the market outlook; diamonds; global issues and developments; gold outlook, issues and trends; and China as a mineral producer and consumer.

Geoscience Australia's Lynton Jaques gave a paper on Australian diamond exploration and potential. Technical papers can be viewed at www.pdac.ca/pdac/pub/papers/2003/index.html.

Outlook

The prevailing mood of PDAC 2003 was optimism because of an improved outlook for mineral exploration and a sense that the recent severe downturn had ended.

This optimism was fuelled by improved gold and nickel prices, an expected increase in demand for other metals, continued diamond exploration successes in northern Canada, and a significant increase in capital raising by Canadian mining and exploration companies.

For more information phone Mike Huleatt on +61 2 6249 9087 or e-mail mike.huleatt@ga.gov.au

EVENTScalendar

Compiled by Steve Ross

- **Coastal GIS 2003**
  University of Wollongong
  7 & 8 July, Wollongong
  Contact: Colin Woodroffe, University of Wollongong
  phone +61 2 4221 3359
  fax +61 2 4221 4250
  e-mail: colin@uow.edu.au

- **Ishihira Symposium—Granites and Associated Metallogenesis**
  Macquarie University
  22 to 24 July, Sydney
  Contact: Ishihara Symposium, c/- Golden Cross Resources, Level 1, 22 Edgeworth David Avenue, Hornsby, NSW 2077
  fax +61 2 9482 8488
  e-mail info@goldencross.com.au

- **Australian Disaster Conference 2003**
  Emergency Management Australia
  10 to 12 September, Canberra
  Contact: Conference Secretariat, PO Box 42, Yarralumla ACT 2600
  phone +61 2 6232 4240
  fax +61 2 6232 4245
  e-mail enquiry@einsteinandedison.com.au

- **Spatial Sciences 2003**
  AURISA and others
  22 to 27 September, Canberra
  Contact: Conference Logistics, PO Box 201, Deakin West ACT 2601
  phone +61 2 6281 6624
  fax +61 2 6285 1336
  www.conference@conlog.com.au

- **Mining 2003**
  29 to 31 October
  Carlton Crest Hotel, Brisbane
  Contact: Mining 2003, PO Box 1153, Subiaco, WA 6904
  phone +61 8 9388 2222
  fax +61 8 9381 9222
  e-mail abbie@verticalevents.com.au

- **6th Petroleum Geology Conference**
  Petroleum Exploration Society of Great Britain and others
  6 to 9 October, London
  Contact: Marta Kozlowska, Institute of Petroleum
  phone +44 20 7467 7105
  fax +44 20 7580 2230
  e-mail marta@petroleum.co.uk
  www.petroleum.co.uk

Atlas of QUAKE FAULT PLANES *available*

For the first time, the focal mechanisms for 84 earthquakes in the Australian region have been determined and compiled into an atlas (published as Geoscience Australia record 2002/19).

The earthquakes are presented in chronological order. The hypocentre, magnitude, focal plane solution (107 in total) and a picture are provided for each earthquake. Additional comments are included where available, as well as the data used to determine the mechanism.

Most mechanisms are derived from the analysis of first motions. Many of the larger events since 1980 also have moment tensor solutions.

Of the 84 earthquakes analysed, 70 are thrust events, 12 are strike-slip and two are normal mechanisms. This is consistent with a model of compression stress in Australia.

Two quality ranking schemes are used in this atlas. One is the Zoback rating, which is a measure of the tectonic stress information. The second devised by Leonard and Ripper is essentially a measure of how well the null axis is constrained.

The type of earthquake (thrust, strike-slip or normal) and the geometry of the fault plane can often be determined by studying the seismic waves from an earthquake recorded at widely disbursed seismograph stations.

The most common method is to plot the initial direction of movement, or polarity, of the P phase onto an equal area stereographic projection, using the azimuth of each station from the epicentre, and the angle of departure from the vertical of the direct ray from the source to the station.

Regions of positive and negative polarity are then separated into quadrants by two mutually orthogonal nodal planes, one of which represents the fault plane and the other an auxiliary plane. But it is not normally possible to determine which plane is the fault plane without additional information (e.g. fault scarp, geology, geophysics or tectonics).

The resulting diagram is known as a focal plane solution, or focal mechanism. The line bisecting the dilative dihedron of a focal mechanism is the P-kinematic axis, and the line bisecting the compressive dihedron is the T-kinematic axis. These axes, and the line of intersection of the nodal planes (B axis), correspond very crudely to the $\sigma1$, $\sigma3$ and $\sigma2$ principal stress axes respectively.

Record 2002/19: Australian earthquake fault plane solutions by Leonard, Ripper and Yue comprises a book and CD. It can be purchased from the Geoscience Australia Sales Centre for $27.50 (includes GST) plus postage and handling.

For more information phone Mark Leonard on + 61 2 6249 9357 or e-mail mark.leondard@ga.gov.au

National gravity database *updated*

More than 1.2 million point gravity measurements comprise the latest Australian National Gravity database released on May 30.

This edition includes onshore and offshore data for the area extending from 8°–48°S and 108°–162°E.

Roughly 390 000 gravity stations have been added. The extras are recent additions, data no longer embargoed, and offshore data that were not included in the 2002 release. All data are provided in GDA94 coordinates.

The database is updated annually as a cooperative effort involving Geoscience Australia, state and territory geological surveys, private companies, universities and other organisations.

A CD-ROM containing the database and an ER Mapper gravity grid of Australia can be purchased from the Geoscience Australia Sales Centre for $99 (includes GST) plus postage and handling.

Alternatively, the database and grid can be downloaded free from Geoscience Australia's web site.

Commonplace and unusual in *latest* GAZETTEER

The ultimate resource for Australian geographic names and their locations is the *Gazetteer of Australia 2002*, released in April.

Where else would you find a town called Nowhere Else? Try Tasmania. And what springs to mind as the most common geographical name in Australia? Look up Spring Creek.

South Australia also has a couple of noteworthy ones. Mamungkukumpurangkuntjunya Hill is the longest place name in Australia and there is a homestead called Didyabringyagrogalong.

These are among 297 220 authorised geographical names in the gazetteer, which covers Australia and its offshore regions.

This latest version has been improved by including three more fields: a 'postcode' field that has postcodes for 14 652 places, a 'state identity' field, and a 'concise gazetteer' field that flags names included in the *Asia–Pacific Concise Gazetteer*.

Government authorities responsible for administering official geographic names provided the gazetteer data. It is developed under the auspices of the Intergovernmental Committee on Surveying and Mapping and updated annually as a cooperative effort with Geoscience Australia.

Since the gazetteer's first release in 1995, more than 82 500 geographical names have been added.

The gazetteer is the authority on the location and spelling of Australia's geographical names ranging from built features such as airstrips and homesteads to natural features such as mountains and hot springs. To check the spelling of a town's name or a geographical feature visit the Place Name Search at www.ga.gov.au/map/names/

The *Gazetteer of Australia 2002* is available as fixed-length text files on a CD-ROM for $540 (single user) plus postage and handling.

To order a copy phone Freecall 1800 800 173 (within Australia) or +61 2 6249 9966, or e-mail mapsales@ga.gov.au

Another *seven* products free on-line

Seven more of Geoscience Australia's digital data products are available free on-line under the Commonwealth Government's Spatial Data Access and Pricing Policy, which means for these products there are few limitations on commercial use or value-added activities.

They can be downloaded in ArcInfo Export, ArcView Shapefile or MapInfo mid/mif formats, and are suitable for GIS applications.

Australia's River Basins 1997 resulted from a commonwealth–state/territory government project to create a national database of major hydrologic basins. There are boundary and attribute information for 12 divisions, 77 regions and 245 basins, which are the basis for collecting national hydrologic data and assessing water resources.

Commonwealth Fisheries 2003 shows the boundaries of each Commonwealth Fishery in Australian territory (except the Australian Antarctic Territory), as set out in the Fisheries Management Regulations 1992 and relevant Management Plans administered by the Australian Fisheries Management Authority.

Aboriginal and Torres Strait Islander Commission (ATSIC) Boundaries 2001 contains the geographic boundaries of the Regional Council areas and Wards as defined by ATSIC.

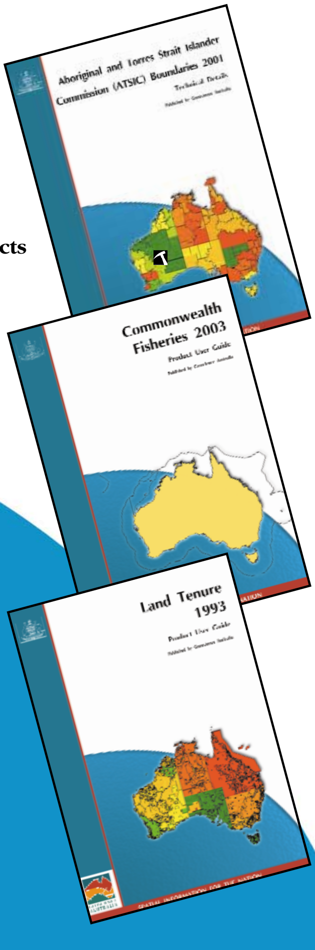
National Public and Aboriginal Lands pre-1998 contains boundary and attribute information for parcels of public (freehold and leasehold) and Aboriginal and Torres Strait Islander land in Australia that are larger than 40 hectares. Selected smaller areas are shown by point locations (includes nature reserves, forests and Aboriginal land).

Land Tenure 1993 contains boundary and attribute information for parcels of public, private and Aboriginal lands in Australia. Data are sourced primarily from Government Gazette Notices, cadastral maps and plans.

Vegetation: Post-European Settlement 1988 shows vegetation in 30 000+ hectare areas, plus small areas of significant vegetation such as rainforests and crop land.

Vegetation: Pre-European Settlement 1788 shows vegetation in 30 000+ hectare areas, plus small areas of significant vegetation such as rainforests.

For more information about these products contact Geoscience Australia's National Mapping Division on +61 2 6201 4201 or visit www.ga.gov.au.



REVISED & UPDATED BROCHURE

LANDSLIDE awareness

This handy colour brochure provides an excellent summary of landslides in Australia: what causes them, what areas are prone, common types, and indicators (such as saturated ground, leaning walls and fences, and new cracks in roads), as well as some common-sense advice on how to minimise the effects of landslides.

There are lots of photographs and diagrams and it is written in simple English, which makes the brochure an ideal handout at community meetings.

The brochure was produced as a double-sided A3 sheet folded to A5 for ease of postage or for slipping into a pocket.

Geoscience Australia and Emergency Management Australia produced the brochure with assistance from the University of Wollongong. To obtain copies phone Matt Hayne from Geoscience Australia's Risk Modelling Group on +61 2 6249 9536 or e-mail matt.hayne@ga.gov.au

For those wanting more on landslides, peruse the Australian Landslide Database via www.ga.gov.au or www.ema.gov.au.

Fast tool
for emergency managers

AusDIN Demonstration Portal

Home | Submit URL | News Headlines | About AusDIN | FAQs | Contact Us

Web Resources - [help]

Event Type
Natural: bush fire (79), cyclone (53), drought (29), earthquake (40), flood (55), geomagnetism (4), heatwave (21), landslide (31), meteorite (12), severe storm (46), storm surge (30), tsunami (29), volcano (27)
Man-made: air crash (16), building collapse (11), chemical/nuclear (23), disease (7), land crash (16), space junk (7), structure fire (39)

Coverage
ACT (14), NSW (49), NT (14), QLD (25), SA (11), TAS (19), VIC (30), WA (13), island territories (13), Australia (100), international (85), global (48)

Activity
prevention [illegible] mitigation (98), response (119), risk assessment (147)

Information Type
fact sheets (180), kids stuff [illegible] manuals (1), maps [illegible] legislation (20), newsletters [illegible] media releases (46), research/academic (115), policies (1), recent

Who's Who
contact lists (8), [illegible] home pages (61)

Special Interest Groups (SIGs)

Current Weather Warnings - [Pop-up Map]
...by region, updated every 10 minutes for demonstration
also check the latest details at the Bureau of Meteorology.
Last updated: 12:16 18-Jun-2003 EST

Legend: 🟥 Fire, ▨ Storm, 🟩 Wind, ▨ Other, ☐ None
NB: Not all warnings may be displayed. Click on map, or states below.

State/Territory Summaries:
NSW/ACT Coastal Wind Warning (1)
NT Coastal Wind Warning (1)
Fire Weather Warning (1)
QLD Ocean Wind Warning (1)
SA Ocean Wind Warning (1)

All phases of emergency (disaster) management, from policy and planning to risk assessment and recovery, benefit from ready access to up-to-date and relevant information.

The Australian Disaster Information Network (AusDIN) is a national initiative that aims to meet such needs by improving the sharing of emergency management information.

A key element of AusDIN is a web portal—a central mechanism for information exchange and linking emergency management expertise.

Gateway

The portal will be the gateway to existing stores of information. It is not an information warehouse, although links, metadata and catalogues will have to be stored on the AusDIN server. Owners of the information being distributed are responsible for the provision, maintenance, validation, and control of access.

AusDIN will not set standards and protocols, but will benefit greatly from them and will help promote the adoption of standards.

Content development will be the responsibility of users.

Development

A feasibility study was undertaken in 2000 by EarthWare Systems, which led to Geoscience Australia developing the first prototype modelled on the Australian Geoscience portal. Since then the AusDIN portal has evolved in three stages.

In stage 1 the feasibility and technical capability required of AusDIN were demonstrated.

In stage 2 the content and capability were expanded to bring AusDIN closer to operational capability, for use by a few special-interest user groups. Stage-2 was completed in July 2002.

In stage three, users have been expanding the portal's capability to meet their particular needs.

The primary address for the prototype portal is www.ausdin.net. The stage-2 version is on the development site at www.digitalearth.com.au/ausdin/. At this address select the most recent version from the development log. This site eventually will be moved to www.ausdin.net.

Features

The portal features are in varying stages of development.

Front-page options deliver access to web resources in three clicks. These links to sites (pages), which are grouped by topics under themes and super-themes, are useful for those who do not know where to find the information they need, or are interested in finding out what is available. The disadvantage is that an expert is required to assemble and classify the links.

A semi-automated system allows registered users to add URLs. Submission of a URL automatically triggers an e-mail request for permission to access the page in question (i.e. to deep link). The URL is only installed if permission is granted. Thus, the portal is self-evolving in response to user needs.

User registration is supported, which allows usage to be monitored and determines URL-adding privileges. User-profile customisation, introduced in the stage-1 version of AusDIN, has been abandoned as users generally opt for unrestricted access. User information is secure.

Users may enter a key word and press 'search'. Commercial search systems are excellent and can access information beyond the scope of AusDIN. AusDIN provides links to Google and Teoma.

Forty-five AusDIN-approved servers (domains), comprising 6700 web pages and 14 000 documents are searched currently. A crawler automatically reads the documents and indexes key words to make searching fast.

Other information that can be accessed directly from the front page includes current news, live (real-time) data, recent events, warnings, gazetteer of place names and locations, education, frequently asked questions, and user feedback. A web mapping capability is being considered.

The AusDIN portal is currently open access with no restricted links. It is readily expandable to incorporate new features and embellish existing ones.

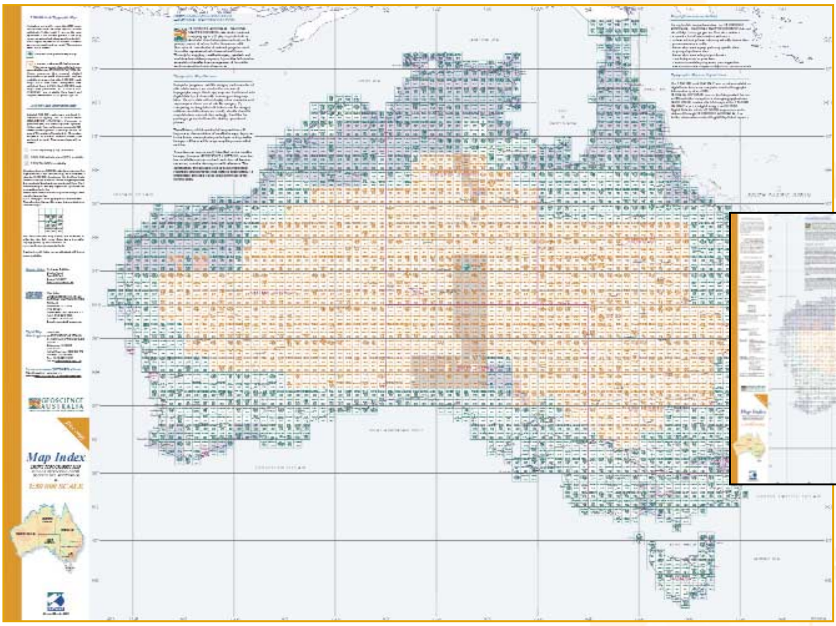
Management

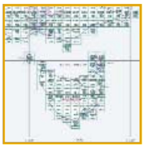
Development of AusDIN and its portal is directed by a steering committee under the auspices of the Australian Emergency Management Committee (AEMC). This committee comprises representatives from state/territory emergency management committees, Emergency Management Australia, and other commonwealth agencies and departments.

Emergency Management Australia (Attorney General's Department) provides the AusDIN Secretariat and manages its business affairs.

For more information phone Rob Lee, Emergency Management Australia on + 61 3 5421 5245 or e-mail rlee@ema.gov.au

Defence maps for public use *indexed*





For the first time, a national map index has been released that shows all the Department of Defence 1:50 000-scale topographic map sheets available to the public.

Maps at this scale will interest many because of the detail. One centimetre represents 500 metres, and each sheet covers an area about 30 kilometres from east to west and north to south.

There are approximately 2600 map titles. Most cover a large part of northern Australia above the Tropic of Capricorn, but there are some select areas in all mainland states.

The maps are mainly topographic line maps. About 400 are orthophoto maps, which combine aerial photography and the line maps.

The orthophoto maps are shown in light brown on the index. The topographic line maps are marked in purple.

These maps are produced by the Department of Defence and distributed through Geoscience Australia and its retailer network across Australia.

For more information or copies of the map index contact Geoscience Australia Sales Centre on Freecall 1800 800 173 (within Australia) or visit www.ga.gov.au. Retailers are listed at www.auslig.gov.au/products/purchasing/retailers.htm