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AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

AUSGEO *news*

~ *Geoscience* Australia ~

OCTOBER/NOVEMBER 2000 **ISSUE No. 59**

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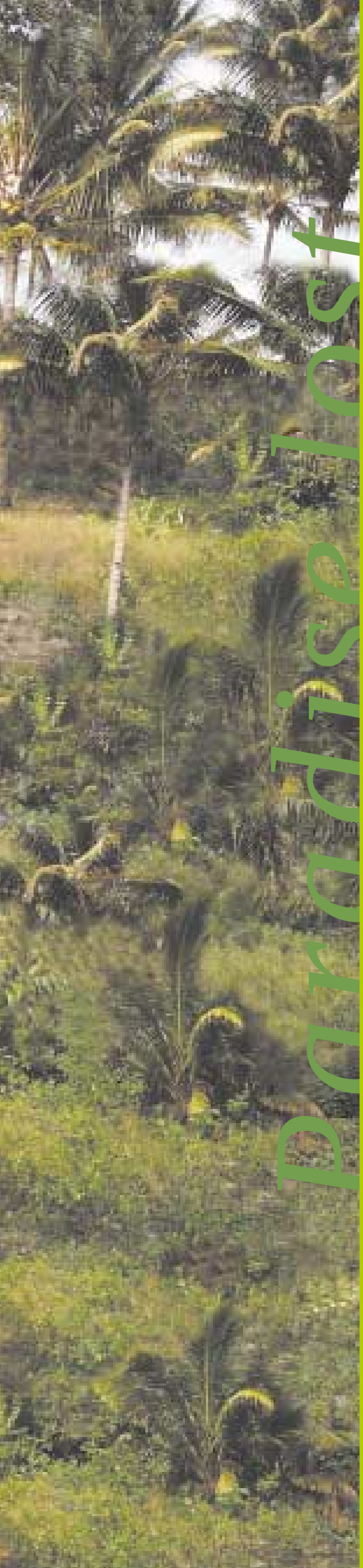
Romeo—an 11-megaton shot fired from a barge near Bikini Atoll (Marshall Islands, Pacific Ocean) on March 26, 1954. Romeo was one of six atmospheric tests carried out as part of Operation Castle by the United States of America.

Photo: United States Department of Energy



Paradise lost

NAURU *seeks* AGSO *help* AFTER PHOSPHATE MINING

imagine… a picture-perfect Pacific island of about 2150 hectares covered by a riot of coconut palm, pandanus, mango, wild almond and native hibiscus thriving in phosphate-rich soil and hot, humid weather. This beautiful island was Nauru at the beginning of last century—before phosphate mining began in 1907.

Nauru's economy was built on phosphate mining. But the removal of vegetation with no rehabilitation has made the island's central plateau a barren landscape of limestone pinnacles. Hot air builds above this bare limestone, disperses the cloud and reduces rainfall. Over the years, drought has hit the island, retarded its vegetation and thinned out bird habitats.

Nauru phosphate will be depleted in the not too distant future, and the island's economy must look to other industries. The central plateau is important to Nauru's well being and therefore rehabilitation is urgent. But can this be done?

Feasibility

A joint Nauru–Australian study completed in September 1994 found that after almost 100 years of phosphate mining, the central plateau could be rehabilitated. But it would require massive earth works and a lot of money (A$66 million) to level approximately 1300 hectares—if that was the government's preferred solution. Luckily, the sale of residual phosphate should cover costs. But the problem for Nauru's government was collecting reliable land management data that would help it make informed decisions about how to improve and develop the heart of the island.

At the end of last year, AGSO was commissioned by the Nauru Phosphate Corporation (NPC) and the Nauru Rehabilitation Corporation (NRC) to develop a detailed geographic information system (GIS) for Nauru (see *AusGeo News* no. 55, 1999). This system would offer in electronic form, detailed information for use in mining and rehabilitation, environmental management, civil engineering, surveying, urban design and planning, landscape architecture, energy, and waste management. AGSO was the ideal choice because two of its geologists (Bill McKay and Keith Porritt) had carried out a scoping study on Nauru in April 1999, and had conducted similar work on Christmas Island in the Indian Ocean.

Multiple phases

Essential to the GIS was the complete orthophotographic coverage of the island, as well as a digital elevation model (DEM). So in phase one, AGSO geo-corrected any aerial images of Nauru and built the DEM.

In the orthophotos, various distortions due to the landscape and camera lens were removed. The size of an individual cell or pixel in the high-resolution orthophotography is 15 x 15 centimetres on the ground, which provides sufficient detail to see individual trees, bushes and limestone pinnacles. A reflective surface DEM with one-metre spot heights was created directly by computer techniques. A second DEM of ground spot heights on a five-metre grid was created from manual observations using an analytical plotter. By combining the DEMs and the orthophotography, further details such as the heights of buildings or trees can be estimated. In phase two, the data was reworked and integrated and metadata compiled.

In phase three, the basic GIS (level one system) and the full GIS (level two system) were developed, CDs and training manuals for each system were produced, and training courses were conducted on Nauru for key stakeholders and users of the system.

AGSO's Bill McKay (left) hands over the Nauru GIS to Nauru Rehabilitation Corporation Chair, Lui Eoaeo, and Chief Executive Officer, Graham Pascoe.

(Right to left) Bill McKay helps Porthos Bop and Robin Daoe during level two training.

AGSO's Keith Porritt delivers level two training to Nauru Government officers.

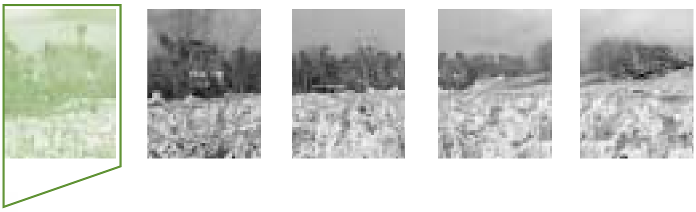
Phase three completed

The GIS was formally handed over to Mr Lui Eoaeo, Chair of the Nauru Rehabilitation Corporation (NRC) on June 30. In one integrated system, the Nauru government has at its fingertips a decision-support, planning and map-making capability to underpin its long-term program to rehabilitate and develop extensively mined-out phosphate areas of Nauru.

AGSO's Bill McKay, Keith Porritt and Neal Evans recently completed the Nauru GIS commissioning by running three training courses for staff from the NRC, NPC, and Nauru's Department of Lands and Survey.

Design, planning and cadstre management issues using the GIS were considered during the training courses, through on-going discussions and at ad hoc workshops. Tasks addressed by the AGSO team using the level two GIS while on Nauru involved: siting large excavation test pits and a trial rehabilitation area; investigating hydrological features and possible catchment areas; visualising options for relocating the airstrip; and examining ways that remaining phosphate resources might be identified and mined. Among interested parties, the level one GIS was demonstrated to a forum of school principals, teachers and Nauru's Minister for Education.

The level one version is based on ArcExplorer GIS software and packaged onto an autorun CD-ROM with tutorials and electronic copies of the user manual and associated reports. Numerous copies of the level one CD were provided to the NRC to distribute within the corporation and elsewhere in government. The level one GIS was installed on a number of PCs in government offices.



The level two version consists of three additional CDs of high-resolution data. It provides extensive capability for further analysis and development of the information holdings with licensed ArcView GIS software. Examples presented in the training courses and provided on the self-paced CD tutorials draw on actual field data, which helps staff to appreciate how the system could be used. The project was completed on schedule and within budget. It shows that AGSO can assist with decision-support, environmental management and rehabilitation where significant national, regional or local issues are involved.

Mr Vinci Clodumar, Nauru's Permanent Representative to the United Nations in New York and Director of the NRC, in a letter of thanks to AGSO noted: 'The GIS has delivered an excellent planning and decision-support system that reflects practical understanding of land tenure, land use and sustainable development issues affecting renewable and non-renewable resources on Nauru'.

With proper planning using tools like the GIS, Nauru could see the development of thriving fishing and shipping industries and restore a tropical paradise that tourists would find so attractive.

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AGSO vigil traces NUCLEAR *testing*

For anyone letting off a nuclear explosion—AGSO is watching and will report the event to signatories of the Comprehensive Nuclear-Test-Ban Treaty (CTBT).

There is a chance that you won't be detected if you've placed a small nuclear explosion in a barge in the south Atlantic, and detonate it on a rainy day within 10 seconds of a nearby large earthquake. Otherwise AGSO's discrimination capability using a global network of sensors can trace the event, as leader of AGSO's Nuclear Monitoring Program, Dr David Jepsen explains.

▲ Location of nuclear explosions 1945–1998

May 28, 1998 and we were on high alert. I was working the four to midnight shift and examining the data every five minutes. I was looking for a clear explosive-like waveform from a nuclear test of about 10 kilotons—the size that would be expected from a new player in the nuclear weapons game. What complicated the matter was a large earthquake in Afghanistan 30 minutes before the nuclear explosion in Pakistan. Also there were numerous aftershocks, but at least we had an idea in which region the explosion would occur.

The recorded waveforms of the nuclear explosion were a lot simpler (as expected) than the Afghanistan earthquake and associated aftershocks. But we might have missed it if the nuclear explosion occurred in the coda of that big quake.

Smaller nuclear explosions aren't as easy to discriminate as the characteristics of the recorded waveforms mix with the earthquake and mine blast population. A thorough understanding of the source dynamics, geophysical properties of the source region, and propagation path characteristics to the receiver is required to discriminate these smaller events. We have a good understanding of the known nuclear test sites. But we need to extend our knowledge globally so that we can flush out possible evasive nuclear testing in unknown areas.

AGSO's nuclear monitoring program began in 1986 as the result of a Cabinet submission, and has been actively involved in monitoring nuclear explosions worldwide and testing systems that would be able to monitor a future treaty. When negotiations started in 1994 for the CTBT, AGSO was heavily involved in providing technical advice and was part of the Australian negotiating delegation.

The first nuclear test: Trinity, July 16, 1945 was set off by the United States in the 'Journey of Death' desert, New Mexico. **Photos Berlyn Brixner. US Department of Energy**

Treaty history

The United States let off the first nuclear explosion, named Trinity, in 1945. Shortly afterwards, two bombs were dropped over Japan. The Soviet Union started their program in 1949 and the United Kingdom in 1952. The French took up nuclear testing in the 1960s, as did China.

With a proliferation of nuclear explosions in the early 60s, the USA, UK and Soviet Union agreed on a limited test ban treaty. This banned all nuclear explosions in the atmosphere, outer space and oceans. But nuclear explosions could still be tested underground. China, not a signatory to this tripartite agreement, continued with atmospheric explosions until 1980. Concerned about the spread of nuclear weapons technology to other countries, the USA, UK and Soviet Union also signed a non-proliferation treaty. In 1974 the same countries signed a threshold test ban treaty to limit the size of underground nuclear explosions to 150 kilotons.

At one stage, the USA accused the Soviet Union of detonating nuclear explosions greater than 150 kilotons. The British proved this was not the case. The geology of the Soviet test sites resulted in much stronger signals than from comparably sized explosions in the unconsolidated materials of Nevada where the USA was conducting tests.

In 1992 the USA, UK and Soviet Union commenced a moratorium on testing. In 1994, CTBT negotiations started and by 1996 all P5 nations (USA, UK, Soviet Union, France and China) had stopped nuclear testing. In mid-1998, India resumed testing followed shortly after by Pakistan with two explosions.

The CTBT verification system was designed to monitor nuclear explosions underground, in the water, and in the atmosphere down to one kiloton. A number of technologies to verify compliance of the treaty were discussed. Final consensus was 321 monitoring stations from four technologies (seismic, hydroacoustic, infrasound and radionuclide) to monitor tests in these environments. Other options that were considered, such as the use of satellite technology, were rejected because of prohibitive costs.

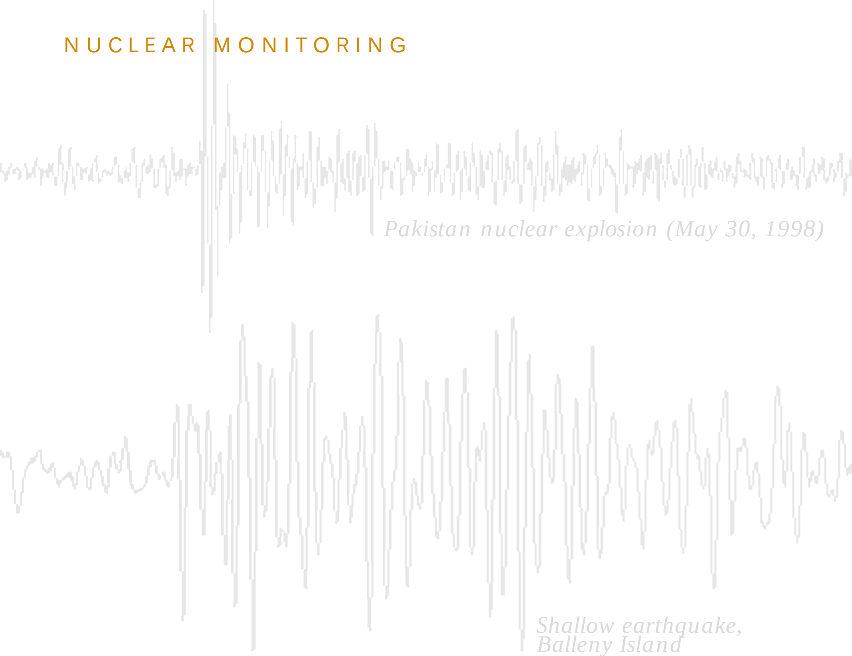
Australia signed the CTBT as soon as it was opened for signature in September 1996 and ratified it about two years later. This means Australia is obliged to verify compliance with the treaty and participate in the construction and operation of international monitoring stations in territories governed by Australia.

Event screening criteria

The global monitoring system currently being set up for verification of the treaty will record more than 20 thousand events a year. The idea behind discrimination of nuclear explosions is to screen out events caused by natural sources or non-nuclear human phenomena. The remaining events can then be scrutinised and findings handed into the international arena for judgment.

A number of screens can be defined by using current knowledge of differences between earthquake and nuclear explosion sources, as well as the hypocentral location of the event. For example, a nuclear explosion should generate more high-frequency energy than an equivalent-sized earthquake, have a simpler waveform, and generate comparatively little shear-wave energy (although shear stress release in the rocks around the explosion and source dynamics can complicate the picture).

The current screening criteria agreed upon by State Parties to the treaty consist of three discriminants: Ms:mb, depth, and synergy of seismic location with hydroacoustic data. Ms:mb has proved to be the most robust teleseismic discriminant for shallow seismic events and is based on the well-documented observation that nuclear explosions generate less surface-wave energy than equivalent-sized earthquakes.



The depth discriminant was developed to screen out events that are confidently deeper than a depth threshold (10 km in this case) for which it is unfeasible to test an underground nuclear explosion. Likewise, seismic-hydroacoustic criteria were developed to screen out oceanic seismic events which are confidently located in water depths and sub-oceanic material in which it is infeasible to install and test explosions, and have no hydroacoustic explosive characteristics.

These event-screening criteria are capable of screening out approximately 60 per cent of all global seismic events of mb 3.5 or greater. It is expected that as the International Monitoring System evolves, the screening capability of these discriminants alone will get close to meeting the well-coupled one kiloton (around mb 4.2) explosion target, for which the monitoring system was designed. The smaller, more difficult events will rely heavily on the application of regional discriminants. Understanding their regional variability is a complex problem and will involve tireless examination of 'groundtruth' data and geophysical phenomena.

AGSO's future role

AGSO will continue to perform discrimination research to improve Australia's capability to verify compliance of the treaty. Recently we held an International Event Screening Meeting in Alice Springs to consider improvements to current seismo-acoustic event screening criteria.

Since AGSO is one of two national data centres for the Australian National Authority that reports directly to the CTBT Organisation, we will be responsible for constructing and operating six seismic stations, four infrasound stations and one hydroacoustic station. Last year AGSO carried out site surveys for two infrasound sites in Tasmania and south-west Western Australia. These sites will be installed in 2001.

AGSO will continue to provide technical advice to the Departments of Defence, and Foreign Affairs and Trade on suspected nuclear explosions and ambiguous events. As well, AGSO must be ready with technical evidence to respond to potential, although remote, on-site inspections in Australian territory.

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Photos courtesy of the
US Department of Energy

FORUM PROBES *need for* GEOSCIENCE *in environment issues*

There is a lot happening below the surface of AGSO. No-one would be surprised that about 45 per cent of current project outcomes focus on locating and promoting Australia's mineral and petroleum wealth. It is after all a geoscience organisation and it creates geological maps and databases. But AGSO is in the knowledge industry rather than the resources industry. It is involved in more than helping explorers find resources to dig up.

Much scientific effort goes into compiling unbiased data for environmental managers faced with such issues as resource sustainability, conflicts in resource usage, community safety from natural hazards, and greenhouse gases. In the past AGSO did not overtly seek such research projects, although that is changing. And it has not openly promoted the breadth of its expertise. But more and more AGSO is approached by industry and all levels of government to look at the sub-surface and Earth's geological history for answers to environmental symptoms appearing on the surface.

This work dubbed 'environmental geoscience' occurs in all AGSO research divisions (Minerals, Petroleum and Marine, and Geohazards and Geomagnetism).

Forum

At the October science forum AGSO scientists asked whether they should raise the visibility of their environmental geoscience work and identify more opportunities to get involved. The overall response was 'yes'. AGSO geoscientists believe they should 'signpost' their environmental research so people are aware of what they do. They want to be involved in finding viable solutions to some environmental questions concerning Australian communities—questions that can only be answered by looking below the surface and working across scientific disciplines.

The forum was structured around six groups that grappled with environmental geoscience issues and what AGSO could and should be involved in. Discussions focused on the following broad topics: resource availability, environmental degradation, natural hazards, anthropogenic hazards, estuarine and coastal environments, and offshore marine environments.

Resource availability

Resource access is a global need and Australia needs mineral and petroleum exploration for the wealth it generates. But there is an emerging international issue: what to do with waste from extracting raw materials. AGSO has the skills and is researching ways of storing unwanted extracted material and by-products (e.g. the GEODISC study with particular emphasis on re-injection of CO_2).

Australia introduced new environmental legislation in July 2000. This means those extracting resources in Australian territory must consider not only the economic, but also environmental and social values of the community. Other nations follow the same policy.

Geoscience information, integrated with other information (e.g. biological information), provides a better understanding of environmental impact and land management problems. AGSO is a public agency for supplying objective advice concerning access and land use. It can gather geoscience data for the exploration industry to use in broad plans for sustainable development. It can also develop indicators (e.g. the Regional Forest Agreement process) to assess exploration and mining priorities against sustainable development requirements.

Environmental degradation

Geoscience has an obvious role in solving such problems as: salinisation of soil and water, acid sulphate soils, soil erosion and degradation, radioactive waste disposal, re-injection of greenhouse gases, and heavy metal contamination. AGSO has a broad skill base and is familiar with the field-based disciplines that would be called upon for solving these problems. In addition, AGSO is one of the only national organisations undertaking geochemical studies and has a good understanding of sedimentology, as well as excellent geophysical capabilities (electromagnetic and seismic surveys) to map and model the processes and systems causing the problems. Close liaison with other organisations through a Cooperative Research Centre project would provide hydrology and biology input, and some in-house research capability in groundwater would expand what AGSO can do.

Natural hazards

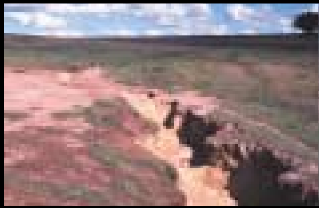
The average annual cost of natural disasters in Australia between 1967 and 1999 was about $1.1 billion. Floods and storm surges associated with tropical cyclones result in the largest losses. Vulnerability increases as population and development expands in coastal regions. Community leaders and caretakers want accurate information about the potential impact of natural hazards on their community (e.g. building damage, health costs and possible sea level rise).

AGSO has been building tools such as databases that governments, community planners and international aid agencies can use for public safety—i.e. to reduce the loss of life, property damage and economic disruption in the event of a natural disaster. Databases exist for tsunamis, storm surge, earthquakes and landslide, and those of a meteorological nature.

AGSO, the Bureau of Meteorology, state and local governments and universities all compile hazard data with little methodological consistency.

▶ *Continued on page 27*

SALINITY



SALINITY

SALINITY surfaces as a *geological problem* needing **in-depth** study

Australia is experiencing degradation of its agricultural land and river systems because of dryland salinisation—and the problem is growing. Three million hectares of Australian farmland currently suffer from dryland salinity or saline seepage caused by saline groundwater rising to the surface. More than half of Australia's rain-fed, arable land and 85 per cent of the areas that support cereal crops are at risk. Each year it costs the nation more than 100 million in lost production, and around 130 million in damage to roads, railways and rural towns.

Unchecked salinity will make Adelaide's water exceed World Health Organisation guidelines two days in five by 2020, destroy freshwater streams and ecosystems in the Murray–Darling Basin, reduce irrigation and town water supplies, and damage the infrastructure of many country towns. While the causes of salinisation are fairly well understood, a new approach is required for mapping and predicting salinity as AGSO's Dr Ken Lawrie, leader of the 'Gilmore' project explains.

The accumulation of salt in the sub-surface is a natural phenomenon that has occurred across the Australian continent over many thousands (or millions) of years. We know from mining records of the past century, and the accounts of some of the first explorers, that salt was in the Australian landscape long before there was significant clearing of native vegetation for farming.

The processes responsible for the development of saline land and water are complex. Most of the salt originated from the oceans and was deposited by rainfall. It has accumulated over hundreds of thousands of years, and been redistributed in the landscape by weathering and erosion, and surface and groundwater flow.

Dryland salinity has been attributed to human disruption of the hydrologic cycle. Clearance of native vegetation, and a system of agriculture dependent on shallow-rooted annual crops and pastures that use less water than the natural vegetation, has resulted in an increase in groundwater recharge. The consequence is rising water tables and in places a mobilisation of salts stored in the regolith.

Saline waters flow to lower parts of the landscape along preferential paths. Where watercourses, including major rivers, intercept these seepages, their salt loads are increased. Where saline groundwaters reach close to the soil surface, they restrict crop growth and damage roads and buildings. The potential damage to freshwater ecosystems is enormous.

One solution widely canvassed is to reverse the process by planting forests that would use more water and keep water tables down. Although trees use up a lot of groundwater, they also reduce run-off into surface creeks and rivers. This has consequences downstream where reduced surface flow means there is less water for irrigators, communities and the ecosystem. It also means creeks and rivers can become more saline (at least in the short term). In considering possible intervention strategies, a balance must be found for sustainable management of water resources.

A knowledge of where salt is stored in the regolith and the bedrock, and the regolith architecture that constrains groundwater flows, has the potential to provide a framework for hydrological studies that can model the salinity risk in the sub-surface. This knowledge has the potential to enable targeted intervention strategies to be adopted when allied with an understanding of groundwater flow rates, links with salt stores, and rates of groundwater rise.

We began looking at the problem a few years ago in the eastern margin of the Murray–Darling Basin when we were examining the geology for gold and copper deposits. What started out as a consultancy job for one company grew over months into the Gilmore project that involved 50 scientists from 14 research organisations. The core parties in the Gilmore project are AGSO, in conjunction with the Cooperative Research Centres for Landscape Evolution and Mineral Exploration (CRCLEME) and Australian Mineral Exploration Technologies (CRCAMET), as well as CSIRO's Division of Mining Exploration and the Bureau of Rural Sciences.

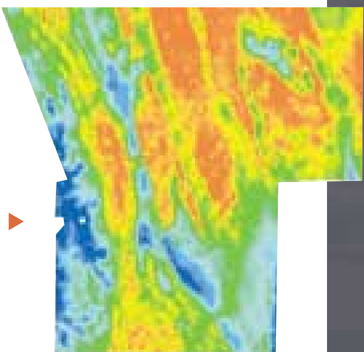


Figure 1. An airborne electromagnetics image (TEMPEST system) from the Gilmore project area in central-west New South Wales. Red colours are more conductive (related to more saline groundwaters); blue colours relate to either resistive bedrock or fresher groundwaters.

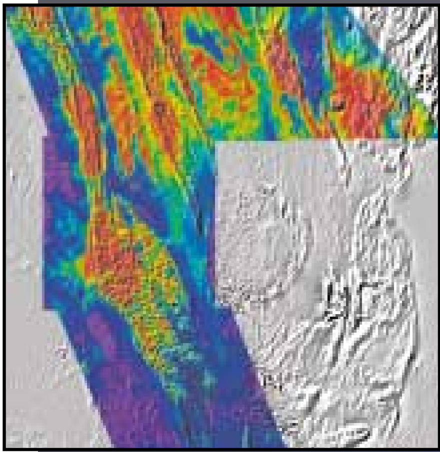


Figure 2. An airborne electromagnetics image (colour) draped over an airborne magnetics image (greyscale), central-west New South Wales. The image shows the conductivity modelled for the interval 40–50 metres below the surface. Red colours are more conductive (related to more saline groundwaters); blue colours relate to either resistive bedrock or fresher groundwaters.

Figure 3. Insights into the health of catchments—this image shows natural radiation emitted from minerals in soils and bedrock. Combined with digital elevation models, these images are used to map soils and understand landscape processes to help identify likely salt-affected areas. Red hues relate to soils developed on granitic rocks. Black hues show soils on mafic rocks and sandstones. White hues mainly relate to areas of active erosion. Mottled green hues on lower parts of the landscape correspond to soils on alluvial plains.

Drilling an air core hole to investigate regolith architecture, north of Illabo, NSW

Mapping salinity in the sub-surface

The main objectives of the Gilmore project were to map salt stores, the nature of regolith materials, the bedrock and regolith architecture (i.e. of aquifer systems), and potential groundwater flow systems that control salt movements in the sub-surface. This was in an area between the Lachlan and Murrumbidgee Rivers in New South Wales. Building on previous studies and new airborne survey technologies developed for the minerals exploration industry, we developed a 'systems' approach to mapping salinity that integrates geological, geophysical and hydrogeological methods for the assessment of salinity risk.

The project involved studying the bedrock geology—its composition, structure and architecture—and the regolith layer that blankets much of the landscape in which the salt sits. In effect, we mapped the sub-surface groundwater pathways that move the salt from recharge sites to lower landscape stores. This work provides the physical framework for other research to consider such variables as land use, vegetation, climate, and groundwater recharge rates.

Critical to the research was the TEMPEST system—a piece of equipment flown over the study area to collect electromagnetic information (AEM data) used to measure the salinity of the top 200 metres of soil, sediment and rock. When calibrated by drilling data, the geophysical data show where the salts are stored, from the just below the surface to 200 metres depth. The density of the data determines whether the method is suitable for planning at a catchment and/or paddock scale.

In hilly country, we used different airborne surveys. Digital elevation models were combined with airborne magnetics and gamma radiometrics to provide information on likely areas for salt accumulation and pathways along which some salt may be mobilised.

Field work

Considerable drill hole information was already available for our study area—approximately 7000 drill holes from the minerals industry and NSW Department of Land and Water Conservation. In addition, we drilled approximately 100 holes because we needed samples and water data from specific sites to calibrate the geophysical surveys and to better understand the nature of the groundwater system.

From our field work and airborne surveys, we know that in our study area there are between 50 and 200 metres of cover (up to 120 metres of transported sediment and 70 metres of weathered bedrock) before you get to fresh rock. The land surface is fairly flat, but below there are buried hills that over thousands of years have been covered by sediments. Old fault zones that localise copper and gold deposits also act as hydrological barriers. The creeks in the area are largely fresh water on the surface, but highly saline groundwaters (thought to be up to 1.5 times more salty than sea water) and fresher, stock-water quality groundwaters occur in different areas within the regolith layer.

At present, we are building our understanding of the groundwater system so that we can develop salinity risk maps and land-use plans for managing salinity risk in the project area.

Tackling the problem on a national scale

Earlier this year, the research agencies involved in the Gilmore project contributed to a Cabinet submission from the Commonwealth Department of Agriculture, Forestry and Fisheries (AFFA) to tackle the salinity problem. In response, the Prime Minister announced in November a $1.4 billion joint federal–state government National Action Plan to pursue salinity and water quality issues. As part of that plan, AFFA will manage a $100 million project involving the Bureau of Rural Sciences, AGSO, CRCLEME, CSIRO and relevant state agencies. The project will use Gilmore project methods to develop salinity risk maps in 20 catchments thought to be at greatest risk of salinisation. These maps will provide a basis for developing, in conjunction with local communities, land-use option plans for managing salinity.

For more information about the Gilmore project phone Ken Lawrie (CRCLEME/AGSO) on +61 2 6249 9847 or e-mail ken.lawrie@agso.gov.au. For more on the national salinity and water action plan contact David Dent (BRS) on +61 2 6272 5690 or e-mail david.dent@brs.gov.au

Geophysical grids join automatically with mathematical *help*

Agencies like AGSO have been surveying and compiling datasets of small areas of Australia for many years. But there are problems when these surveys have to be stitched together to make maps of large regions or the entire continent. Differences in survey flying height, instrument efficiency, calibration, and measurement units make the job difficult.

AGSO's Dr Brian Minty has been researching techniques for adjusting data sets and stitching them together to make such maps as the Magnetic Anomaly Map of Australia. He shared his research ideas at an AGSO seminar.

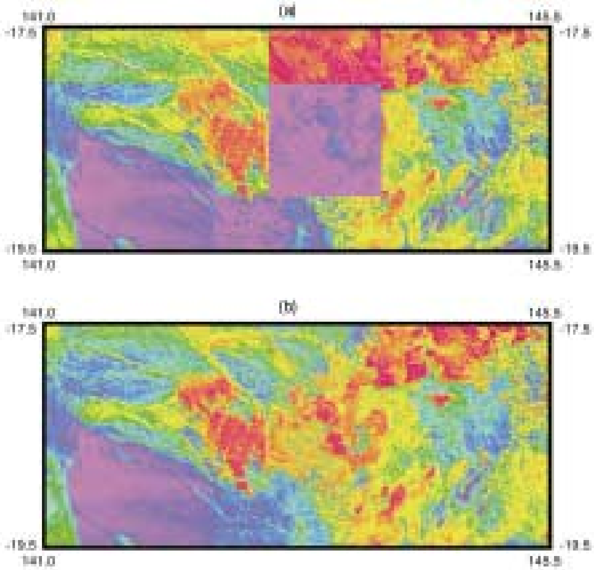


Figure 3. Automatic grid levelling of airborne gamma-ray spectrometric data from North Queensland, Australia: (a) composite grid of total count before levelling, and (b) after levelling.

Ideas on joining grids in a seamless way crystallised with the initiation of the Radiometric Map of Australia project. Airborne gamma-ray data from diverse surveys, flown over several decades, had to be joined up (figure 1). Many surveys were reported in units that are an indirect measure of the radioactivity of the Earth (count rate), while others were reported in actual concentrations of the radio-elements (potassium, thorium and uranium). Count rate measurements depend on several factors including the equipment used. For example, detector volume and efficiency influence the count rate as does the size of the windows used to monitor potassium, thorium and uranium. As well, flying height has a big influence. Many of the older radiometric surveys were flown at 150 metres compared with most modern surveys flown at 60 to 80 metres. Surveys at lower flying heights accumulate far more counts. So before the gridded data could be joined into one coherent dataset, they had to be reprocessed and reduced to absolute concentrations of the radio-elements.

Poor calibration contributes to poor background estimation and poor processing. This can also lead to level shifts between surveys. But even if all calibrations are done correctly, there are environmental effects such as soil moisture that reduce the amount of radiation coming from the ground. So even with the best calibration, if two adjacent surveys are flown at different times of the year, the estimates in the area with the higher soil moisture would be on the low side and the surveys would not match up.

Traditional solution

The traditional solution for joining radiometric grids or surveys that do not match is back calibration. This involves going into the field and taking measurements on the ground with a calibrated portable spectrometer that gives absolute concentrations (parts per million or percentages of the radio-elements). Airborne measurements are then compared with these so that they can be mathematically converted to concentrations on the ground. Back calibration corrects data, but it is very expensive to carry out.

To produce maps of large regions or the whole continent, an enormous number of surveys require back calibration. This would take years and cost hundreds of thousands of dollars. A smarter way of joining data is needed.

Mathematical solution

One alternative, that does not require the expense of returning to survey areas to take ground measurements, focuses on grid overlaps—i.e. looking at differences in overlap area between two grids to determine the scale and shift needed to join the surveys. (Shifting can be as straightforward as halving the count rate for one survey to match the neighbouring survey to correct a problem caused by differences in detector volumes.)

This method of joining grids is normally applied sequentially. In other words, grid 2 is levelled to grid 1, then 3 to 2 and 4 to 3, and so on. In the case of a large map combining dozens of surveys, sequential levelling of grids propagates errors and distorts the map. This is a huge problem for agencies such as AGSO that produce national compilation maps. The successful solution takes a broader approach to the levelling of overlapping grids. Rather than dealing with the surveys sequentially, the grids for the whole continent or region are viewed as one entity and the mismatch among the grids is seen as a single inverse problem.

Two stages

The new method uses a two-stage process that involves the solution of a system of simultaneous equations. The first stage looks at each pair of survey grids that overlap and works out the best shift and best scales to join them. These are referred to as 'relative' shifts and scales. In the second stage, these relative measures are used to calculate an 'absolute' shift and scale for each grid. One base grid is specified as the 'absolute grid'. All other grids are fitted to the base grid in a way that best honours the relative shift and scales (figure 2).

For this method to work, three conditions must be satisfied. There has to be a base grid to bring everything back to some level otherwise there is no unique solution. All grids have to be interconnected in some way so that they can be levelled together. There should be a reasonable dynamic range in overlapping areas otherwise there will not be sufficient information to solve the problem.

Final corrections

Even with good survey data, there will be small differences at the grid boundaries. These differences are corrected by a procedure called feathering (also known as suturing or seamless joining). After two grids have been levelled, any residual difference between the grids is gradually spread between them and smeared or tapered down to zero. The procedure is computing intensive, but easy to implement.

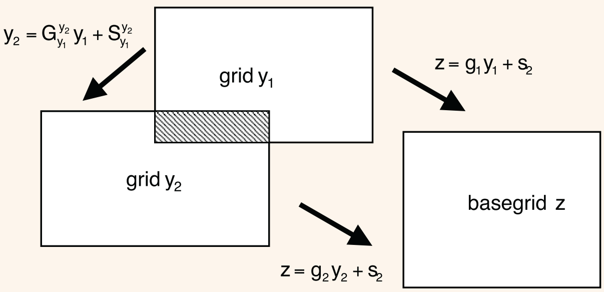


Figure 2. The relationship between the relative shift and scale for overlapping grids, and the absolute shift and scale to a base grid. The various terms are defined in the text.

Remarkable results

Automatic, rapid levelling by computer minimises the warp for big compilation maps and produces an end product that is very close to the truth in a matter of hours. For example, a similar method to that described above was used to produce the magnetic map of Western Australia. Ninety-one magnetic grids were processed—from levelling to feathering—in several hours. In the past, this compilation would have taken weeks to produce and the quality of the end product would be inferior to today's computer-generated output. An example of radiometric levelling is shown in figure 3.

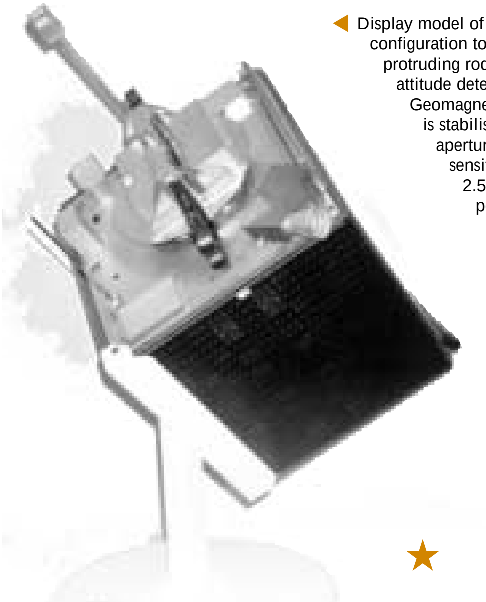
Not all problems have been solved though. Areas where there is little variation in uranium are proving a challenge for the levelling of radiometric data, and the 'noise' in some old data throws doubt on data reliability. Further field work therefore may be necessary to correct problems once all currently available airborne geophysical data have been processed.

A new grid database

For flexibility in choice of region and grid resolution, AGSO is developing a new airborne geophysical grid database and plans to offer clients digital options rather than printing a variety of maps. In the database, grids will be levelled and feathered and stored at their optimum grid resolution. But the grids won't be joined until clients specify the area and grid cell size required. Once these specifications have been logged, special software will interpolate the necessary grids and do a final feathering and join them to produce the required grid. This means that in the future clients will be able to order precisely the grid they require, then download it a few hours later.

For more details phone Brian Minty on +61 2 6249 9228 or e-mail brian.minty@agso.gov.au

Figure 1. Digital gamma-ray spectrometric data coverage (shaded areas) of Australia.



Display model of SUNSAT, which is similar in size and configuration to FedSAT. A magnetometer is mounted on the protruding rod, which is used to provide approximate attitude determination based on the International Geomagnetic Reference Field model. When the satellite is stabilised, a star camera (the box with the hooded aperture) provides accurate attitude information. A sensitive magnetometer is located on the tip of a 2.5-meter boom shown here in its pre-launch position.

CAMERA STARS IN FEDSAT EXPERIMENTS *to update magnetic reference field*

Dr Charles Barton outside the Hermanus Magnetic Observatory in South Africa with the staff responsible for the SUNSAT magnetometer experiment. From left: Louis Loubser (magnetometer development and calibration), Charles Barton (AGSO), Peter Sutcliffe (external fields and space weather research) and Peter Kotzé (main and crustal magnetic field modelling).

Scientists around Australia are readying a micro-satellite called FedSAT for launch in Japan in November 2001 as part of Australia's celebration of federation. Experiments on board FedSAT vary from improving satellite communication systems to measuring particle densities in the ionosphere.

AGSO is involved in magnetic field experiments that will be conducted as FedSAT orbits Earth. These experiments plan to measure the Earth's main magnetic field, the crustal magnetic field, electric currents and particle density in the near Earth space environment. Crucial to data interpretation is a small camera (roughly the size of a human hand) that will be attached to FedSAT. The camera photographs stars.

Star camera

To measure the direction and strength of Earth's magnetic field, FedSAT will carry a three-axis fluxgate sensor or magnetometer. But before AGSO can use data from the magnetometer, it needs to know which way the satellite is pointing.

A digital atlas of all known stars will be stored in the memory of the star camera. With each image the camera takes, it finds the three largest stars and compares their locations with the star atlas, then estimates the direction in which the camera is pointing relative to Earth. Because FedSAT is a 50-centimetre cube weighing 58 kilograms, the star camera has to be small, light and consume very little of the satellite's power.

The only available star camera to meet FedSAT specifications was developed for an earlier satellite (SUNSAT) by Stellen Bosch University in South Africa. AGSO, the Ionospheric Prediction Service and the Cooperative Research Centre are buying a second generation of the star camera, but will modify it to suit FedSAT experiments.

Earlier this year, AGSO's Dr Charles Barton visited Stellen Bosch University and also the Hemanus Magnetic Observatory in South Africa, which was responsible for building and calibrating the magnetometers for SUNSAT. This visit was valuable for learning about SUNSAT's equipment, particularly as much of FedSAT's magnetic calibration and characterisation will be done in Australia at the Canberra Magnetic Observatory.

Micro-satellite features

FedSAT will not be 'hard wired' to do one particular task after launch. Certain systems will be self-activating and autonomous, such as the one that stabilises the satellite when it is released from its launch vehicle. Other systems will be configured on command from the ground. This software ground-controlled circuitry with its sophisticated gating systems allows scientists and engineers to reconfigure FedSAT after it has left Earth. This flexibility is important for changes to experiments and also if circuitry is damaged because of radiation or extremes of heat and cold.

Data use

AGSO wants FedSAT data to update the magnetic reference field in the Australian region, and it needs this for three reasons. Earth's magnetic field continually changes, and so the magnetic compass, which is essential in navigation, needs correcting. The second reason is AGSO uses magnetic fields in interpreting data for mineral exploration. Magnetic anomalies point to major structures in Earth's crust and places to search for minerals. The third reason concerns space weather and hazards.

Disturbances of the magnetic field are linked to solar events. These can have hazardous consequences such as radiation risk to people in space, high-altitude aircraft and space systems such as satellites—the components of which can be damaged or made useless by particle radiation. On Earth, disturbances can increase currents and corrode pipelines and burn out transformers.

Data by satellite is much quicker and less costly than trying to measure every spot (if that were possible) on Earth's surface. An orbit close to Earth would give AGSO the best data. But satellites can't fly lower than about 300 kilometres because the drag in Earth's atmosphere limits their life. Also, in regard to FedSAT, other experiments on board (those looking at properties in the ionosphere and magnetosphere) require it to fly very high above Earth. The orbit of FedSAT therefore will be a tradeoff among the different objectives of the scientific experiments on board. FedSAT will be one of a succession of satellite magnetic field surveys. NASA carried out the first in 1980 and the most recent were OERSTED (a Danish satellite launched on a NASA vehicle in February last year) and SUNSAT also launched early in 1999.

For more information telephone Charlie Barton on +61 2 62149 9611 or e-mail charlie.barton@agso.gov.au

GEOPHYSICIST PREPARES FOR YEAR AT MAWSON, ANTARCTICA

Theatre assistant for the resident surgeon, librarian, movie projectionist, hydroponics gardener, and brewer of home-style beer are a few of the side jobs that Martin Purvins will carry out in his new posting as geophysicist at Mawson Station, Antarctica, over the next 12 months.

On November 19, Mr Purvins boards the *Aurora Australis* in Fremantle, Western Australia, and sails to Antarctica where he will operate the geophysical observatory for AGSO and observe weather for the Bureau of Meteorology.

On the way he will stop at Heard Island to update geophysical readings that haven't been taken for 15 years.

'I am looking forward to this because I take readings from a site set up by one of my heroes, Sir Douglas Mawson', Mr Purvins says.

▲ Martin Purvins sets up a magnetometer on AGSO lawns to practise work he'll carry out on Heard Island on his way to Antarctica in late November.

Mr Purvins will have to chase some large elephant seals, each at least a tonne in weight, from the old abandoned observatory before he can take the readings, however.

Pre-voyage training is essential even for an experienced petroleum geologist like Mr Purvins. He has a very short changeover period (less than a day) with the geophysicist he is replacing in Antarctica.

Two weeks at AGSO in Canberra ensures he can operate Mawson observatory instruments. Further training in Melbourne (five weeks) and Hobart (six weeks) prepares him for additional jobs he may have, particularly during the isolation of the Antarctic winter with its six weeks of darkness and 200 kilometre/hour winds.

Mawson instrumentation varies from computers with multiple software to theodolites and quartz horizontal magnetometers. There is also an old-fashioned instrument, which to a lay person is something akin to a cork and magnet on a string that is waved around.

'This instrument is a back-up in case modern ones fail or are damaged', says Mr Purvins.

'But it takes practice to use and I'm finding it is more of an art than science to take magnetic readings correctly.'

The main aspect of geophysical work at Mawson is measuring the Earth's magnetic field, which continually fluctuates and changes. Other work includes monitoring natural (earthquakes) and human-induced (nuclear testing) seismic events in the Southern Hemisphere. Taking air samples and measuring naturally occurring radioactivity are also part of the job.

Mr Purvins will be one of up to 25 personnel at Mawson Station during winter 2001. There will be twice this number in summer (from November this year until March 2001) when various scientific studies will be conducted, from biology (of seals and penguins) to physics (cosmic rays and sub-atomic particles from space).

When asked why he wanted to spend time in Antarctica Mr Purvins replies, 'Most people are either jealous or think I'm crazy. There are few people in between.

'It is unique; the last wilderness and I feel very privileged to go.'

In the past 15 years, work has taken Mr Purvins around Australia, New Zealand, Japan, Vietnam, Thailand, Saudi Arabia and Qatar—often for several months at a time.

He says the separation from his wife is always difficult. 'But with the internet and e-mail it is not as daunting as Mawson's day when his fiancée didn't hear from him for two years', he says.

ANARE (Australian National Antarctic Research Expeditions) will equip Mr Purvins for Antarctica. AGSO and the Bureau of Meteorology fund him for the year.

AGSO COLLECTIONS MOVE IN-HOUSE

AGSO is reorganising its many electronic data and physical materials collections and bringing them all to its Symonston facility in Canberra to be managed by a special collections management group.

The collections being moved include the digital data (much of it on old nine track tape) stored by the National Australian Archives, and more than 50 truckloads of tapes and related material stored in Sydney. Moving the digital collection is a major operation, but it will be completed in November this year. The reorganisation gives AGSO an opportunity to improve the management and storage of its most important collections. A single business unit will manage all of AGSO's digital and physical data for its petroleum, marine geoscience, rock specimen and palaeontological sample collections, and every item in the collections will be recorded on a sophisticated database.

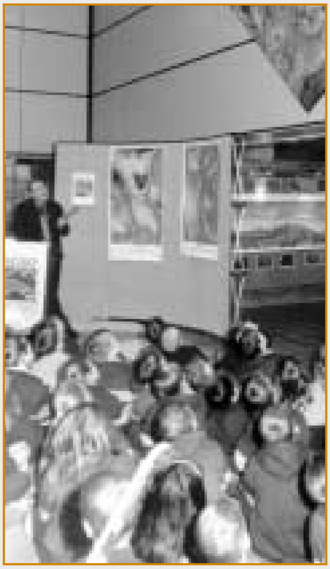
Collections management committees will guide decisions of the AGSO Data Repositories unit. These committees will comprise scientific staff with specialist skills in the particular collection. The collections include:

1. Digital seismic survey and well log data collected by exploration companies and lodged under the Petroleum (Submerged Lands) Act. This collection includes more than 330 000 digital magnetic tapes, some analogue magnetic data, and paper data. The tape media range from 21 track one-inch tapes to modern high-density 3590 media. The largest number of tapes comprises nine track seismic field tapes.
2. Core and cuttings and liquid and gas samples, much of it lodged under legislation, including:
   - samples from more than 5200 petroleum wells and stratigraphic holes;
   - more than 150 000 metres of down hole drilling core;
   - more than three million metres of down hole drill cuttings;
   - 3250 onshore side wall core samples;
   - 14 000 thin sections and 9000 reservoir plugs;
   - more than 1200 open file destructive analysis reports; and
   - a collection of liquid and gas hydrocarbon samples.
3. Approximately 3500 Well Completion and Seismic Survey reports lodged under legislation. Drilling support data such as wireline logs, end of well reports and similar data are also in the collection.
4. More than 60 000 film seismic sections submitted under legislation.
5. Digital geoscience data collected by AGSO under its Continental Margins Program and other activities, including 65 000 seismic field tapes.
6. More than 4600 film seismic sections from AGSO's marine surveys.
7. More than 40 000 palaeontological samples, most of which contain many individual specimens.
8. More than 100 000 rock samples collected by AGSO field parties over the 50 years of AGSO's work.

A new data repositories manager is being appointed to lead a team of eight people dedicated to a high standard of service for access to these important national assets. The repositories unit will soon have a web page so clients can search online for database holdings.

For more information about or contacts for AGSO Data Repositories phone +61 2 6249 9222 or e-mail ausgeodata@agso.gov.au

School's in as AGSO displays AUSTRALIAN BOUNDARIES in 3D



Parliamentary Secretary Warren Entsch launches the latest map of Australia's jurisdiction—a three-dimensional version—with the help of Bonython Primary School students.

Mr Entsch quizzed students on their geographical knowledge and they came up trumps, being able to point out places such as Tasmania and Antarctica. But he had students stumped on Australia's geology. None was aware that Australia has an active volcano (Big Ben on Heard Island) and that it erupted in 1992. Nor were they aware that Australia has more territory under the sea than land surface.

Mr Entsch told students that much of Australia's seabed is as poorly known as outer space and so AGSO has been asked to map large, remote sections with special equipment.

'One piece of equipment sends sound waves from the ship's hull to the seafloor which then bounces back like an echo and shows the shape and depth of the ocean bottom', he says.

'These bits of information and lots of smaller maps were joined together like a giant jigsaw to make the large three-dimensional map we are looking at.'

MANAGEMENT COURSE

puts **workers** in a class of their own

▲ All smiles after finishing their course and being congratulated by AGSO CEO Neil Williams (second from left) are Irina Borissova (left), Penny Ursem and Bruce Kilgour (right).

A new class of workers has appeared in the AGSO ranks—students of the Graduate Certificate of Management course.

Science, technical and administrative staff have been signing up for a 12 month part-time course with the Australian Graduate School of Management to give them the edge in dealing with organisational issues.

Dave Harris, Manager of AGSO's Sales Centre, says that until two years ago his job involved computer systems. Due to changes in the workplace, Mr Harris's work nowadays focuses on sales and AGSO's external clients.

'The practical focus of the course and the fact that it starts off by looking at how organisations work, how change affects organisations and how people deal with change all help in the day to day work at AGSO', he says.

'In terms of practical things, the course has improved my communication skills and is building my management skills—something that I didn't have a lot of experience in.'

Peter Maher, a recent graduate of the course, has had a finance-focused career. He says the course will open up new practice areas for him.

'I was looking at project management courses at the time this was advertised, so it was an opportunity for career development', he says.

He sees value in the course because 'it teaches you to deal with change, be proactive, and go out and do things for yourself'.

Irina Borissova, one of last semester's graduates, says she signed on for the course because after 20 years she wanted some different skills to complement her scientific and technical skills.

'Learning why we work in certain ways, and how to work together to get greater output—the team dynamics aspect—is one of the really good things about this course', she says.

Ms Borissova recommends the course to other AGSO staff, but warns that it is very demanding on family life.

The course comprises seven hours class time a week for lectures, discussion and a group project. Readings and assignments take up 10 hours of private time each week. There are four streams in the course, each of six weeks duration, and an exam when a stream is completed. All discussions, group work and assignments are related back to the workplace.

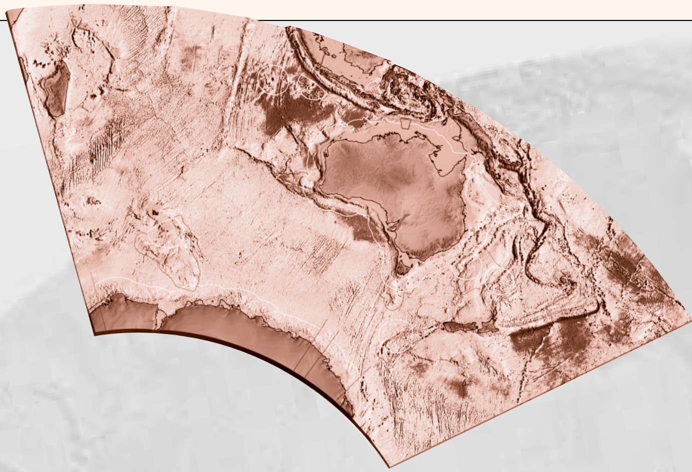
Because students work full time and the course is time intensive, course coordinators are lenient about when assignments are completed and exams are taken.

Student numbers from AGSO are limited to five or six a year and this is the second year that AGSO has participated. AGSO workers who recently graduated from the August 1999–June 2000 course were Irina Borissova, Peter Maher, Bruce Kilgour, Penny Ursem and Steve Le Poidevin. The course is run by a consortium of New South Wales TAFE (Technical and Further Education) colleges, the Canberra Institute of Technology and the University of Western Sydney. Academics, consultants and others with management experience give the weekly lectures.

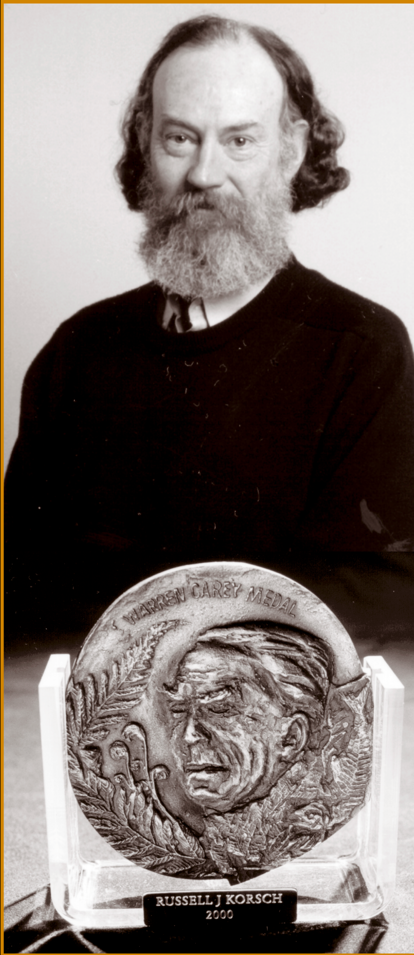
For further information about the course phone Len Hatch on +61 2 6249 9300 or e-mail len.hatch@agso.gov.au

Students donned 3D glasses for a better perspective on water depth and land mass heights of the large map (5 metres by 3 metres) on display in AGSO's foyer.

In four years Australia will make a submission to the United Nations to add another five million square kilometres to its marine jurisdiction. To make this claim, the seabed beyond Australia's 200 nautical mile zone is being mapped in detail by AGSO to show the extent of Australia's continental shelf.



PRESTIGIOUS GEOLOGY MEDAL GOES TO KORSCH



AGSO's Dr Russell Korsch was awarded the Geological Society of Australia's SW Carey Medal for contributions to tectonics in the Australian context at the 15th Australian Geological Convention in July. This is one of two major awards presented by the Society at its convention that takes place every 18 months to two years.

Dr Korsch has worked in many fields including regional geology, tectonics, sedimentology, basin analysis and deep seismic reflection analysis of the crust. He is known for his work on the geology of the New England orogen and the sedimentary basins of central and eastern Australia.

When asked what stands out in his 30 years of research, Dr Korsch says it is the insights gained from deep seismic work that force a re-examination of previous models and a change in ideas.

'Virtually every deep-seismic line that we collect shows up something that was unexpected', he says. 'So you need to re-think your work and put it into context.'

One example was the line through southern New England in New South Wales, called the Gunnedah-New England line that imaged a major fault. 'Everyone assumed this was a major structure that dipped 70 degrees to the east', he says.

'Our seismic work showed that it was a very shallow feature and that the main structure dipped to the west.'

Such major shifts in knowledge can have a huge impact on mineral exploration.

Dr Korsch is currently Research Group Leader of the Regional Studies and Minerals Systems research group in AGSO's Minerals Division. He has been an AGSO scientist for 15 years. Prior to joining AGSO, Dr Korsch

Call for research proposals for EXPERIMENTS IN 2001 & *beyond*

Submissions by FEBRUARY 19, 2001

lectured at Armidale College of Advanced Education and at Victoria University in Wellington. Significant events in his career include four expeditions to Antarctica and a few years in California and New Zealand where he saw first hand the rapid nature of tectonic processes.

'Granite thrust over 40 000-year-old gravels, very young river terraces folded into anticlines, and the San Andreas Fault certainly opened my eyes', he says.

Dr Korsch's current role in AGSO concerns helping other geologists develop their science and making sure regional projects are heading in the right direction. He says that what he really wants to do through the regional projects he supervises is continue to build a three-dimensional understanding of the evolution of Australia. In effect, provide the framework for all of Australia's mineral systems and mineral deposits.

The SW Carey Award namesake was Professor of Geology at the University of Tasmania and a key proponent of continental drift and plate tectonics before most of the geological world came around to the professor's way of thinking. Alfons Vandenberg from the Geological Survey of Victoria won the other major award, the WR Browne Medal.

Estuaries scrutinised in National Audit by AGSO scientists

Australia has a long coastline and hundreds of estuaries and coastal waterways—964 in fact. Half of them are in pristine condition, which is good news for those who live along the coast or flock to coastal areas for their annual holidays. However 28 per cent have undergone major change. The concern is which ones and how far reaching are the changes.

AGSO and the National Land and Water Resources Audit and its partners have been studying and assessing the condition of Australia's estuaries and coastal waterways. AGSO's Urban and Coastal Impacts project (UCI) is building a database about estuarine types, dimensions and sediment facies. The UCI project's work will be accessible via the web in 2001.

Preliminary findings

The Audit and UCI teams found that of Australia's estuaries and coastal waterways, approximately 50 per cent are in pristine condition, 22 per cent are largely unmodified, 17 per cent are modified, and 11 per cent are severely modified. Maps have been drawn using these preliminary findings. They show the distribution of the four conditions by State and also geographical region of Australia. A report on near-pristine estuaries has been posted on the Audit's website (www.nlwra.gov.au).

Estuaries and coastal waterways have also been divided into three energy classes to show the dominant forces controlling the estuarine shape, ecology and circulation—namely wave, tide and river. It appears 335 estuaries and waterways are wave-dominated, 468 tide-dominated, and 161 river-dominated. AGSO compiled this classification using national tidal data, and coastal wave heights and periodicities, to compute wave and tidal energies. Fluvial sediment discharge data were also calculated. Satellite images of most Australian estuaries were then reviewed to classify them into similar geomorphological categories. AGSO is finding good agreement between the energy and geomorphological classifications. These classifications provide the

The Australian National Seismic Imaging Resource (ANSIR) seeks bids for research projects for experiments in the second half of 2001 and beyond.

ANSIR is Australia's major national research facility in the earth sciences. It was created to encourage and assist world-class research and education in the field of seismic imaging of Earth. It operates a pool of state-of-the-art seismic equipment suitable for experiments designed to investigate geological structures from environmental and mine scale through to continental scale. ANSIR is operated jointly by the Australian Geological Survey Organisation and the Australian National University.

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

Details of the equipment available, access costs and likely field project costs, as well as the procedure for submitting bids for equipment time are available on the web at http://rses.anu.edu.au/seismology/ANSIR/ansir.html. This web site also shows an indicative schedule of equipment for projects that arose from previous calls for proposals.

Over the next year, controlled source equipment will be used on both sides of the continent. People interested in proposing piggy-back experiments should contact the ANSIR Director for details of the scheduled experiments. The long-period portable instruments are in heavy demand; potential users are urged to submit bids at the earliest opportunity. Spare capacity on short-period portable instruments in 2001 is anticipated, however.

Researchers seeking to use ANSIR in 2001 and beyond should submit research proposals to the ANSIR Director (see right) by February 19, 2001.

Any further queries should be directed to:

- **Dr Barry Drummond (particularly for projects requiring ANSIR's seismic reflection equipment) ANSIR Director, GPO Box 378, Canberra ACT 2601. Tel. +61 2 6249 9381 or e-mail barry.drummond@agso.gov.au or**

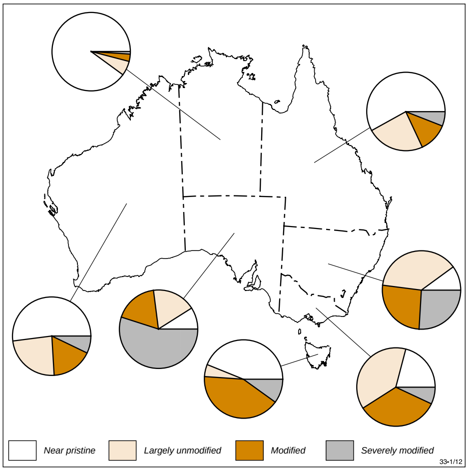
- **Prof Brian Kennett (particularly for projects requiring ANSIR's portable seismic recorders), Research School of Earth Sciences, Australian National University, Canberra ACT 0200. Tel. +61 2 6249 4621 or e-mail brian.kennett@anu.edu.au**

ANSIR AUSTRALIAN NATIONAL SEISMIC IMAGING RESOURCE framework for identifying sources and sites of potential impacts and also resource management and environmental protection options.

Database and sediment facies mapping

AGSO is building a database (Oracle based) about all of Australia's estuaries and waterways. Such measurements as the estuarine water area, the width and length of the estuary, the length of the channel opening to the sea and the width of the entrance opening at the coastline have been digitised from Landsat TM (satellite thematic mapper) images of the estuary.

A major task for AGSO has been mapping several sediment facies (or biological habitats) in the 450 estuaries that were identified in the Audit's initial assessment as having been 'modified'. With the cooperation of state organisations that provided aerial photographs of estuaries, AGSO has been mapping up to nine facies in different estuaries. The mapped facies are digitised over Landsat TM images and archived according to national database standards. Users will be able to overlay the digital facies maps on a variety of spatial imagery in their own geographical information systems (GIS).



The data and knowledge that AGSO provides for the Audit will be used in assessments of coastal waterway conditions. Likewise, state organisations will refer to AGSO's findings when making decisions about conservation and development of estuarine resources. The UCI project's output will be available next year via three websites: the Audit, AGSO (www.agso.gov.au), and the Cooperative Research Centre for Coastal Zone Estuary and Waterway Management (www.coastal.crc.org.au). All geoscience data about Australia's estuaries and coastal waterways will become part of the national Land and Water Resources Atlas.

For more information about AGSO activities within the Audit telephone Jim McCrea on +61 2 6249 9414 or e-mail jim.mccrea@agso.gov.au

BIG WET brings home risk of landslides & *need for community awareness*

It is March and the rainy season. Two days of heavy rain brought on by Cyclone Justin, and Paluma Road north of Townsville in north Queensland is blocked in places by fallen trees and landslides. An elderly couple is driving home from the coast. A branch across the road blocks their passage. The woman alights and pushes the branch away. The branch supports the base of a small landslide. In moments, material tumbles down on top of her.

Landslides in Australia tend to kill people in ones and twos. Few are as dramatic and can be recalled like the Thredbo landslide in one of Australia's favourite ski villages. Yet they are a hazard that interests local governments because apart from the safety issue, landslides can cause million-dollar damage. AGSO's Cities Project has been researching landslides in Australian communities, as Dr Marion Leiba explains.

▲ A small landslide on Paluma Road, north of Townsville, that killed a woman in March 1997.

Landslides have killed at least 82 and injured 53 people in Australia, and damaged or destroyed more than 200 buildings. They affect railway lines and cause millions of dollars damage to roads.

The New South Wales Rail Services Authority estimates that it spent approximately $25 million a year from 1989–1996 on the Wollongong to Brisbane railway line because of slope instability problems. One mitigation measure for frequent landslides, an artificial tunnel north of Wollongong, cost around a million dollars to build.

Water, topography and gravity generally cause landslides. One of the main triggers is very heavy rain. About 50 millimetres of rainfall in a day may cause landslides. Water soaks into soil or into cracks in rocks and creates pore water pressure. It reduces the strength of rock and soil.

The term landslide encompasses a range of earth movements—from rock falls from cliffs or the roofs of caves or overhangs which are quite dry events to debris flows that can be 50 per cent water. In the past five years in Australia, more than half the landslides that caused deaths or injury were due to the fall or topple of a single rock. Slow-moving slumps that have a curved slip plane and tend to occur in uniform material are also regarded as landslides. But the ones that kill most people throughout the world and make news headlines are debris flows, also called mud flows, mud slides and, if they occur on the side of a volcano, lahars. The Thredbo landslide was a debris flow.

A large debris flow because it is very fluid and very mobile will affect not only the hillside but also the flat land at the base of the hill or escarpment. But not all landslides are fast moving. They can move tens of metres per second or just millimetres per year. Even the slow ones, if they keep moving over many years, can tear houses apart and damage roads and railway tracks.

A spring beneath an area of Warburton in Victoria feeds a slow-moving landslide that has been inching its way for almost 50 years. Consequently, one road is no longer used, telegraph poles lean on strange angles, and four houses have been evacuated and demolished. Consultants could not see any way of alleviating the problem and so the small parcel of land affected by landslide has been quarantined from construction. Insurance policies in Australia do not normally cover landslides.

Landslides can be triggered by human activity. People add weight to the top or move weight from the bottom of a landslide-prone area by building a house, adding fill, or climbing on an unstable rock. Explosions can also cause a landslide. The shear strength of the rocks is reduced by vibrations and the rocks slide away.

Mitigation measures

One way to prevent the single-death events is community awareness—letting people know about safety around rocks and cliffs, overhangs and caves. AGSO has produced two bright brochures aimed particularly at children and teenagers who tend to make up the statistics of injuries and deaths from sand cave-ins and rocks falling from cliffs.

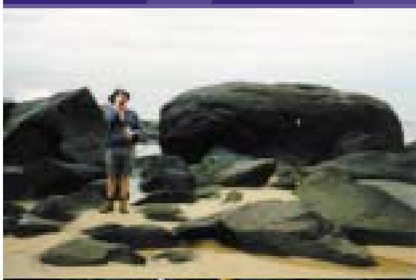
AGSO is also involved in landslide risk assessments in urban areas of eastern Australia—Cairns, in and around Brisbane and Wollongong. These are intensive research projects being conducted by a small group of AGSO scientists working with universities, emergency managers and local councils. AGSO is developing complex datasets with layers of maps (from geology to building use and population density), hazard history, scenario modelling, and risk estimations which local councils can use when making decisions about planning and community safety, or in the aftermath of a natural disaster.

Top: Landslide on Kuranda Range Road, February 1999

Above: *Suburban Cairns* — the raised cleared land between the power poles comprises debris flow material from the escarpment in the background.

Below: Boulders from one of the debris flows that blocked the Captain Cook Highway

Bottom: Landslide on Lake Morris Road near Cairns after heavy rain, March 1999



Cairns risk assessment

Cairns is the administrative centre for a large part of north Queensland and Torres Strait, as well as for mining operations in Papua New Guinea and Irian Jaya. It started as a campsite for fishermen but soon became a port for exporting gold, tin, red cedar and sugar. A railway line was built in the late 1800s to early 1900s from Cairns to the Atherton Tableland to transport produce to port. Rail services have been disrupted numerous times over the years by landslides after torrential rain.

Approximately 120 000 people live in Cairns and this can swell by 10 000 during the tourist season. It has a tropical climate with heavy rain in the summer. Each year more than 2000 millimetres of rain fall in the coastal corridor increasing to 7000 millimetres on the range behind the escarpment. Tropical cyclones bring extreme rainfall on average once every two years. Cyclone Rona (February 11, 1999) brought 300 millimetres of rain to Cairns in 24 hours, which triggered numerous shallow landslides and road closures.

The Cairns area consists of a plateau, an escarpment, Trinity Inlet, the Barron River mouth, Freshwater Valley and the coastal plain. The bedrock is more than 200 million years old and rifting occurred about 60 million years ago.

The first step in Cairns landslide risk assessment was determining what types of landslides occur. There is no evidence of deep-seated, slow-moving landslides in the Cairns area. But there are two types that are shallow and fast moving. The first type involves small rock falls/slides and debris slides and flows that affect roads and railways on the steep slopes of the escarpment. In heavy rains, this material can encroach on people's back yards and occasionally damages houses.

The second type occurs with continuous torrential downpours. The landslides on the slopes and sides of the valleys coalesce, rake in boulders, mud and trees, and incorporate debris accumulated in the stream beds to form large debris flows. The coarse material is dumped when it reaches flatter land and flash flooding and wash outs occur.

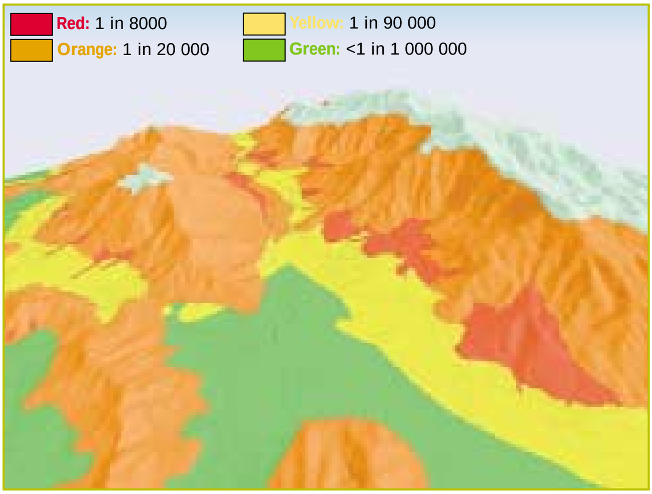


Figure 1: Probability of building destruction per annum by landslide—Redlynch, Cairns

Redlynch, a Cairns suburb, is being built on two old debris fans that have built up over the past 30 000 years. The last debris flow recorded in this area was in the 1960s, however. Others in the past 50 years include a number of large debris flows at Ellis Beach that were triggered by 700 millimetres of rain in less than five hours. Three metres of debris were dumped at various spots along 10 kilometres of the Captain Cook Highway—an arterial road to Cairns—and boulders up to three metres long were hurled into the sea like marbles.

Probability

The second step in landslide risk assessment involves estimating the size, frequency and probability of being hit by one. Data from aerial photographs, geological maps, models of slope processes, historical research (old newspaper and literature reports, shire council records, and the memory of long-term residents) as well as site inspections and other research in the field are brought together in a landslide GIS (geographic information system). From the GIS, landslide and potential debris flow runout zones are imposed on maps of Cairns to see which areas are at risk.

Of course, more than the landslide zones are important in a full risk assessment. Landslides that recur along a windy mountain road with no housing and don't disrupt essential services can be costly to keep clearing and repair, but are usually nuisance value only. The vulnerability of people, buildings, major transport routes and other infrastructure should be factored into assessments.

REPORT LANDSLIDES!

Your observation adds to the Australian landslide database.

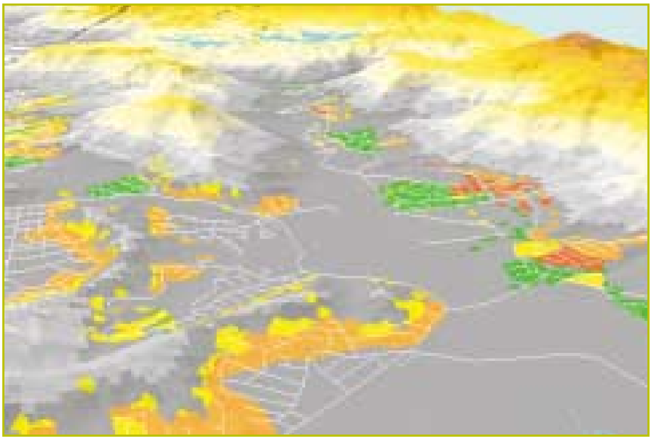
See the database at ***www.agso.gov.au***

Just click on 'geohazards', then 'landslides', and 'map landslides'.

This database contains information about hundreds of Australian landslides. It is used for public awareness activities, such as producing pamphlets and giving public lectures, and for landslide risk assessment.

We need 'volunteer landslide spotters' to tell us about new landslides. Your information helps keep the database up-to-date, and you can check out your landslide on the AGSO website. Volunteers receive an official AGSO Landslide Spotters certificate in appreciation of their help.

***Please contact:* Dr Marion Leiba, AGSO, GPO Box 378, Canberra ACT 2601. Tel. (02) 6249 9355, fax (02) 6249 9911 or e-mail marion.leiba@agso.gov.au**



Red: 5–6 buildings
Orange: 1–4.99 buildings
Yellow: 0.5–0.99 buildings
Green: 0.1–0.49 buildings

Figure 2: Total risk of building destruction (number per sq. kilometre per 100 years)—Redlynch, Cairns

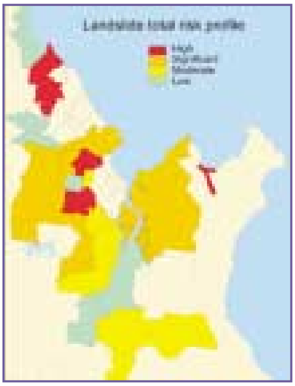


Figure 3: Landslide total risk profile taking into account community vulnerability

Risk

Two sorts of risk maps are developed from the Cairns landslide GIS. 'Individual or specific risk maps' show the probability of an individual building, person or section of the road in the Cairns area being destroyed by a landslide in a year (see figure 1). This is a useful planning tool for property development.

The others are 'total risk maps' that show the number of houses/flats and people in a given area that could be destroyed in a certain time period. They take into account the probability of landslide and the locations of buildings and residents (see figure 2). Total risk maps are useful for emergency management purposes because they marry the risk of hazard with the locations of elements at risk. They are useless for planning purposes, however, because unpopulated areas are rated as zero risk.

A further step in the Cairns risk assessment was producing maps that ranked the suburbs in terms of total risk. This took into account community elements—the location of hospitals, State Emergency Services, police, water mains, electricity sub-stations (the critical facilities essential to Cairns if hit by a natural disaster) and the community profile (e.g. elderly, private car ownership in case of evacuation). This gives an idea of the vulnerability and resilience of an entire community to a particular hazard (see figure 3). Risk of earthquake, flood, cyclone wind and storm tide also were added to datasets to come up with a multi-hazard risk assessment of Cairns in the form of 'community total risk maps'.

Vulnerability

Areas of Cairns are vulnerable to landslide, particularly the hill slopes. The Captain Cook Highway, Kuranda Range Road and Cairns–Kuranda rail line pass through steep slopes affected by landslides. This makes the Cairns community vulnerable to isolation by land in sustained torrential rain. As well, in the past flash flooding and debris flow have destroyed the pipeline that carries the Cairns water supply, and some parts of relatively new suburbs at the foot of the escarpment are in the path of future debris flows.

No houses in Cairns have been destroyed by large debris flows, but susceptible areas have been closely settled for less than half the average recurrence interval of such landslides. The annual risk of fatality on the hill slopes is estimated as one in 100 000; in the proximal parts of debris flows, one in 9000; and in the distal area of debris flows, one in 200 000.

No areas of Cairns are therefore considered high enough risk of landslide to be quarantined—provided people who build homes on debris flow fans are aware of the slight risk and have evacuation procedures for extreme rainfall. For mitigation against small landslides, measures such as adequate drainage and retaining walls, appropriate siting of dwellings, and planting trees are recommended. Small debris flows can be deflected sometimes by channels or levees. But the residual risk from large debris flows remains.

Already this year spring rains have brought record falls in many Australian areas. What will summer bring?

For more information about landslide risk assessments phone Marion Leiba on +61 2 6249 9355 or e-mail marion.leiba@agso.gov.au

Cairns city and inner suburbs viewed from the east.
Brian Cassey Photography

Continued from page 10

National standards are needed and there should be a one-stop shop for advice on disasters and natural hazards in the Asia–Pacific region. As well, additional historical data are needed. Magnitude and frequency information in the databases is based only on human memory and 100 years of documentation.

Although hazard research is well established in a number of organisations, its application to risk assessment is not. AGSO is building the general framework for risk assessment by integrating geological data and land-use maps with essential information such as population densities. But this needs further work to incorporate data gathered at different scales and resolutions (e.g. a region and a city scale). There is also a need for input from geotechnical and structural engineers and economic risk analysts so that community leaders and caretakers get information in a form that helps decision-making.

AGSO can compile the much-needed historical data by researching paleohazards. This data should provide additional and more reliable estimates of maximum magnitudes and return periods.

Anthropogenic hazards

Anthropogenic hazards refer to environmental problems caused by human activity—such things as the effects of mining and petroleum extraction and nuclear and other waste. The geoscience input includes baseline studies—what were the characteristics prior to human activity—and forecasts of the impacts of the activity in 10 or 100 years.

The discussion group came up with a list of 20 emerging environmental issues or problems. Seven were considered significant issues for AGSO. They are fuels use (greenhouse effect), ground and surface water quality and understanding water residues, urban and mining waste and the footprint this leaves on the biology, airborne pollution (from fires, plumes, contamination and spills), nuclear waste, quarrying for construction materials, and landslides and subsidence.

AGSO has databases that can be manipulated in different ways to address all seven issues. For example: for greenhouse gases, petroleum databases are being used to pinpoint potential areas for re-injecting CO_2. Spatial information datasets for natural hazards could be applied to contamination risk assessments.

In regard to water quality, AGSO has the capability to provide the underlying, critical, geological knowledge so essential to understanding problems. Specialised skills in geochemistry and water analysis and the ability to do aqueous geochemical modelling means AGSO should be called in early for water quality studies. AGSO also has the skills to find construction materials, determine their quality and quantity, and assess the impact of their removal.

Estuarine and coastal environments

Coastal zones with estuaries are highly valued for living purposes, but many are affected by human activity. Sediment and sewage are examples of what humans discharge into estuarine zones. Major land use change in Australia over the past 100 years, urbanisation along the coast, and construction of breakwaters, bridges and the like have all had an impact.

Australia is expected to grow. There will be increasing population pressure on coastal areas. And that pressure and the resultant imbalance will bring demand for AGSO input. Lifestyle factors that are essential to Australia's population—access to fresh water, land stability, access to building materials, safe land on which to build, amenities that people are going to use—involve science that can and should be done by AGSO. Many shire councils don't have the resources to deal with such issues. AGSO can provide the knowledge that helps local governments and others manage these areas for everybody.

AGSO could do the following: coastal water geochemistry including benthic geochemistry; geomorphology and sedimentology (exchange of sediments, nutrients and pollutants between estuaries and the continental shelf); and stratigraphy and hydrology to deal with issues concerned with acid sulphate soils, and groundwater quality (water–rock interactions, saline water contamination). AGSO's geoscientific knowledge can help coastal cities develop in a more sustainable way.

Offshore marine environments

The Australian government has an Oceans Policy that is being implemented by a process known as Regional Marine Planning. This policy aims to protect biodiversity but allow for economic, social and cultural needs. Over the next couple of years $50 million dollars will be spent assessing and preparing management plans for Australia's ocean domain. The process has begun in the south-east region of Australia.

Australia is establishing marine parks to protect its ocean biodiversity. But it does not want these so huge that economic activity is precluded offshore. It has to decide on park boundaries. AGSO is involved by mapping the seafloor, bedrock and sediment facies so that links can be forged with the biology.

Australia is an island continent with a range of marine environments—situated from the tropics to the polar region—that need consideration. Geoscience has much to offer in the marine environment—for example, mapping marine benthic habitats, studying ecosystem response to perturbations via geochemical cycles, and researching the palaeoenvironment.

AGSO has excellent technical capability, laboratory facilities, and holds a large 'seabed' database and respository useful to offshore industries and planners of national parks. Its geological data can be integrated with biological information through cooperative efforts with such agencies as CSIRO to provide useful products to environmental managers.

Consideration

AGSO is generally seen as an information provider for the mining and petroleum industries. Its research capabilities are much broader, however, and the community needs environmental geoscience input. AGSO has the skills to present complex datasets in formats suitable for managers. But current work plans need to be weighed against additional projects aimed at helping community decision-makers.

Forum outcomes will be considered at AGSO's senior management planning meeting in late November, when work plans for the next five years are discussed.

FREE book!

NEW EDITION SHOWS AUSTRALIA'S STILL THE PLACE FOR MINERAL RESOURCES

Australia's Identified Mineral Resources 2000 (AIMR 2000) contains a nation-wide assessment of the ore reserves and mineral resources base for all major and a number of minor mineral commodities mined in Australia. Produced by the Mineral Resources and Advice project, AIMR 2000 provides government, industry and investment sectors as well as the general community with an authoritative and important understanding of Australia's known mineral endowment and level of exploration activity at the start of the 21st century.

National assessments of this type are assuming global significance as attention is paid to issues concerning cost-effective, cleaner mining and product stewardship. AIMR 2000 includes international rankings, summaries of significant exploration results, brief reviews of mining industry developments, and an analysis of mineral exploration expenditure and drilling across the states and Northern Territory. The report examines trends in resources of all major and a number of minor mineral commodities, and finds that Australia continues to rank highly as a leading mineral resource nation.

While mineral exploration expenditure declined further in 1998–99 to $837.8 million, Australia marginally increased its share of worldwide expenditure on exploration, attracting 18.7 per cent in 1999—up from 17.5 per cent in 1998. AGSO remains optimistic that this growing recognition of Australia's high potential for discovery of new mineral deposits by overseas companies will have a continuing positive impact on exploration.

AIMR 2000 includes a reduced version of the latest map of Australia's mines and major mineral deposits. The map, produced by AGSO for the Minerals Council of Australia, summarises information relating to mineral deposits and major mineral commodities.

AIMR 2000 is free from AGSO's Sales Centre or it can be mailed on request for the cost of postage and handling (in Australia $7.50) by phoning +61 2 6249 9519 or e-mailing sales@agso.gov.au. For further information phone Bill McKay on +61 2 6249 9003 or e-mail bill.mckay@agso.gov.au

Hydrothermal Iron–Oxide Copper–Gold & Related Deposits

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Prospectors & Developers Association of Canada

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phone 0011 1 416 362 1969

fax 0015 1 416 362 0101
e-mail info@pdac.ca

Global Disaster Information Network

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Rydges Hotel, Canberra

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'2001: An Oil & Gas Odyssey'

Australian Petroleum Production & Exploration Association

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Australian Gold Conference

Australian Gold Council & Chamber of Minerals & Energy of Western Australia Inc

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phone +61 8 9226 1511

fax +61 8 9226 1544
e-mail enquiry@conference.australiangold.org.au

EVENTS calendar

Compiled by Steve Ross

DIGITAL UPGRADE OF OUTCROP GEOLOGY MAPS UNDERWAY—*first releases*

Available now: an improved, digital version of outcrop geology for 25 first or second edition maps from AGSO's 1:250 000 geological series.

Data for each of the 25 map sheets includes geological polygons (litho-stratigraphic units), linear structural features (faults, dykes, folds, trends, lineaments), and point features (mines). Polygons have a range of attributes extracted from each individual map including unit name, lithological description and geological age. Lines and points are feature coded according to the AGSO publication 'Symbols used on geological maps'.

The data evolved from the original, elementary CAD quality representation, into its present, topologically structured GIS format. The re-release features much improved and updated information contents. The original (map) stratigraphic unit names are validated against AGSO's Stratigraphic Index database and, where superseded, replaced with current names.

Additional attributes from the database (e.g. stratigraphic number, position and genealogy within a stratigraphic sequence hierarchy, and geological ages) are added to all geological units with a known stratigraphic unit name. Where possible, geological boundaries and other linear features (such as faults) at adjoining map tiles are edge-matched. In addition to improved information content, data are rigorously validated and tested.

The digital outcrop geology data for the 1:250 000 maps (in ArcInfo, ArcView and MapInfo formats) cost $165 each (includes GST) plus postage and handling. The data can be bought from the AGSO Sales Centre by phoning +61 2 6249 9519, or e-mailing sales@agso.gov.au

For more details about the data phone Dmitar Butrovski on +61 2 6249 9825 or e-mail dmitar.butrovski@agso.gov.au.

1:250 000 map sheet name	Map sheet number	AGSO catalogue no.
Ayr	SE55–15	24280
Burketown	SE54–06	25079
Cambridge Gulf	SD52–14	34672
Camooweal	SE54–13	34681
Cape Van Diemen	SE54–02	34676
Cloncurry	SF54–02	23909
Croydon	SE54–11	34679
Dobbyn	SE54–14	25105
Donors Hill	SE54–10	25103
Galbraith	SE54–03	34677
Georgetown	SE54–12	34680
Gilberton	SE54–16	34682
Julia Creek	SF54–13	34685
Lawn Hill	SE54–09	34678
Lissadell	SE52–02	34673
Macdonald	SF52–14	34683
Medusa Banks	SD52–10	24552
Millungera	SE54–15	25102
Mornington	SE54–01	34675
Mount Isa	SF54–01	34684
Normanton	SE54–07	25101
Red River	SE54–08	22682
Robert	SG51–11	34686
Westmoreland	SE54–05	34632

NEW VERSION DATASET LISTS LATEST ON AUSTRALIA'S MINERAL DEPOSITS

AGSO has released a new version of its National Mineral Deposits Dataset compiled as part of the OZMIN mineral deposit database. Version 3 incorporates the latest production and resource figures, updates information for existing deposits, and adds more than 100 new deposits to the dataset (mainly recent discoveries) since the previous version, which was released in 1997.

The dataset contains comprehensive information compiled from the literature for more than 1050 of Australia's major mines and mineral deposits. OZMIN covers 60 mineral commodities (including coal) and has been designed so that attribute data can be retrieved and analysed in relation to spatial data contained in geographic information systems (GIS). For a given deposit, OZMIN contains:

- full location details;
- deposit characteristics, including cumulative production and resource information for each commodity;
- host rock unit and lithology information;
- details of major structures and igneous bodies proximal to a deposit that may be genetically related to the mineralisation; and
- a comprehensive list of relevant references.

The information in OZMIN has been tightly structured so that for a given attribute, the user can select from a list of values contained in authority or reference tables. These tables are either corporate authority tables (e.g. geological provinces, stratigraphic names, geological timescale, mineral names) shared by other AGSO databases or reference tables set up specifically to service OZMIN attributes. Some unstructured text fields have been provided to enter information which may be regarded by the compiler as important but cannot be captured adequately by the structured responses.

OZMIN is currently implemented in AGSO's corporate Oracle database system and is available to purchasers as an Oracle export, in ASCII format (comma delimited), or in Microsoft Access operating under Windows 95 or later versions.

The documentation manual (AGSO record 2000/18) that accompanies the dataset has been completely revised to reflect the modifications and additions to OZMIN. It is supplied as part of any digital data package sale or can be purchased separately for $27 (includes GST; catalogue no. 33468) as a pdf file on CD.

The complete digital data for the National Mineral Deposits Dataset is available in the formats listed above for $3777 (includes GST; catalogue no. 34192) or as an upgrade to purchasers of previous versions for $540 (includes GST; catalogue no. 34193). The data can also be provided as a subset (e.g. according to commodity, geological region, state/territory). A quote can be arranged on application.

For further details phone Greg Ewers on +61 2 6249 9580, e-mail greg.ewers@agso.gov.au or phone Murray Hazell on +61 2 6249 9375, e-mail murray.hazell@agso.gov.au

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MAJOR REPORT

HYDROCARBON CONCEPTS from Browse Basin–Timor Sea study released on CD

Explorers evaluating risks such as migration and trap integrity at scales ranging from regional to prospect-specific will want a copy of this major interpretative report on hydrocarbon migration and seepage in the Timor Sea and northern Browse Basin. The study area is greater than 365 000 square kilometres and extends from the coastline to abyssal water depths (see figure 1).

The study uses as its framework a comprehensive interpretation of 55 RadarSat Synthetic Aperture Radar (SAR) (minimum double coverage, up to five-fold coverage in some areas) satellite scenes acquired over the region. These data were used to map areas of liquid hydrocarbon seepage (in time-series) and then integrated with other key remote sensing data sets from the region, including: water column geochemical sniffer (WaSi) data from six regional to detailed surveys (approximately 18 000 line kilometres) and Airborne Laser Fluorosensor (ALF) data.

Three types of ALF interpretations were included, namely:

- reprocessed Mark III ALF interpretations from six recent and detailed AGSO surveys (total approximately 10 500 line kilometres). These surveys were area restricted but covered three representative geological provinces, including the Yampi Shelf, the northern Browse Basin–southern Vulcan Sub-basin, and Nancar Trough–Sahul Syncline;
- interpretations from reprocessing of BP Mark II ALF data. All of the regional Mark II ALF surveys acquired by BP during the late 1980s and early 1990s have been reprocessed. These data provide continuous, though regional (~5000 metre line spacing) coverage over much of the study area;
- original BP interpretations from the BP regional Mark II ALF reports.

The interpretations derived from these independent seepage detection technologies (i.e. SAR, WaSi and ALF) have been compared and contrasted, and then tightly integrated with petroleum geological information. This includes regional seismic data; isopach maps of key reservoir, source and sealing units; rift and reactivation fault maps; DEM/ bathymetry, gravity and magnetics data; and seafloor sediment sample distributions and analyses.

The study contains a detailed evaluation of the relative response of the assorted remote sensing technologies over three areas where detailed SAR, WaSi and ALF data are available.

These 'pilot' areas were the Yampi Shelf (Cornea–Londonderry area), the northern Browse Basin–southern Vulcan Sub-basin (Woodbine to Elm), and the Nancar

FREE!

DOWNLOAD OUR GIS DATA DICTIONARY —it's *free*!

If you are trying to maintain consistency and quality in geoscientific data entries, don't reinvent the wheel. AGSO has placed its data dictionary for GIS products on the web. It is regularly updated and free to download. The latest release is available at http://www.agso.gov.au/information/data_dictionary.html. Changes include the addition of numerous themes for geohazard GIS data and a revised 'feature coding scheme'.

The AGSO dictionary is a specification for the capture of geoscientific data in a GIS environment. It forms a foundation for the production of GIS data by specifying rules regarding data structure. The dictionary covers such issues as conventions on themes naming, feature types, and attribute values. The specifications are independent of GIS software used to manage the data.

The first version of the dictionary was released in early 1998 to create a common framework for GIS data structure and specifications within AGSO. Since then it has grown into a comprehensive document describing more than 100 spatial themes and continually expands with the development of new GIS products.

Themes, features and attributes

Similar features are often aggregated into spatial *themes*. Themes are views of spatial data with similar conceptual and attribute characteristics. Themes are organised into a number of *topics*—geology, geophysics, geochemistry and geochronology, mineral deposits and mineral potential assessment, surveys and field observations, urban infrastructure, terrain physiography, and cartographic themes.

In themes, real-world objects and phenomena are called *features*. All features have certain properties or *attributes*. Only those attributes identified as being of scientific value and importance are modelled and described in the dictionary. For example, features in a geology theme may include litho-stratigraphic units, geological boundaries, faults, marker beds, veins and dykes. Each feature has an associated set of attributes and rules.

Feature attributes have strictly defined data type and length. Rules specify feature usage and, for some attributes, values that can be assigned to them. Thus, it is desirable to standardise attribute values by means of *look-up (authority) tables*. These are pre-defined lists of allowed values applicable to a particular feature attribute. In a geology theme, Stratigraphic Index number, stratigraphic genealogy, and lithological description are some of the attributes for litho-stratigraphic unit features.

The section that lists selected authority tables presents the revised AGSO *feature coding scheme*. Under the scheme, most features have a unique code with full description, and a symbol code for cartographic depiction using line or marker symbol sets created by AGSO cartographers.

For more details phone Dmitar Butrovski on +61 2 6249 9825 or e-mail dmitar.butrovski@agso.gov.au

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Trough–Sahul Syncline (Laminaria-Corallina area). The interpretation then used, among other things, the concepts derived from the pilot areas to assess the migration/seepage processes over the entire region.

The results of the study are presented in GIS format (ArcView) on CD. The GIS contains all of the data and results listed above, including tiffs of key SAR scenes. Also on the CD are:

- a full interpretative report containing text, maps and images (pdf and MS Word formats);
- tabulated data of all SAR and ALF anomalies (MS Excel format); and
- a full MS PowerPoint presentation of all salient data, results and interpretations.

The report has a number of exploration applications. It would be particularly useful to explorers seeking a regional appreciation of migration and seepage in the area (i.e. either at the permit-scale or for acreage evaluation). It would also have relevance at the prospect scale, for evaluations of such factors as charge and fault and top seal integrity. The concepts are generic and can be applied to exploration in similar environments to the study area.

The report was produced by AGSO, in association with Nigel Press & Associates (NPA) of the United Kingdom, RadarSat International (RSI) of Canada and the Australian Surveying and Land Information Group (AUSLIG).

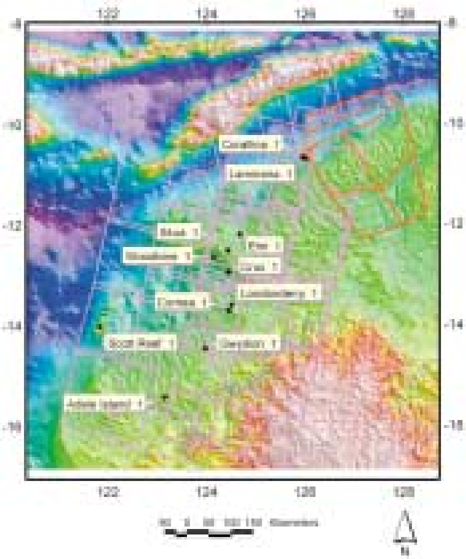


Figure 1. Location map showing area of study, with extent of coverage of SAR data (purple). Location of Zone of Cooperation and key wells are indicated.

For more information about this study or to buy a copy of the CD contact either Geoff O'Brien on tel. +61 2 6249 9342, e-mail geoff.obrien@agso.gov.au or Jim Colwell on tel. +61 2 6249 9346, e-mail jim.colwell@agso.gov.au

NEW MAPS AND DIGITAL DATA *of the Eastern Goldfields offer exploration insights*

AGSO has finalised four maps and associated digital data to help exploration in the northern Eastern Goldfields. Parliamentary Secretary Warren Entsch released the Sir Samuel 1:250 000 geology and solid geology maps at the Mining 2000 conference in September. The Ballard and Leonora 1:100 000 geology maps were released at the end of October.

Sir Samuel 1:250 000 sheet—geology and solid geology maps

The second edition Sir Samuel 1:250 000 geology sheet provides a regional generalised representation of detailed outcrop mapping undertaken by AGSO and the Geological Survey of Western Australia under the National Geoscience Mapping Accord. This mapping was previously released in six 1:100 000 sheets. The new solid geology map was compiled from an integration of AGSO's interpreted 400-metre line spacing aeromagnetic data, detailed industry data, and control from outcrop mapping. The sheet area covers parts of three poorly exposed, north–south aligned, greenstone belts. From west to east, they are the Agnew–Mount Keith, Yandal and Dingo Range belts.

Most greenstones were deposited over the interval 2700–2690 million years. A sequence including the Kathleen Valley Gabbro in the west of the Agnew–Mount Keith belt is inferred to be older (~2740 Ma). The Jones Valley Conglomerate, also in the Agnew–Mount Keith belt, represents some of the youngest greenstone and was probably deposited during the interval 2685–2665. Extensive regions of granite and granitic gneiss separate the greenstone belts.

Ultramafic-hosted nickel sulphide mineralisation is common in the Agnew–Mount Keith belt and includes the Cosmos, Perseverance, Rocky's Reward and Mount Keith deposits. The solid geology map shows that ultramafic rocks are abundant in this belt. In contrast, ultramafic rocks are only a minor component of two greenstone belts to the east.

Consequently nickel prospectivity is considered to be much lower in the eastern two belts. Gold is also confined to the greenstone belts; however significant deposits are located in both the Agnew–Mount Keith (Bellevue, Genesis and New Holland) and Yandal (Mt McClure, Bronzewing, Darlot and Centenary) belts. The Yandal greenstone belt is the most extensive, but poorly exposed.

The solid geology map shows the interpreted distribution of key greenstone lithologies and major structures, and places the known deposits in the regional context. Considerable exploration potential for gold is inferred, particularly in areas of regolith-covered greenstone. These maps will be an excellent aid to industry and should help reduce exploration risk.

Ballard 1:100 000 sheet—geology map

The new outcrop-geology map is a complete revision of the first edition of 1991, mapped by AGSO as part of a joint NGMA project with the GSWA. It includes generalised 1:10 000-scale company mapping of the ultramafite-rich centre and south of the Mount Ida greenstone belt, and delineation of new finds of ultramafites in the north of the belt. Of particular interest are exposures of high-temperature ultramafic volcanic rocks (komatiites) on the eastern side of the belt. These rocks originated as an enormous flood of very hot lava poured onto the bottom of a shallow Archaean sea. In many places it quickly cooled and formed spectacular dendritic olivine crystal growths.

In topographic lows it ponded, cooled slowly, and allowed growth and settling of equant olivine grains which, in some areas of the Eastern Goldfields, were accompanied by droplets of nickel sulphide. Nickel orebodies formed, as at Kambalda for example. At Ballard, the ponded flows reached 600 metres in thickness, which allowed chemical fractionation to take place and form 150 metres of gabbro at the top of the unit. Clinopyroxenes in the gabbro form coarse-grained, branching (harrisitic) crystal growths.

The map complements record 1999/46 on the 'Geology of the Ballard 1:100 000 sheet (3039), Western Australia' (see this issue of *AusGeo News*), and will be of considerable value to mineral explorers and those assessing the mineral resource potential of the area.

Leonora 1:100 000 sheet—geology map

The Leonora 1:100 000 sheet map includes data from an extensive remapping of the area's Archaean rocks. It replaces mapping first released in 1991 and an updated version released in 1994. The new map is based on some 2500 additional field observations that include many outcrops not previously examined.

Highly prospective greenstones comprise approximately 50 per cent of the bedrock in the Leonora area; however, regolith is laterally extensive and covers more than 75 per cent of the sheet area. Significant gold mine production or resources include those from the Sons of Gwalia, Tarmoola, Harbour Lights and Tower Hill mines. These deposits occur within the bounds of the greenstone domains, but a considerable portion of the resource at Tarmoola is hosted by granite. Felsic volcanic-rich sequences in the eastern part of the main greenstone belt extend onto the Weebo sheet to the north, where they host base-metal mineralisation at Teutonic bore. The printed map provides an insert of the solid geology that depicts the distribution of greenstone associations and structures throughout the area. This insert also helps place mineralisation occurrences in geological context and will assist effective exploration in areas of regolith cover.

Paper copies of the Sir Samuel, Ballard or Leonora maps cost $53.96 each (includes GST) plus postage and handling. Digital data for the Sir Samuel sheet costs $165 (includes GST), and the Ballard and Leonora sheets cost $107.91 each (includes GST). Maps and digital data are available from the AGSO Sales Centre by phoning +61 2 6249 9519 or e-mailing sales@agso.gov.au.

For more information about the Sir Samuel and Leonora sheets phone Songfa Liu on +61 2 6249 9522 or e-mail songfa.liu@agso.gov.au. For details about the Ballard sheet phone Alan Whitaker on +61 2 6249 9702 or e-mail alan.whitaker@agso.gov.au

RECORDS galore IN STORE!

AGSO has produced a plethora of records about its activities over recent months. Here are a few available to readers.

Eastern Goldfields

- Record 1999/37: Geology, structure and mineral resources of the Mount Keith 1:100 000 sheet
- Record 1999/46: Geology of the Ballard 1:100 000 sheet
- Record 2000/02: Geology and geophysics of the Ballimore and Sandalwood 1:100 000 sheet areas

The first two reports present the results of detailed geological mapping and structural analysis of economically important parts of the Eastern Goldfields of Western Australia.

The third report presents the results of geological and geophysical mapping of little-known areas in the north of the goldfields. These areas in the Eastern Goldfields were mapped by AGSO as part of a joint NGMA Project with the Geological Survey of Western Australia.

The Mount Keith 1:100 000 sheet area covers the western edge of the Wiluna–Agnew greenstone belt, which hosts the Mount Keith nickel mine. In the east are parts of the Yandal greenstone belt, which hosts Bronzewing and Mount McClure gold mines.

The Ballimore 1:100 000 sheet area includes part of the unconformably overlying Proterozoic sequence of the Earaheedy Basin. The Sandalwood 1:100 000 sheet area includes the unusual Mount Fisher gold deposit, which occurs in a chert layer that extends north and south of the mine for 10 kilometres. This deposit produced 852 kilograms of gold between 1937 and 1989. Much of the greenstone in the sheet areas is under cover and under-explored, so there is potential for future gold discoveries. The potential for economic nickel deposits is, however, low; ultramafic rocks are a minor component of the greenstones in the area, and where exposed are poor in olivine. Some point-source magnetic anomalies may be caused by kimberlite and, if so, may have potential for diamonds.

The three records are available from the AGSO Sales Centre for $26.98 each (includes GST) plus postage and handling.

Pilbara Goldfield

- Record 2000/05 [CD]: Facsimile copy of the Aerial Geological and Geophysical Survey of Northern Australia (AGGSNA) Reports (1 to 26, 28, 46, 48, 51 to 59) for Western Australia (Pilbara Goldfield)

The AGGSNA was a Commonwealth initiative that documented the mineral deposits of the Pilbara region between 1935 and 1939. The reports by Finucane and others contain descriptions of the geology, history and production, economic geology and, in some cases, the water supply. The maps contain the geology outlines of the vein and lode systems (many now removed due to extraction), drill and sample assay results, mining methods, mine plans and sections, and areas of alluvial workings.

The AGGSNA reports are valuable documents that are fragile and relatively rare. This recompilation of the AGGSNA reports, carried out as part of the North Pilbara project synthesis, will be of value to mineral explorers and prospectors working in the Pilbara (from a current exploration and a historical perspective). The reports and their maps have been scanned and captured on a CD which is available from the AGSO Sales Centre for $26.98 (includes GST) plus postage and handling.

Research cruise East Antarctica

- Record 2000/38: Joint Italian–Australian marine geoscience expedition aboard RV *Tangaroa* to the George Vth Land region of East Antarctica during February–March 2000

The geophysical data collected on this expedition includes 1827 kilometres of multi-channel seismic data and 562 kilometres of Chirper sonar data. Water profile measurements and water samples were collected at nine stations and seabed bottom photographs were made at 11 stations.

The expedition discovered and mapped a shelf sediment drift deposit covering about 400 square kilometres lying in a deep section of the George Vth Basin west of the Mertz Glacier. The drift thins to the north into an acoustically transparent veneer. This implies that the drift is from the outer continental shelf, with sediment being transported landwards across the shelf and into an 85-metre-deep inner shelf basin.

The 'Mertz Drift' is more than 35 metres thick and core samples demonstrate that it is composed of laminated, anoxic, gelatinous olive green, silicious mud and diatom ooze. While the lower sediments are laminated, there is a 20 to 50 centimetre thick sandy drape at the surface over the whole drift. This suggests that a recent (late Holocene) change in the depositional environment has occurred, possibly related to changes in the extent of the nearby Mertz Glacier tongue, current regime and/or persistence of sea ice over the shelf area.

On the continental rise, seismic sections were taken across a contourite drift deposit and submarine canyon system in 2500 to 3500 metres water depth. Piston cores were collected along the profile of one drift deposit which gave a preliminary mid-Pliocene age to truncated strata that crop out on the drift's steeper lee side. These data provide useful site-survey information in support of a proposal for drilling key sites along the Antarctic margin.

The record costs $26.98 (includes GST) plus postage and handling.

Other recent records

- Record 2000/40: Rabaul earthquake and caldera structure (RELACS) program
- Record 2000/37 [CD]: Errors in digital elevation models derived from airborne geophysical data
- Record 2000/33 [CD]: Skua airborne laser fluorescence survey interpretation report
- Record 2000/32 [CD]: Haydn airborne laser fluorescence survey interpretation report
- Record 2000/31 [CD]: Browse airborne laser fluorescence survey interpretation report
- Record 2000/30 [CD]: Yampi laser fluorescence survey interpretation report
- Record 2000/27 [CD]: AGSO airborne laser fluorescence surveys data comparison report
- Record 2000/14: Seismic tomography of Tasmania—data processing report

For copies and prices of these AGSO records phone the AGSO Sales Centre on +61 2 6249 9519 or e-mail sales@agso.gov.au

Revision provides *10-year direction* for Australian geomagnetic reference field

The year 2000 revision of the Australian geomagnetic reference field (AGRF00), released by AGSO as a software package, is the best available field model for regional direction-finding applications. The model provides a 10-year basis for updating magnetic surveys to a common epoch, identifying large-scale crustal magnetic anomalies, and for defining the magnetic field vector required for computer modelling of induced magnetic anomalies.

AGRF00 is a numerical description of the geomagnetic field and its secular (annual) change over Australia and adjoining regions, including most of Papua New Guinea and much of eastern Indonesia. It should be used for the time interval 1995 to 2005 within a spherical cap-shaped region of radius 24° centred on latitude 24°S and longitude 135°E.

The model

AGRF00 represents a combination of the Earth's main (core) field and the long-wavelength crustal field. The model describes the geomagnetic field on a regional scale intermediate between the global scale of the International Geomagnetic Reference Field (IGRF) and the local scale of detailed ground and aeromagnetic surveys. Irregularities in the magnetic field caused by local crustal anomalies are not represented by AGRF00.

INTERNATIONAL GEOMAGNETIC REFERENCE FIELD COEFFICIENTS

gh	n	m	nT	nT/yr	gh	n	m	nT	nT/yr	gh	n	m	nT	nT/yr
g	1	0	-29615	14.6	h	5	5	107	0.1	g	8	3	-8	0.4
g	1	1	-1728	10.7	g	6	0	72	1.0	h	8	3	8	0.0
h	1	1	5186	-22.5	g	6	1	68	-0.4	g	8	4	-17	-1.0
g	2	0	-2267	-12.4	h	6	1	-17	-0.2	h	8	4	-21	0.3
g	2	1	3072	1.1	g	6	2	74	0.9	g	8	5	9	0.3
h	2	1	-2478	-20.6	h	6	2	64	-1.4	h	8	5	15	0.6
g	2	2	1672	-1.1	g	6	3	-161	2.0	g	8	6	7	-0.5
h	2	2	-458	-9.6	h	6	3	65	0.0	h	8	6	9	-0.4
g	3	0	1341	0.7	g	6	4	-5	-0.6	g	8	7	-8	-0.7
g	3	1	-2290	-5.4	h	6	4	-61	-0.8	h	8	7	-16	0.3
h	3	1	-227	6.0	g	6	5	17	-0.3	g	8	8	-7	-0.4
g	3	2	1253	0.9	h	6	5	1	0.0	h	8	8	-3	0.7
h	3	2	296	-0.1	g	6	6	-91	1.2	g	9	0	5	0.0
g	3	3	715	-7.7	h	6	6	44	0.9	g	9	1	9	0.0
h	3	3	-492	-14.2	g	7	0	79	-0.4	h	9	1	-20	0.0
g	4	0	935	-1.3	g	7	1	-74	-0.4	g	9	2	3	0.0
g	4	1	787	1.6	h	7	1	-65	1.1	h	9	2	13	0.0
h	4	1	272	2.1	g	7	2	0	-0.3	g	9	3	-8	0.0
g	4	2	251	-7.3	h	7	2	-24	0.0	h	9	3	12	0.0
h	4	2	-232	1.3	g	7	3	33	1.1	g	9	4	6	0.0
g	4	3	-405	2.9	h	7	3	6	0.3	h	9	4	-6	0.0
h	4	3	119	5.0	g	7	4	9	1.1	g	9	5	-9	0.0
g	4	4	110	-3.2	h	7	4	24	-0.1	h	9	5	-8	0.0
h	4	4	-304	0.3	g	7	5	7	-0.2	g	9	6	-2	0.0
g	5	0	-217	0.0	h	7	5	15	-0.6	h	9	6	9	0.0
g	5	1	351	-0.7	g	7	6	8	0.6	g	9	7	9	0.0
h	5	1	44	-0.1	h	7	6	-25	-0.7	h	9	7	4	0.0
g	5	2	222	-2.1	g	7	7	-2	-0.9	g	9	8	-4	0.0
h	5	2	172	0.6	h	7	7	-6	0.2	h	9	8	-8	0.0
g	5	3	-131	-2.8	g	8	0	25	-0.3	g	9	9	-8	0.0
h	5	3	-134	1.7	g	8	1	6	0.2	h	9	9	5	0.0
g	5	4	-169	-0.8	h	8	1	12	0.1	g	10	0	-2	0.0
h	5	4	-40	1.9	g	8	2	-9	-0.3	g	10	1	-6	0.0
g	5	5	-12	2.5	h	8	2	-22	0.0	h	10	1	1	0.0

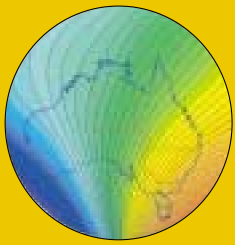
The main field model in AGRF00 is based on an extensive dataset comprising all available vector survey data from the modelled area. The data includes AGSO's Third Order ground survey (1967–1975), MAGSAT satellite data (1980), the United States Navy's Project Magnet high elevation aeromagnetic surveys (1983–1990), and magnetic observatory and repeat station data for the region.

The secular variation model is based on geomagnetic observatory and repeat station data collected by AGSO magnetic observatories in Canberra, Gnangara, Learmonth, Charters Towers, Alice Springs and Macquarie Island, and observatories in New Zealand and Western Samoa. The repeat station data used in the model was collected over the period 1995 to 2000 from the AGSO-maintained network on mainland Australia and offshore islands, Papua New Guinea and the south-west Pacific region.

The model should only be used within a cap of radius 24° because of edge effects associated with the numerical modelling. The model must not be used outside the area of the 28° cap. AGRF00 supersedes the previous model, AGRF95, and is the fourth in the series of AGRF models that began with AGRF85.

The software

An AGRF00 software package is available on CD or diskette from the AGSO Sales Centre for $269.80 (includes GST; catalogue no. 34283). Two main programs to evaluate AGRF00 are included in the package, one for single point locations and the other for a regular grid in latitude and longitude. The AGRF00 software provides the option of calculating either AGRF00 or IGRF 2000. FORTRAN77 source code for the programs is provided. Software to carry out geodetic coordinate conversions is also included in the package.



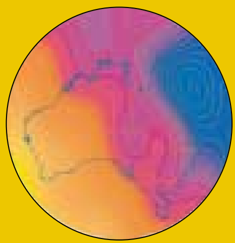
Colour contours of magnetic declination (decimal degrees)

Translucent colour contours of magnetic declination

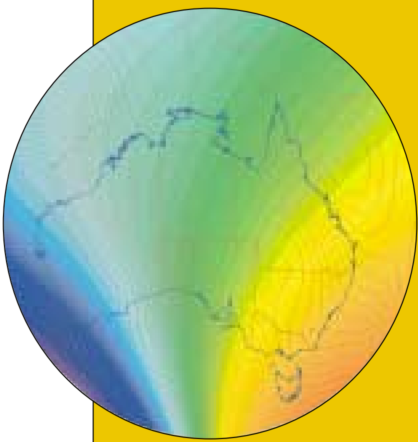
gh	n	m	nT	nT/yr
g	10	2	2	0.0
h	10	2	0	0.0
g	10	3	-3	0.0
h	10	3	4	0.0
g	10	4	0	0.0
h	10	4	5	0.0
g	10	5	4	0.0
h	10	5	-6	0.0
g	10	6	1	0.0
h	10	6	-1	0.0
g	10	7	2	0.0
h	10	7	-3	0.0
g	10	8	4	0.0
h	10	8	0	0.0
g	10	9	0	0.0
h	10	9	-2	0.0
g	10	10	-1	0.0
h	10	10	-8	0.0

- Spherical harmonic coefficients for IGRF 2000. Main-field coefficients are in units of nT; secular variation coefficients for extending IGRF 2000 to 2005 are in nT per year. You will recognise this table from the February 2000 issue of *AusGeo News* (page 21). Unfortunately, there were errors in the spherical harmonic coefficients that were published—so please use the coefficients printed to the left.

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



Colour contours of secular variation (annual change) of magnetic declination (minutes-of-arc/year)

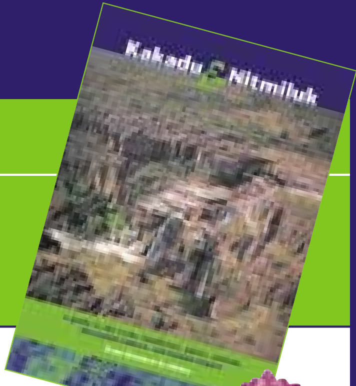


Contours of the secular variation (annual change) overlain on colour contours of declination.

new

Kakadu & Nitmiluk

GUIDEBOOK HAS APPEAL FOR *old-landform* BUFFS



If you want a real story, one that spans 2500 million years of Earth's history and perhaps 50 thousand years of human existence, then grab a copy of 'Kakadu & Nitmiluk'. This stunning guidebook is rich in geological information about these two national parks and jam-packed with colour photos and maps. It will appeal to anyone who loves spectacular scenery, wildlife documentaries, a bit of exercise, and yearns to visit the Top End of Down Under.

Park formation and history

The landforms of Kakadu and Nitmiluk evolved through the interaction of geology and climate over many millions of years. The remarkable gorges, stark cliffs and tumbling waterfalls formed from processes involving deposition of sediments, volcanic eruptions, intrusion of molten magma, folding, erosion and the invasion and retreat of seas.

Kakadu National Park is 200 kilometres south-east of Darwin in the Northern Territory. Almost 20 thousand square kilometres in area, it is Australia's largest mainland national park. It was declared a national park in 1979 and given World Heritage listing in 1981 by UNESCO for its natural and cultural values. Only 17 sites worldwide have this distinction. Kakadu has some of the largest uranium deposits in the world at Coronation Hill, Ranger and Jabiluka. The park's landforms have been the backdrop for international films such as *Crocodile Dundee* and featured in numerous documentaries.

Kakadu is unusual because it contains almost the entire catchment of a large river system, the South Alligator River. There are five major habitats in Kakadu (plateau and gorges, hills and ridges, lowlands, wetlands, coastal flats and estuaries) that support rare and endemic species. About a third of Australia's bird species live in Kakadu. The largest collection of Aboriginal rock art in Australia, excellently preserved, makes the park an important archaeological region. The evolving art styles in more than 5000 gallery sites reveal how Aboriginal people adapted to environmental cycles and the visits of Asians and arrival of Europeans.

Nitmiluk National Park, an area of almost 3000 square kilometres, butts the southern border of Kakadu. Its major attractions, Katherine Gorge and Edith Falls, are popular with tourists. The Katherine River gently zig zags its way through sandstone cliffs of the Arnhem Land Plateau in the dry season. In the wet season (November to March) it is a raging torrent with violent whirlpools and two-metre high waves. Edith Falls is a series of picturesque plunge pools and waterfalls where the Edith River descends the plateau. Approximately 530 thousand tourists visit Kakadu and Nitmiluk each year.

The guidebook

The 120-page guidebook titled *Kakadu & Nitmiluk: A guide to the rocks, landforms, plants, animals, Aboriginal culture and human impact* is published by AGSO in collaboration with the Northern Territory Geological Survey, Environment Australia, Parks Australia, and the Parks and Wildlife Commission of the Northern Territory. The Geological Society of Australia and Energy Resources of Australia provided support. Parliamentary Secretary to the Minister for Industry, Science and Resources, Warren Entsch launched the guidebook in Darwin on October 27. Written for the lay person it describes:

- the geology and geomorphology of both parks and the surrounding region;
- diverse habitats that highlight the strong relationships between geology, landform, soil, climate, flora and fauna;
- local Aboriginal cultures and the exploits of explorers and pastoralists; and
- 48 walking trails that range from easy, short excursions through protected pockets of monsoon rainforests and woodlands and around billabongs to more challenging hikes (up to 66 kilometres) that scale the escarpment and cross gorges and parts of the plateau.

Also included is information about camping facilities and commercial tours, and helpful hints on getting the most from a visit. Pictorially, the book offers easy-to-read maps, foldout diagrams, and 160 ground and aerial photos taken by landscape photographers Ian Oswald-Jacobs, Collin Totterdell and Peter Jarver.

The Kakadu & Nitmiluk guidebook by Dean Hoatson and others is a steal at $24.75 (includes GST), plus postage and handling; phone +61 2 6249 9519 or e-mail sales@agso.gov.au for a copy.

For more details about the guidebook phone its primary author Dean Hoatson on +61 2 6249 9593 or e-mail dean.hoatson@agso.gov.au

▲ Parliamentary Secretary Warren Entsch launches the Kakadu and Nitmiluk guidebook in Darwin.

▲ Guests at the book launch include Parliamentary Secretary Warren Entsch (second right) and Senator Grant Tambling (far left) pictured outside the launch venue, the Museum and Art Gallery of the Northern Territory.