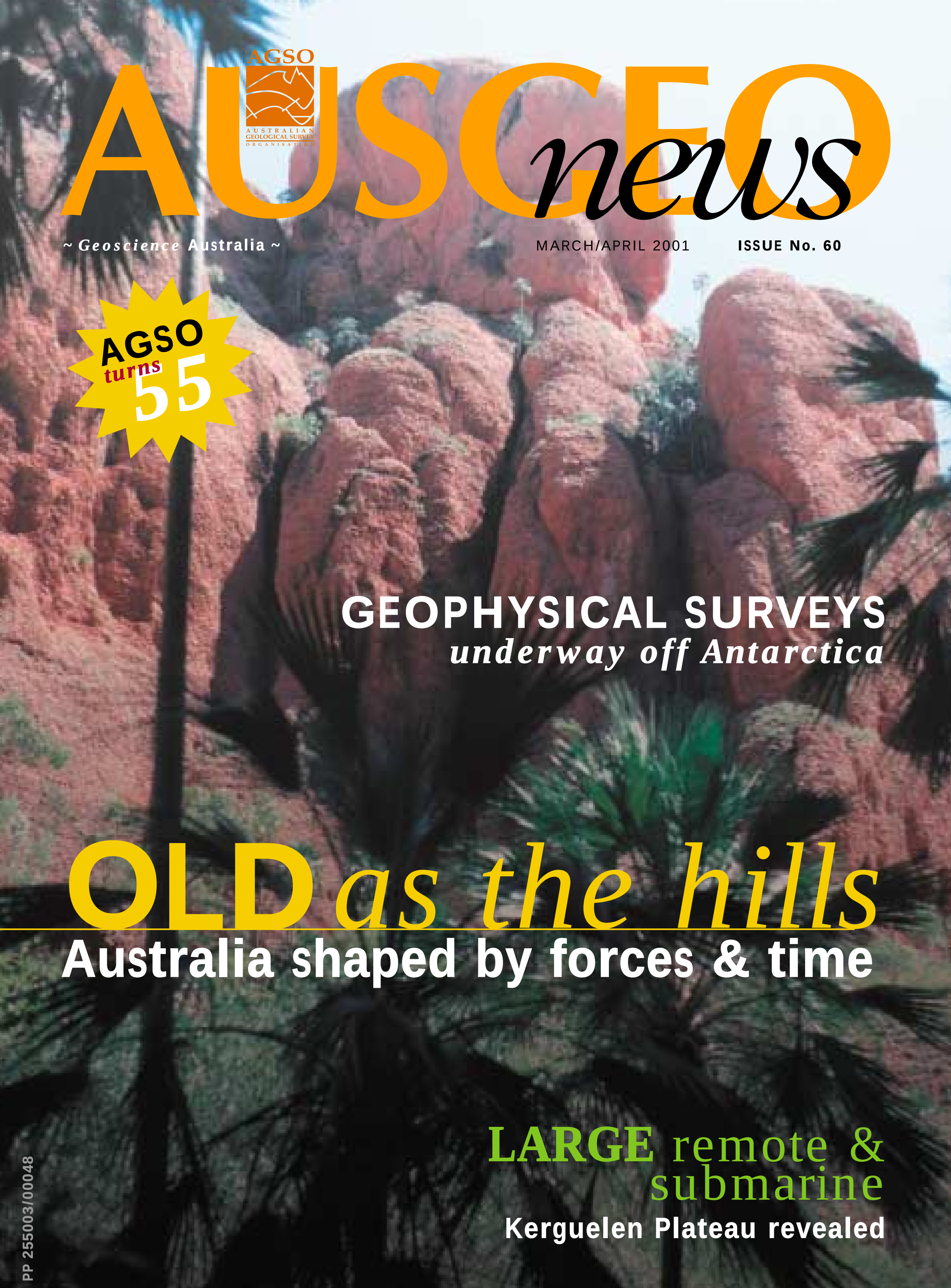

AGSO
AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

AUSGEO news

~ Geoscience Australia ~

MARCH/APRIL 2001 ISSUE No. 60

AGSO turns 55

GEOPHYSICAL SURVEYS *underway off Antarctica*

OLD *as the hills*

Australia shaped by forces & time

LARGE remote & submarine

Kerguelen Plateau revealed

PP 255003/00048

Also: Argon dating at AGSO, gravity network fixed absolutely, rocket remains found...

AUSGEO News
March/April 2001
issue no. 60

Editor Julie Wissmann
Graphic Designer Karin Weiss
Photographer Brett Ellis

This publication is issued free of charge. It is published six times a year by the Australian Geological Survey Organisation.
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ISSN 1035-9338

Printed in Canberra by
National Capital Printing

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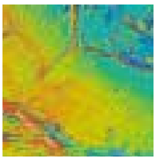
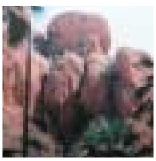


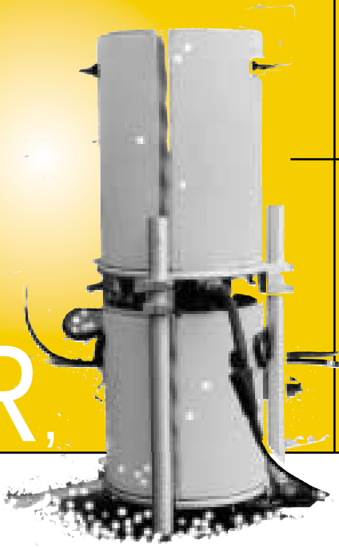


Conglomerate and sandstone formed 360 million years ago (in the Devonian) when the Bungle Bungle Range area was traversed by rivers and much of northern and central Australia was hot, dry and sand blown. See article about Australia taking shape on page 11.

Today *Livistona* palms grow tall in the crevices near Echidna Chasm, Bungle Bungle Range in Purnululu National Park, Western Australia.

Photo: Dean Hoatson

New PORTABLE GRAVIMETER, the *absolute* for *reference network*



Ray Tracey assembles the gravimeter sensor by placing the dropping chamber on top of the laser interferometer.

What takes only a few minutes to set up, operates off a field vehicle's 12-volt power supply and can achieve 10-microgal precision in 10 minutes? AGSO's new portable absolute gravimeter that in coming months will start re-establishing the Australian Fundamental Gravity Network.

The network comprises approximately 800 gravity stations in 200 locations around Australia. The stations are reference points for gravity surveys and are used for setting engineering standards and defining the shape of the Earth in the Australian region.

The first stations were established in 1950. Over years various stations have been destroyed and there have been additions and adjustments to the network. The last major refurbishment of the network was in 1980. It needs to be checked and rebuilt in places.

Station checks

A gravimeter measures the force of the Earth's gravitational field. In the past most station measurements have been taken with relative instruments, which indicate differences in gravity from one point to another rather than the force of gravity at a point. The current network therefore is a network of differences between points, with errors caused by instrument drift.

With the absolute gravimeter, measurements taken at each station give an absolute value or indicate the force of gravity at that point rather than in relation to other points in the network.

It would be extremely time consuming and costly to do repeat readings in 800 stations to check and correct instrument drift. It is much cheaper and more efficient to buy a portable absolute gravimeter, use it to establish a large number of absolute points, and readjust the network and its relative measures to fit those points.

'As a first pass in re-establishing the network, from April I will start visiting about 60 established stations around Australia to take measurements with the absolute gravimeter', says AGSO's Ray Tracey.

'I will begin in New South Wales and then do the rest by chartered aircraft, because many stations are at airports.'

Mr Tracey says that distances will allow him to get to no more than three stations a day.

A computer that records sensor measurements fits neatly in the back of a field vehicle and runs off the vehicle's power.

The gravimeter

The gravimeter uses Newton's original idea of an object falling towards the ground. It measures the rate of acceleration of a falling mass.

In the top chamber of the gravimeter sensor, a small satellite free falls a short distance in a vacuum. In the bottom chamber the descent is tracked as hundredths of micro metres per second squared (1×10^{-8} m/s^2 or 10 microgals) by a laser system.

The sensor is placed over the station (which is generally a small aluminium plug nestled undercover outside a building) and connected by two 10-metre cables to a computer that records measurements. The computer fits neatly in the back of a field vehicle and runs off the vehicle's power. At each station the satellite will be dropped a couple of hundred times, with a second between each drop, for a statistically acceptable level of accuracy.

AGSO's portable absolute gravimeter is the only one in Australia and one of four built so far by Micro-g Solutions in Colorado, United States. After the initial establishment of the Australian Fundamental Gravity Network, the gravimeter will be available to state and territory surveys and other government institutions.

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

MAJOR REPORT ON ESTUARIES HANDED TO AUDIT

Executive Director of the National Land and Water Audit, Colin Creighton, accepts AGSO's report on Australian Estuaries and Coastal Waterways from CEO Neil Williams (centre) and Deputy CEO Trevor Powell (right).

A 10-month effort by AGSO staff and contractors culminated in the hand over of a major report on Australian estuaries and coastal waterways to the National Land and Water Audit at the end of February.

The Audit assesses the status of Australia's natural resources and under the Audit theme of ecosystem health, AGSO was contracted to look at the condition of Australia's estuaries (1048 estuaries and coastal waterways) and collect details on modified ones.

'The Audit needs information about modified estuaries—their sediments, water quality, fish, the impact of retaining walls and bridges—before it can get into priorities for management', says the Audit's Executive Director, Colin Creighton.

'Some of this information already existed but it sat in filing cabinets in different agencies and states, making it very difficult to grab the range of data needed for decisions about proper management of catchments.'

Mr Creighton says AGSO was ideal for Audit work because it could draw on a multi-disciplinary team that could deliver a compilation of services in one package.

'The bottom line is that AGSO could draw together disparate pieces of data, map the sediments and habitats, compile the information and deliver management-based datasets for our web-based system', he says.

'In a short time frame, AGSO coerced air photos of 1000 estuaries out of different agencies, determined which estuaries had been modified, mapped the sediments of those estuaries, determined changes in morphology and conditions, and produced a good compilation including some remote-sensed imagery for our atlas site.'

Mr Creighton says that because of AGSO's work the government has really good information for anyone dealing with Australian estuaries.

AGSO created a national geoscience database for the Audit called 'ozestuaries'. It integrates data from the Australian Estuarine database and new data acquired for the Audit. New data include geometrical measurements, facies (habitat) areas, denitrification rates and efficiencies, and sediment rates and contents of estuaries and other coastal waterways. AGSO's report to the Audit is titled 'Australian estuaries and coastal waterways: A geoscience perspective for improved and integrated resource management'.

For further information about the report or database phone Dave Heggie on +61 2 6249 9589 or e-mail dave.heggie@agso.gov.au

AGSO starts 2002 graduate recruitment rounds

AGSO requires staff of the highest order and, with this in mind, is once again embarking upon a round of university visits to promote the organisation to potential staff. The visits follow on from last year's successful Graduate Recruitment Program, which culminated in nine graduates joining AGSO in January this year. Details of these graduates can be found at the AGSO website http://www.agso.gov.au. The group was selected from more than 150 applicants, of which 50 were interviewed by senior AGSO staff.

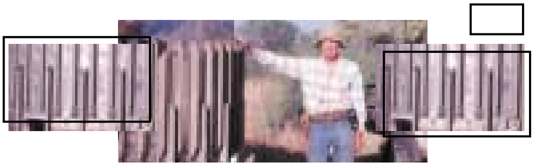
AGSO seeks graduate students with skills and qualifications in the areas of geoscience and geophysics, as well as mathematics, physics and information management. The plan is to increase the intake from this year's nine to at least 12 in the 2002 intake.

Successful graduates choose interesting AGSO projects from within all research divisions, and participate in external rotations elsewhere in the Australian Public Service. Each graduate is allocated a mentor from senior management to assist during the graduate year.

As well, they are involved in a comprehensive developmental program of seminars and workshops designed to enhance skills on such issues as project management, leadership, career directions, information/knowledge management, client satisfaction, and strategic thinking.

This year senior AGSO representatives will visit more universities than in 1999. Details of visits can be found at the AGSO website.

For further details about the program phone Len Hatch on +61 2 6249 9015 or e-mail Len.Hatch@agso.gov.au



ROCKET REMAINS found on map mission

The second rocket fragment was crushed on impact.

When geologists go into the field they often find a few surprises. But when geologist Albert Brakel and field hand Eugene 'Mack' McClellan went to the Georgina Basin last year, they did not expect to stumble across pieces of a rocket launched from Woomera in the late 1960s.

Brakel and McClellan, with Pierre Kruse of the Northern Territory Geological Survey, were remapping the Tobermory 1:250 000 Sheet, just north of the Simpson Desert along the Queensland–NT border—an area that had not been mapped systematically since 1958–9. They were in the area because it has potential for lead-zinc mineralisation and diamonds. And in Queensland, the Georgina Basin also contains a world-class petroleum source rock, and phosphate.

They were on a hill looking at a good example of the lateral interfingering of Ninmaroo Formation carbonates with fine-grained sandstone of the Tomahawk beds, when McClellan scanned the distance with binoculars. He noticed what appeared to be a water tank that was not on the map.

Continued over page...

NOTHING RETIRING ABOUT AGSO AS IT CELEBRATES ITS 55TH BIRTHDAY

Plenty to smile about as AGSO celebrates its emerald anniversary: (from left) Glenn Simon and Megan Lech, CEO Neil Williams, and Emma Murray holding an emerald.

After 55 years of unfailing service to the resources sector and the Australian government, AGSO, Australia's national geoscience research/geological survey organisation celebrated its emerald anniversary on March 19.

The idea for a national survey organisation was conceived during the Second World War when there was a need to assess Australia's reserves of strategic minerals. The organisation was born in 1946 and called the Bureau of Mineral Resources (BMR).

In 1946 BMR set about compiling a series of geological and geophysical maps of the entire Australian continent, at a scale of four miles to the inch (today 1: 250 000 or 1 cm to 2.5 km). Staff was faced with a land area of more than seven million square kilometres and 500 map sheets to fill.

BMR's field mapping began in 1947 in collaboration with the Western Australian Survey. Teams of geologists were often in the bush for six or seven months of the year gathering data that would gradually fill in the blank map sheets. Geophysical mapping of the continent began in 1950 when BMR bought and fitted out a DC-3 aircraft.

Through BMR's field work, major mineral deposits were discovered, including bauxite at Gove, manganese at Groote Eylandt, and uranium at Coronation Hill.

BMR geoscientists also surveyed territories outside mainland Australia. They were involved in expeditions to Antarctica and nearby islands and carried out field surveys in Papua New Guinea before independence.

In the 70s BMR entered the computer age and began finding new ways to collect, collate and store data. By the 80s BMR's work was no longer land-locked. The organisation equipped a purpose-built ship to research Australia's continental margin. It cut back its field surveys and devolved regional mapping to state geological surveys—although years later BMR again became involved in regional mapping through a Commonwealth–States agreement known as the National Geoscience Mapping Accord. In 1992, BMR was restructured and renamed the Australian Geological Survey Organisation.

Today AGSO still serves the national interest. It continues to research and compile geoscience data that encourages exploration of Australia's mineral and petroleum resources—although the detail is much greater and the technology is very sophisticated compared with 55 years ago. In keeping with community needs, AGSO is involved in environmental management issues such as salinity, is working with local authorities on natural disaster mitigation, and is helping Australia maintain its wealth by researching untapped resources in its marine areas.

AGSO quietly celebrated its emerald anniversary with chocolate cake for staff and visitors in the café of its Canberra headquarters.

For further information phone Gail Wright on +61 2 6249 9174 or e-mail gail.wright@agso.gov.au

Dr Albert Brakel stands beside the first rocket fragment found while mapping the Tobermory Sheet, just north of the Simpson Desert.

Investigation showed the tank was a three-metre-diameter, cylindrical part of a rocket. It was standing upside-down and, remarkably, not deformed by impact.

The interior was a chaotic tangle of cables and equipment that included components made in France and at the Weapons Research Establishment at Salisbury, South Australia. It was part of a rocket launched from Woomera in the late 1960s by the European Launcher Development Organisation (ELDO).

Six kilometres away on the following day, another rocket piece was found. Originally a cylinder like the first piece, it was squashed on impact and lay on its side. There were scorch marks on one end. Inside, among the damaged cables and equipment, was a component that had a 23/9/66 date of manufacture. Two smaller fragments were also found in the area.

ELDO launched seven rockets in a northerly direction from Woomera. Three were attempts to orbit a satellite, but none succeeded. The first of the seven was launched in May 1966, and consisted of a British Blue Streak first stage with dummy French and German second and third stages. The other six followed between November 1966 and June 1970. The first stages of these flights generally returned to Earth in the Tobermory–Simpson Desert region; the second stages, if they worked, came down north of New Guinea.

The pieces found on Tobermory were from a Blue Streak first stage. The date of manufacture on the second piece rules it out as being part of the first ELDO rocket. From which other firings it and the other fragments could have come is under investigation by Roger Henwood and Stan Spencer of the Woomera Heritage Society. The society is recovering the rocket pieces, which will be put on display in the Woomera museum as part of Australia's space history.

For more details phone Albert Brakel on +61 2 6249 9697 or e-mail albert.brakel@agso.gov.au before July 6.

VISIT CRUCIAL TO PNG HAZARD MONITORING

Training and obtaining spare parts are the main reasons John Bosco spent four weeks in March–April at AGSO headquarters in Canberra away from his usual place of work, the Rabaul Volcanology Observatory on the island of New Britain in Papua New Guinea.

Mr Bosco is in charge of the RVO's technical services. His section maintains the electronic equipment that monitors earthquakes and volcanic eruptions, and detects ground deformation in the New Britain region and at a number of other active volcanoes across PNG.

'We get lots of earthquakes because the RVO is very close to an active fault', Mr Bosco says.

'At least once a week we feel an earthquake, whether it is volcanic related or a regional one, and daily there are probably two or three volcanic earthquakes which are not felt but the instruments pick up.'

Mr Bosco says that last November the RVO recorded a big earthquake around 7.6 on the Richter scale and lots of aftershocks that went on for three weeks.

Although earthquakes are normal, everyday events at the RVO, they can be life threatening. Mr Bosco has to ensure that seismometers and other recording equipment are working and that his staff is trained to handle them and make repairs.

The recording equipment helps RVO staff to determine whether a volcanic eruption is imminent and whether authorities need to evacuate people.

'We make the decision, after looking at the activity, whether evacuation is warranted. We then advise the Disaster Coordination Centre and provincial authorities to get people out of harm's way', he says.

He says that if instruments aren't working properly or in a bad state of repair, the repercussions could be terrible.

RVO equipment was designed and installed by AGSO staff with funding provided by AusAID. Mr Bosco spent time in AGSO's engineering unit to meet with and learn from those who built the equipment.

'It has been good to talk with these guys about our problems, the kinds of faults we get, and improvements that could be made to the equipment', he says.

Because of the relationships he now has with AGSO, Mr Bosco says that when he has a technical problem in Rabaul he will know whom to contact about what to get an immediate answer.

Mr Bosco visited electronics suppliers in Canberra to buy parts for RVO equipment. Most is being sea freighted to Rabaul, but some urgent pieces needed for equipment that is idle because of a lack of spares is being air freighted home in time for Mr Bosco's arrival.

'On my air freight list I have spares for seismic recorders because they are the critical part of our network, and small items such as fuses and other electronic components', he says.

Mr Bosco's visit is part of the PNG–Australia Volcanological Service Support Project: Twinning Program being conducted with AusAID funding.

John Bosco in AGSO's engineering unit for some additional training

TEMORA ZIRCON *'out of this world'*

TEMORA ZIRCON

Zircon standards CZ3, R33 and SL13 may sound like something from Star Wars, yet AGSO's standard—simply called 'Temora' after the place where it is found—is the one that is 'out of this world'.

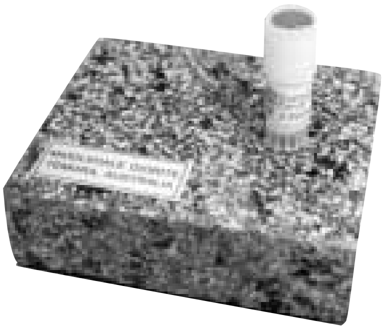
Results from tests carried out on Temora zircons in Canada over the past year and a half show that as a standard for finding the ages of rocks, the Temora zircons approach (and perhaps reach) perfection.

World-recognised authority, Canada's Royal Ontario Museum, conducted two rounds of tests for AGSO. The first round analysed 14 different zircons from a medium- to coarse-grained Temora boulder, and the second tested 12 different zircon crystals from a more abundant, neighbouring coarse-grained rock. Final results were delivered in mid-February.

'Every zircon gave the same answer', says AGSO's Dr Lance Black.

'The 26 zircons from different boulders found in one paddock consistently gave the same age of 417 million years and showed no evidence of lead loss.

'That means there is no disturbance to the isotopic clock in these zircons.'



Vial of 'perfect' zircons and a slab of Middledale Diorite from which the zircons are extracted.

Rock clock

Minute traces of radioactive uranium locked inside the zircon crystal decay over aeons, producing lead in the process. This decay occurs at a fixed rate and is used to work out the age of a rock. If the zircon has been altered or damaged, lead can be lost and the zircon is unsuitable as a benchmark for rock dating.

Only the outermost rims of the Temora rocks show evidence of weathering. They crystallised high in Earth's crust from magma (more than 1000 degrees Celsius in temperature) that did not contain zircons from older melted rocks. If older zircons had been present, the Temora rocks would not provide a worthwhile standard.

Dr Lance Black (second left) presents a vial of zircons and pieces of Middledale Diorite to Chinese delegates (from left) Ms Wu Boer, Professor Liu Dun-yi (who is in charge of China's new SHRIMP) and Ms Wang Yuchi. Photo taken at the Research School of Earth Sciences, Australian National University.

International demand

A number of Australian university laboratories (Australian National University, University of Tasmania, Macquarie University, University of Melbourne) already use the Temora standard in experiments.

The Japanese and Canadian Geological Surveys have supplies of Temora zircons, and in the coming weeks the United States Geological Survey will receive the samples it requested. As well, while on a recent Canberra visit, a Chinese Academy of Geological Sciences delegation headed by Professor Liu Dun-yi collected a vial of Temora zircons (about 5000 grains) for experiments using their new ion micro-probe (SHRIMP or sensitive high-resolution ion micro-probe).

Temora zircon test results have not yet been presented at international meetings or released in international journals. This should happen in the next 12 months.

Dr Black says that more laboratories around the world are expected to take up the Temora standard once they see the 'hard data' that support the claims being made.

AGSO has collected about 1.6 tonnes of Temora boulders (fine- and coarse-grained types) and extracted tens of thousands of zircon crystals from the small quantity (about 10 kg) crushed to date. Hundreds of tonnes of fresh boulders (in a two-kilometre long Middledale gabboric diorite intrusion) remain on a farmer's property, 30 kilometres east of Temora in central New South Wales. This body of rock has enough perfect zircons to meet the world's geochronological demands for decades.

For further details contact Lance Black on +61 2 6249 3125 or e-mail lance.black@agso.gov.au

Argon dating comes to AGSO

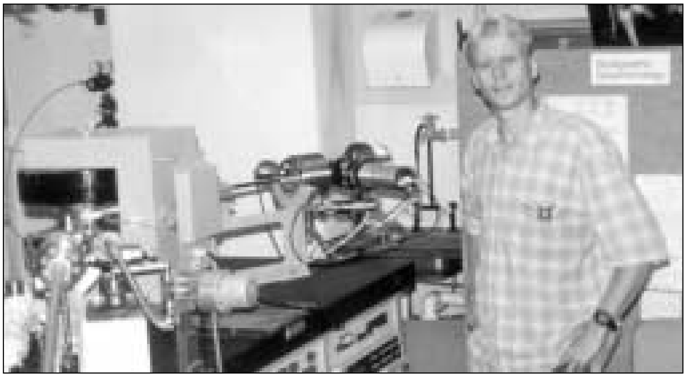
AGSO recently expanded its geochronology capabilities to include the $^{40}Ar/^{39}Ar$ method, with the arrival of Dr Geoff Fraser. Argon geochronology will complement AGSO's strength in uranium–lead geochronology, allowing a broader range of geological problems to be tackled.

Method

Potassium, one of the most abundant elements in Earth's crust, consists of a mixture of naturally occurring isotopes, one of which (^{40}K) is radioactive. The natural decay of potassium (^{40}K) to argon (^{40}Ar) is the basis for K/Ar and $^{40}Ar/^{39}Ar$ geochronology.

A half-life of 1.25 billion years for this decay scheme means the K/Ar and $^{40}Ar/^{39}Ar$ methods can be used to measure geological time from several thousand years ago to the Archaean (>2.5 billion years ago). For example, the K/Ar method was instrumental in development of the geomagnetical polarity time-scale for the past few million years, and has also been used to date lunar samples that are almost four billion years old.

$^{40}Ar/^{39}Ar$ geochronology is a variant of the K/Ar method. It requires neutron irradiation of samples prior to isotopic analysis in order to convert a proportion of the stable ^{39}K atoms to ^{39}Ar via neutron capture and proton emission. Since ^{39}K occurs in an essentially constant proportion to ^{40}K in nature at the present day, the resulting ratio of radiogenic ^{40}Ar to neutron-induced ^{39}Ar becomes a proxy for the K/Ar age. Thus an age can be calculated from the measured $^{40}Ar/^{39}Ar$ ratio, without needing to independently measure potassium content.



Dr Geoff Fraser (pictured) adds argon dating to AGSO's capabilities. Dr Fraser's experience includes the application of isotope geochronology to metamorphic rocks. He is currently involved in analyses for the Gawler Craton and the North Australia projects, using the noble gas isotope laboratory at the Research School of Earth Sciences, Australian National University.

Applications

In theory, many potassium-bearing materials are amenable to $^{40}Ar/^{39}Ar$ analysis; but in practice mineral separates of muscovite, biotite, K-feldspar or hornblende are most commonly used. As with any geochronological technique based on radioactive decay, interpretation of calculated ages depends on understanding the retention characteristics of the daughter isotope, in this case ^{40}Ar.

$^{40}Ar/^{39}Ar$ geochronology is particularly suited to reconstruction of cooling histories in metamorphosed terrains and, in certain circumstances, to direct age determination of deformation fabrics. The method provides information critical to understanding thermal and tectonic histories in crystalline basement terrains. It has also been applied successfully to provide stratigraphic time markers where appropriate, thermally undisturbed, volcanic units occur.

For further information about the $^{40}Ar/^{39}Ar$ method phone Geoff Fraser on +61 2 6249 9063 or e-mail geoff.fraser@agso.gov.au

AURORA AUSTRALIS SEEN IN SOUTHERN AUSTRALIAN SKIES

Heightened Sun activity is creating a glow, known as the aurora australis, in southern Australian skies as far north as Canberra and parts of New South Wales. On the evening of March 31 the aurora was seen in the Canberra area at around 11 p.m. EST (1300 UT).

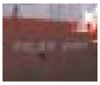
Sightings of the aurora australis this far north are related to solar maximum conditions. Since late March, numerous flares have erupted from the solar surface. They occur in active regions on the Sun where there are sunspots, which are cooler areas of intense magnetic fields. Sunspots are indicators of solar activity in an 11-year cycle that is now near its peak.

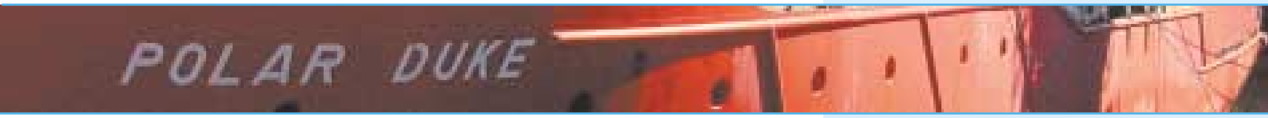
When flares are directed towards Earth, the released energetic particles, travelling at speeds in excess of 1000 kilometres a second, can cause disturbances in the Earth's ionosphere and produce magnetic storms when they arrive some 36 hours later. The resulting distortion of the magnetosphere expands the region where the aurora australis (and borealis) commonly occurs and allows the spectacle to be seen in continental Australia.

Auroral activity is invariably accompanied by intense activity in the geomagnetic field. Real-time magnetic data from AGSO's magnetic observatory at Canberra can be viewed on AGSO's web site: http://www.agso.gov.au. (Select Geomagnetism, then Data and Indices, and finally Real-time Geomagnetic charts.) Past data can also be viewed on the site.

Expect further opportunities to see the aurora in southern Australian skies during this solar maximum.

For more information phone Peter Hopgood on +61 2 6249 9359 or e-mail peter.hopgood@agso.gov.au



MARINE GEOPHYSICAL SURVEYS

underway off *Antarctica*

Australia requires a large quantity of geophysical data to define the shape of the Australian Antarctic Territory (AAT) continental margin and its underlying geology. The government needs this data if it is to lodge a submission delineating the 'extended continental shelf' off the AAT, with the United Nations Commission on the Limits of the Continental Shelf by the deadline of November 2004.

The ice-strengthened survey vessels *Geo Arctic* and *Polar Duke* left Capetown, South Africa, in early and mid-January to begin acquiring the data.

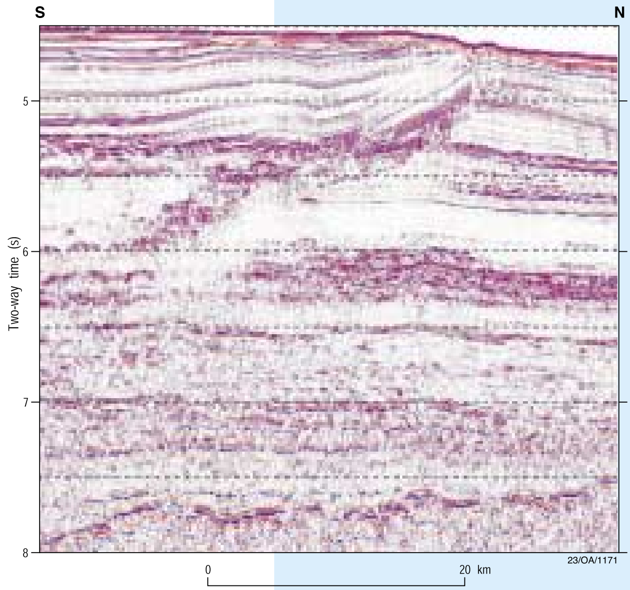
The ships acquired data along a series of widely spaced lines along the length of the AAT, 50 to 500 kilometres from the Antarctic continent, entirely in deep water (500–5000 metres water depth). An experienced geophysical contractor (Fugro Geoteam, Norway) is carrying out the surveys during the Antarctic summer seasons of 2000–01 and 2001–02 in accordance with permit guidelines issued by the Australian Antarctic Division and Environment Australia.

Data acquired

The *Geo Arctic* arrived off the AAT in mid-January. It spent three months acquiring high-quality, deep-seismic data on widely separated deep-water profiles along the 5500-kilometre length of the AAT continental margin from Enderby Land in the west to George V Land in the east. In some areas, these profiles provide the only available geophysical data for up to a thousand kilometres. They provide a comprehensive view of the geology of the continental margin and oceanic crust that formed as India, Antarctica and Australia separated in the Cretaceous and Cainozoic. An example of new data from the Enderby Basin is shown in figure 1.

The *Polar Duke* arrived off the AAT in late January and for seven weeks recorded bathymetry and high-speed seismic data along a series of lines that extend from the shelf break down the continental slope. These lines tie into the southern ends of the profiles recorded by the *Geo Arctic* and complete the margin-wide transects.

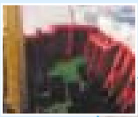
Figure 1. Portion of a seismic section from the Enderby Basin at the western end of the Australian Antarctic Territory, showing unusual structuring within the shallow sedimentary section. Within hours of being shot, the seismic data are processed to brute stack on board the *Geo Arctic* to aid on-line interpretation.

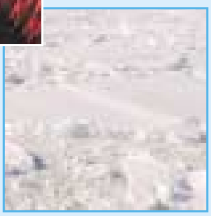


Survey vessel *Polar Duke*, which acquired bathymetry and high-speed seismic data.

Aerial view of the survey vessel *Geo Arctic*, which is being used to acquire deep-seismic, magnetic, gravity and bathymetric data.

The surveys were completed in mid-March *(Polar Duke)* and mid-April *(Geo Arctic)*. Approximately 10 500 kilometres of deep-seismic and potential field data, 3400 kilometres of high-speed seismic data, and 9000 kilometres of bathymetric data were acquired. The *Geo Arctic* will return to the region in 2001–02 to carry out a second deep-seismic survey that will in-fill the lines acquired this summer.





International understanding

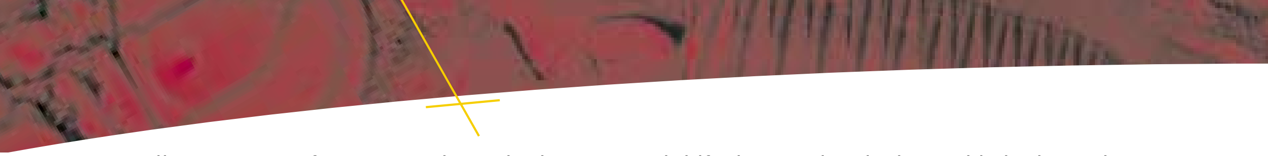
The surveys are the most wide-ranging geoscience surveys carried out by any nation off Antarctica, which is probably the most poorly understood part of the world's oceans. In addition to helping determine the outer limit of the 'extended continental shelf', the data will enhance international scientific understanding of Antarctica and its role in the global climate system, and provide information to support the future management of the environment. Initially data will be interpreted by Australian scientists, but will become available to the wider international scientific community under the terms of the Antarctic Treaty and through the Scientific Committee on Antarctic Research.

Project established

In December 1999, the Australian Ministers for Foreign Affairs, and Environment and Heritage announced that the government would carry out work that would enable it to prepare a submission delineating the 'extended continental shelf' (ECS) off the AAT. The ECS is the area of seabed/subsoil jurisdiction beyond the 200 nautical mile Exclusive Economic Zone, as defined by Article 76 of the United Nations Convention on the Law of the Sea.

The Australian Antarctic and Southern Ocean Profiling Project was set up, under the management of the Department of Finance and Administration in consultation with the Australian Antarctic Division, to acquire and interpret data that would underpin any such submission. Technical aspects of the work are largely the responsibility of AGSO and the Australian Surveying and Land Information Group (AUSLIG).

For more details phone Howard Stagg on +61 2 6249 9343 or e-mail howard.stagg@agso.gov.au



Australia, once part of a supercontinent, broke away and drifted. Over time it changed latitudes and has been both tropical and covered in ice. Continental collision, volcanic eruptions, climate change, and the rise and fall of oceans shaped the landscape. Dr Marita Bradshaw gives a quick summary of the evolution of the Australian continent over the past 600 million years.

GIVEN LATITUDE, *Australia* took SHAPE

CAMBRO–ORDOVICIAN

16/0/141

Cambrian (545–490 million years)

The ancient continent did not resemble today's geography. (See figure.) Ocean covered eastern Australia except for Mt Read in western Tasmania (an area for major base-metal deposits today), a few volcanic islands, and some land in the Mt Isa region. North-western Australia was potted with volcanoes that poured lava across roughly 500 000 square kilometres.

By about 540 Ma, volcanic activity ended in Western Australia but continued in central Victoria and western Tasmania. Shallow seaways extending generally north–south flooded much of the Northern Territory and South Australia, depositing sediments rich with fossils (e.g. trilobites).

Ordovician (490–434 million years)

The climate was warm and a global sea-level rise brought marine conditions back to central Australia. A seaway—the Larapintine Sea—ran east–west across the continent. Shales and siltstones were deposited in many areas at this time (now the source of oil and gas in central Australia). There was volcanic activity in Kosciusko National Park.

By the end of the era the ocean had retreated and Australia was arid. The Larapintine Sea vanished, leaving thick deposits of salt. Tin deposits in Victoria and some gold and copper in New South Wales and Queensland date back to volcanic activity at the end of the Ordovician.

Silurian (434–410 million years)

The climate remained warm. Western and central Australia were arid and sand blown. There were many volcanoes in eastern Australia. As well, much of eastern Australia lifted from the ocean as plates converged along the eastern margin. Granite-bearing tin, tungsten and gold date back to this tectonism, as does the copper-silver-lead-zinc mineralisation in eastern Australia.

"During the Palaeozoic (Cambrian to Permian), Australia sat in low latitudes with a warm and arid climate until it began moving south into freezing conditions."

To kick-start AGSO's science forum on the assembly of Australia, speakers revisited palaeogeographic maps and looked at models of how Australia and its neighbouring plates formed. They honed in on key geological events (major breaks in the continent, changes in continent direction, and the annealing of different structures) in the search for patterns that provide clues to when and where Australian ore bodies and oil fields formed.

Australia is part of a large mobile plate that affects and is affected by neighbouring plates. A major geological event (e.g. continent collision) along one of its boundaries sets off a chain reaction that can cause faulting and uplift, change plate motion and direction, and create new plate geometries.

In the following pages we look at a couple of brief narratives on plate relationships and how Australia assembled and disassembled.

Devonian (410–354 million years)

Hot and dry conditions persisted. The wind continued to build desert dunes through central and northern Australia. Along eastern Australia there was a string of volcanic islands from Mackay to Newcastle. Canberra had beaches, Townsville had coral reefs, and the ocean retreated from most of Tasmania.

Reefs and mud flats flourished off north-western Australia and there were many ocean inlets from Broome to Exmouth.

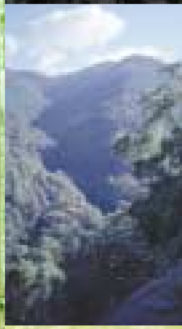
Following uplift and tilting, the sea retreated from inland of Townsville, and a large river system developed and flowed eastward. Land was pushed up around Alice Springs—the onset of the central Australian highlands and the build up of large alluvial fans. By about 360 Ma, volcanism in Victoria peaked and faded.

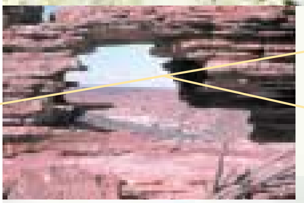
Carboniferous (354–298 million years)

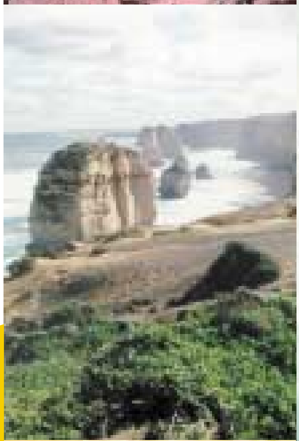
There were a couple of ocean inlets in western and north-western Australia, but the reefs disappeared. Rivers flowed from a broad mountain range in central Australia, depositing sands and gravel along water courses. Volcanic activity continued along the eastern margin of Australia, building a mountain range that looked something like the Andes today. Big volcanic explosions south-west of Cairns produced a lot of ash. In western New England, ancient rivers now long gone carried volcanic material and dumped it along what was then the coast. Igneous rocks from this period bear reserves of tin, copper and molybdenum.

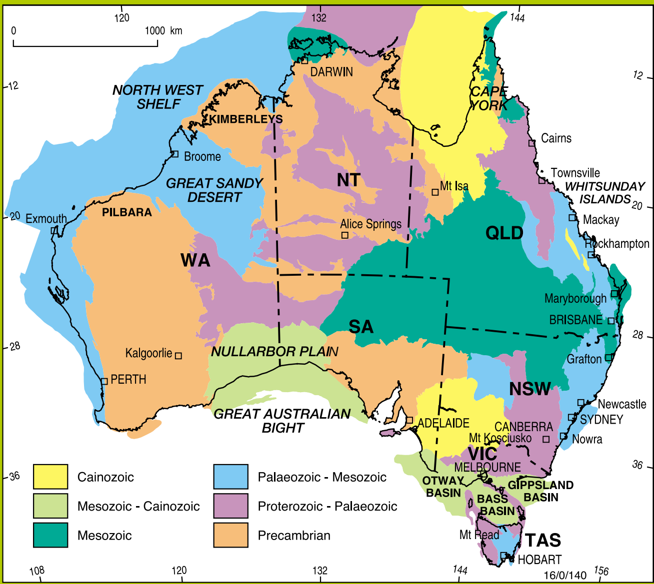
The climate had cooled by the end of the Carboniferous because Australia shifted southwards in latitude (see figure). Ice caps were building on the mountains. Ice from Antarctica (which was sitting adjacent to Australia at this time) advanced eastward across Tasmania and western Victoria.

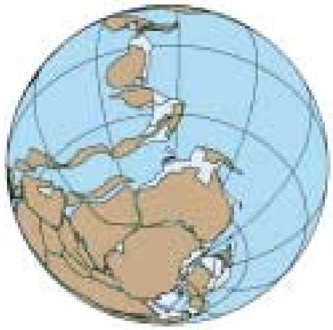










PERMIAN

16/0/139

Permian (298–251 million years)

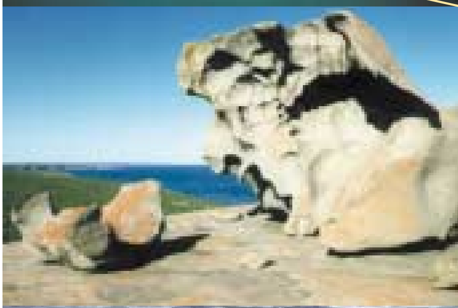
Australia was fire and ice at the beginning of this era. An enormous volcanic belt extended for 2200 kilometres from Sydney to Cairns, and central and southern Australia resembled present-day Antarctica. There were three ice sheets: one across most of central and western Australia, another north of Adelaide, and the third over much of Victoria and Tasmania.

By about 270 Ma the ice began to melt, the sea level rose and sediment was dropped on the seafloor as floating ice thawed. Glacial debris covered the landscape before being washed into low-lying basins or adjacent seas. Extensive wetlands developed.

For millions of years, sea levels rose and fell. Winters were cold enough to freeze sea water. By 265 Ma the volcanic belt became extinct (beginning in New South Wales) and large lakes had formed in south-western Queensland—ideal for peat deposition that would later become coal seams and the source of oil and gas in central and southern Queensland.

About 256 Ma there was plate collision off the central Queensland coast. Submarine volcanism occurred off the coast, and subsidence inland created a north–south seaway from Mackay to Nowra.

The Mesozoic (Triassic to Cretaceous) was characterised by temperate climates that promoted plant development and the formation of coal.



Towards the end of the Permian, sea levels retreated globally and swampy alluvial plains developed from Cape York to Tasmania and around Perth, but particularly in the Queensland interior. The eastern seaway continued to sink but sediments from the mountains filled the trough. Volcanoes erupted east of the trough in New South Wales and in south-eastern Queensland.

Triassic (251–205 million years)

Australia was generally high and dry, despite a worldwide rise in sea level in the early Triassic and another rise later in the era. The climate was hot. Coastal environments of swampy mudflats and sandbars covered the North West Shelf as sea levels rose and fell and rivers flowed and ebbed. Small lakes developed in central Australia and there were extensive wetlands from Grafton to Maryborough. Volcanoes erupted along rift valleys between Grafton and Rockhampton and mountain building occurred in the Great Sandy Desert.

Jurassic (205–141 million years)

Sea levels rose and fell and rose again in the warm and increasingly humid Jurassic. The rivers of eastern Australia expanded and linked to form a huge drainage network at least as big as the Amazon. It stretched from the central Australian highlands across Queensland and northern New South Wales and well beyond the present coastline.

Eastern Australia was densely vegetated and dotted with coal swamps and lakes. From Exmouth to the Northern Territory there was a huge sandy coast with bays, lagoons and deltas that dumped lots of sediment. Deltas and estuaries formed across Cape York and coarse alluvial sands, silt, mud and peat accumulated in the floodplain around Perth.

Near the end of the Jurassic, Australia started to break away from the rest of the supercontinent called Gondwanaland, bringing about a wetter climate. A rift valley formed as Australia and Antarctica began to separate. The deep lakes, forests and rivers of the rift valley would disappear over millions of years, as the rift became an ocean inlet. Artesian water and many of the oil and gas reservoirs in eastern Australia were deposited in the Jurassic.

Cretaceous (141–65 million years)

During the Cretaceous, Australia separated from Gondwanaland, and India broke away from western Australia. Seas slowly flooded eastern Australia from the north, swallowing dense forests of conifers and ferns. Northern and western Queensland was covered by sea. Volcanoes erupted along what is now the Whitsunday Islands. Western Victoria and parts of western New South Wales were a shallow sea.

By 110 Ma sea levels began to fall. The Northern Territory became dry land again and an inland sea along eastern Australia was rimmed by deltas, lagoons and estuaries. Dinosaurs roamed these estuaries. A couple of volcanoes erupted in eastern Tasmania and rivers in the rift valley along southern Australia continued to pour sediment into the Otway, Bass and Gippsland basins. As the Great Australian Bight widened, the rift deepened and sea began to creep eastwards. Several groups of plants became extinct in the salty conditions where the sea encroached.

It was warm and wet in the early Cainozoic and rainforest covered the continent. But it became progressively colder and glaciers formed at the poles. Australia's northward movement to tropical latitudes partly offset the cooling trend.

By about 85 Ma, the inland sea had retreated eastwards from central Australia and Queensland, leaving swamps and coastal marshes. Most of Australia was well above sea level and an inlet separated most of southern Australia from Antarctica. Volcanic activity in the Gippsland was related to the opening of the Tasman Sea. Other volcanic eruptions in eastern Australia were associated with seafloor spreading in the Pacific and the separation of New Zealand.

By the end of the Cretaceous, Australia was an island continent that looked much like its present shape. As India broke away from Australia, there was faulting, uplift and volcanic eruptions south of Perth. Tasmania and Papua New Guinea were still connected to Australia by land bridges, as was a big area of land off north-east Queensland.

At least one large meteorite hit central Australia in the Cretaceous. Large meteorite impacts on Earth at the end of the Cretaceous are thought to have caused mass extinction of land and marine life.

Cainozoic
(65 million years–present)

Australia lay in latitudes of 25–60 degrees south. Temperate rainforest was widespread. Australia and Antarctica drifted apart and shallow seas flooded valleys near Kalgoolie. Bass Strait was a swampy alluvial plain. Sporadic eruptions occurred along the coast of Queensland down to Tasmania. High-quality gems such as sapphires date back to these volcanic explosions. Bauxite began to form in the wet seasons of the coastal north.

By about 30 Ma the climate changed from humid to dry. The Antarctic ice cap began to form, and global sea levels fell and ocean currents changed. The drier climate was more pronounced in central Australia. Australia's opal deposits formed at this time. The shallow seas retreated from the Nullarbor Plain leaving an expanse of limestone. The west Kimberleys experienced volcanic activity.

Five million years ago, sea levels lowered and climate cooled and the Antarctic ice cap expanded. But the continent's northern drift brought the north Queensland coastline into waters warm enough for reef growth.

Over the past two million years, sea levels have fluctuated with the waxing and waning of ice sheets. During one period of low sea level in the past 50 000 years, Aboriginal ancestors migrated to Australia from Asia. These people would have witnessed volcanoes erupting in Queensland and Victoria. They would have been in Australia during the last ice age (18 000 years ago) when there were glaciers in Tasmania and an ice cap on Mount Kosciusko, and when desert dunes formed over much of the continent.

For further information telephone Marita Bradshaw on +61 2 6249 9452 or e-mail marita.bradshaw@agso.gov.au

CONSORTIUM FOR OCEAN GEOSCIENCES OF AUSTRALIAN UNIVERSITIES

5th Australian Marine Geoscience Conference

27 to 29 June, 2001
Centenary lecture theatre
University of Tasmania
Hobart

30 June, 2001
Field trip: Tasman Peninsula coastal geomorphology

Themes

- Marine geoscience and regional planning
- Southern Hemisphere Quaternary palaeoenvironmental records
- Evolution of continental margins
- Estuarine and coastal sediment processes

Registration fee: $100 which includes a copy of conference proceedings, morning and afternoon teas, and the conference dinner. Accommodation is by own arrangement. Bring warm clothing and a raincoat.

COGS 2001 is sponsored by the Palaeoenvironment Program, Antarctic Cooperative Research Centre, and the Australian Sedimentologists Group.

For further information contact Peter Harris, Antarctic CRC, GPO Box 252–80, Hobart Tas 7001. E-mail P.Harris@utas.edu.au

No fault of its own, BUFFER PLATE *turns*

The Philippine Sea plate at the western Pacific margin appears to be the buffer for movement in neighbouring plates. Professor Robert Hall explains.

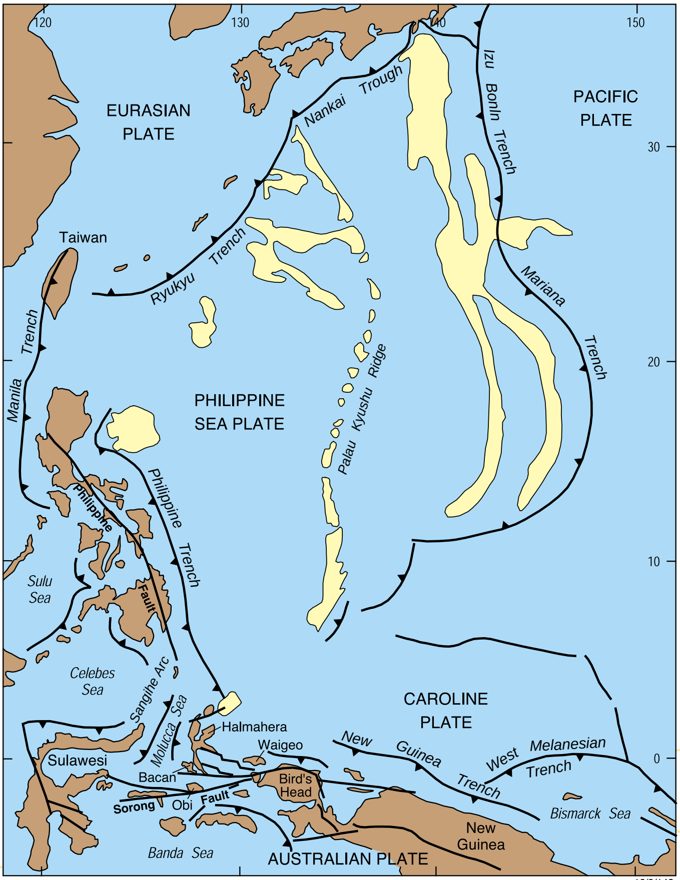


Figure 1. The Philippine Sea plate, with its submarine ridges and a handful of islands in the south, is surrounded by subduction zones.

The Philippine Sea plate is surrounded by subduction zones that separate it from an oceanic ridge system. It lacks a hot-spot track and an accreting boundary that would allow plate growth or expansion.

The largest area of land within the plate comprises the Indonesian islands between Halmahera and Waigeo. The southern part of the plate terminates in eastern Indonesia. The northern region is entirely submarine.

Eastern Indonesia includes a junction between the Australian and Philippine Sea plates with a complex of small plates forming the Eurasian and South-East Asian margins. At the southern boundary of the Philippine Sea plate and the Molucca Sea plate is the Sorong Fault.

Fault zone

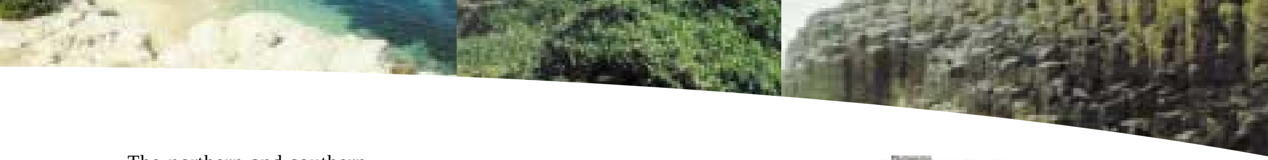
The Sorong Fault system extends from the Bird's Head to Sulawesi, including the islands of the North Moluccas. Fragments of Australian and Philippine Sea plate origin have been found in the fault zone.

The Sorong Fault was initiated about 25 million years ago when a Philippine Sea plate arc collided with the north Australian margin. This caused the Philippine Sea plate to rotate, and allowed the Sorong Fault to move north at the same rate as Australia. The Philippine Sea plate moved northward 10–15 degrees after this collision.

Rotation

The Philippine Sea plate rotated approximately 90 degrees between the Late Cretaceous and Eocene. Clockwise rotation of about 50 degrees occurred, 50 to 40 million years ago when a number of plates in the Pacific moved and reorganised. Collision with the north Australian margin about 25 million years ago caused the second major rotation (approximately 40 degrees clockwise).

Throughout the Late Cretaceous and early Tertiary, parts of the Philippine Sea plate remained at low equatorial latitudes. However there was a significant southward movement of the present southern part of the plate between about 50 and 40 million years ago. The Halmahera–Waigeo region moved south during this period, but elsewhere in the Philippine Sea plate there was northward motion. In other words, the northern part of the plate moved northward and there was southward motion in the southern part of the plate. Between 40 and 25 million years ago there was no rotation and no significant latitudinal shift, which is consistent with convergence between the Philippine Sea plate and Australia during this interval.



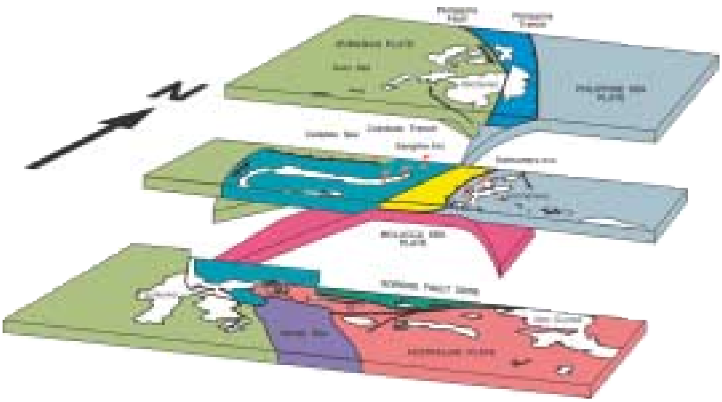
The northern and southern Philippine Sea plate, the eastern Philippines—until about five million years ago when subduction began at the Philippines Trench—and rocks of New Guinea were part of the Philippine Sea plate prior to 25 million years ago.

Volcanic activity

Australia's northward movement during the Neogene did not subduct the Philippine Sea plate. But westward movement of the Philippine Sea plate resulted in subduction of the Molucca Sea plate, first to the west beneath the Sangihe Arc and later beneath Halmahera. Late Neogene volcanic activity began the eastward subduction of the Molucca Sea plate beneath Halmahera.

The oldest potassium-argon ages from volcanic rocks suggest that the Halmahera Arc became active approximately 11 million years ago (although there are signs that thermal activity started as early as 15 Ma). Volcanism began in the south on Obi and extended progressively northwards producing a volcanic arc. By the end of the Miocene an arc extended from Obi, through Bacan, into North Halmahera (about 7 Ma).

The West Philippine Basin, the oldest basin in the Philippine Sea plate, is attributed to backarc spreading.



▲ **Figure 2.** A 3D cartoon of the plates in the Molucca Sea region at present.

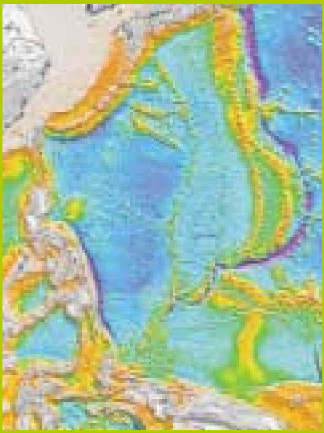
Current movement

The Philippine Sea plate is currently rotating clockwise with respect to Eurasia and keeping pace with Australia's northward motion. It is moving into South-East Asia along the northern Australian margin.

There is a lot of convergence through the Ryukyu Islands, down through Taiwan and the Philippines. The rate of convergence between Eurasia and the Philippine Sea plate increases southward because of a westward subduction at the Philippine Trench. Just north of Halmahera, the Philippine Trench terminates abruptly. A retreating trench on the eastern margin of the plate is compatible with clockwise rotation of the whole plate.

The Molucca Sea plate is being thrust deep into the mantle as a result of thickening material in the central Molucca Sea—an area of very intense seismic activity.

Professor Hall is Director of the London University South-East Asia Research Group. For more details about plate reconstruction of South-East Asia and the south-west Pacific e-mail robert.hall@gl.rhbnc.ac.uk



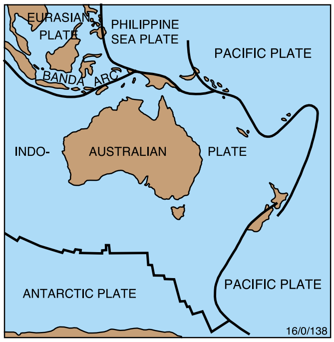
▲ **Figure 3.** A satellite gravity-based map of bathymetry of the Philippine Sea plate.

▲ Volcano in the Halmahera Arc

▲ Volcano in the Sangihe Arc

Boundary dynamics force PLATES to BUMP and *swing*

Australia is a mobile continent inching north-north-east. Its movement and that of its neighbours trigger changes in plate boundary configurations along the Indian, Australian and Pacific plates. Dr Dietmar Müller gives a brief history of plate boundary changes over the past 100 million years in the Indian and Pacific Oceans that involve Australia.



The Australian and Indian plates move faster than any other plates that include a large continent.

Australia moved east between 190 and 130 million years ago; then moved very little between about 90 and 45 million years ago. But in the mid- to late Tertiary, it started moving northward quite fast. These changes were due to two forces first opposing each other and then acting in unison.

At one stage, there were mid-ocean ridges and an evolving ocean basin around Australia. These caused a ridge–push action on at least three sides of Australia and brought the plate to a near standstill. But eventually the mid-ocean ridge just north of Australia met with a subduction zone that began engulfing it. The subducting slab started pulling Australia north and the ridge that was evolving in the Indian Ocean began pushing Australia in the same direction.

Meanwhile, India was on the move. It converged on Eurasia in the past 20 million years. This collision forced the Indo-Australian Plate to break up in the central Indian Ocean, but there wasn't a pre-existing zone of weakness to accommodate the breakup. This caused a broad intraplate deformation zone to form, creating the only oceanic fold and thrust belt in the world.

Capricorn plate forms

With the break up of India and Australia, another small plate formed—the Capricorn plate. The Capricorn plate lies west of 80 degrees east of what was once the Australian plate. The three plates (Australia, India and Capricorn) meet at a triangular region (a diffuse triple junction) in the central Indian Ocean.

The region is being stretched and shortened because of plate movement. The India–Capricorn and Capricorn–Australia zones of shortening merge and subduct beneath an overriding plate. Vertical thickening by means of folding and thrusting occurs where the three plates converge. Thinning of the crust and lithosphere elsewhere in the region is accommodating the stretching.

Pacific plate swerves

The Pacific plate is also mobile. Eastward dipping subduction occurred within the plate around the Pacific Ridge until about 100 million years ago when plate motions changed from east–west to north-west–south-east. The Pacific plate swung 65 degrees to sideswipe the eastern margin of Australia.

About 80 million years ago there was convergence in the area between New Caledonia, the Otway and New Zealand. A subduction zone developed and the Three Kings Ridge and Loyalty Ridge formed east of the subduction zone. Over time these ridges moved towards New Caledonia.

About 45 million years ago the Pacific plate swerved again (40 degrees west or left) and accelerated, and Loyalty Ridge collided with New Caledonia. Norfolk Island Basin opened up and about 25 million years ago the South Fiji Basin opened with a subduction zone to the east.

The Ontong Java Plateau collided with the overriding Melanesian Arc approximately 15 million years ago.

Mantle density differs

Australia is one of at least 200 plates globally. It is still moving—about eight centimetres a year. This movement (and that of the neighbouring plates) creates stress and causes deformation not only along boundaries but also within plates, including earthquakes, folding and other changes to the topography.

Today east and north-east of Australia, many very deep earthquakes occur—earthquake events between 400 and seven kilometres deep. These earthquakes are not related to rapid or sudden plate conditions. They are thought to result from differences in mantle density along a subduction zone.

The mantle density under the south Pacific, in particular, is much less than the surrounding area. A molten slab along the Tonga and Kermadec trenches in the Pacific Ocean is slipping beneath a denser piece of mantle. In other words, a down-going molten slab is opposing upwelling mantle and causing earthquakes very deep in the earth. As parts of the plate sink, the subduction hinge (i.e. the trench) is migrating seaward. A back arc basin is forming as the trench rolls back across the Pacific plate.

For further information phone Dietmar Müller at the School of Geosciences, University of Sydney, on +61 2 9351 2003 or e-mail dietmar@es.usyd.edu.au

Disaster management conference, INTERNATIONAL STAGE for AGSO technology

The Global Disaster Information Network's (GDIN) 2001 conference, held in Canberra from March 21–23, attracted delegates from 20 countries interested in global, regional and national initiatives for sharing and providing disaster management information.

With a theme of 'providing the right information to the right people in time to make the right decisions', GDIN aims to capitalise on communication and information management technologies, such as GIS, remote sensing, and the internet.

▲ The AGSO booth at GDIN 2001: Ingo Hartig (left) and Neil Corby test run the latest information management tools used in hazard risk assessments.

The conference was structured around plenary sessions, meetings and forums. The plenary sessions covered:

- the South Pacific approach to strengthening community resilience through the application of information management tools and technologies;
- an Australian perspective on emergency management;
- use of Earth-observing satellites for disaster management support;
- the future of disaster information management;
- progress on regional and national disaster information networks (including the Australian Disaster Information Network or AUSDIN);
- GDIN concept and models (website portal and organisation); and
- GDIN business planning and funding.

The various Regional and GDIN Working Groups met and there were forums on GIS, disaster information networks, and the media. Presentations were made on EM-DAT (a disaster database, including a unique disaster numbering system), the OECD Futures Project on emerging systemic risks, and remote sensing.

AGSO's booth at the conference was popular, with demonstrations by Cities Project staff covering:

- geospatial field data capture and collection—pre- and post-event damage modelling techniques;
- earthquake and wind modelling methodologies;
- visualisation of disaster information—data integration, analysis and modelling; and
- the Cities Project and risk-GIS methodology as applied to multi-hazard risk assessments.

Demonstrations on the AUSDIN portal prototype to the GDIN Executive and to the Asia-Pacific Regional Working Group by AGSO's Webmaster, Jonathon Root, generated much interest. The portal is being developed by AGSO in collaboration with Emergency Management Australia and other agencies. It will provide internet access to a wide range of information and tools for emergency management decision making.

Further details on individual sessions, presentations and forums, as well as the final day's discussions regarding the GDIN Business Plan, changes to the Ankara Declaration, working-group recommendations and proposals, GDIN 2002 in Italy, and the GDIN Canberra Statement can be found at http://www.ema.gov.au/gdin/index.html.

GDIN 2001 was hosted by Emergency Management Australia and officially opened by Parliamentary Secretary to the Minister for Defence, Dr Brendan Nelson, after an Aboriginal welcoming ceremony by the Ngunnawal people. AGSO was a gold sponsor of GDIN 2001.

For further information about GDIN 2001 phone Charlie Barton on +61 2 6249 9611 or e-mail charles.barton@agso.gov.au

AUCKLAND: Cities on Volcanoes second conference

Cities on Volcanoes II conference, held in Auckland from February 12–15, concentrated on one geological hazard: volcanic eruptions. But conference themes about city preparedness were applicable to other hazards.

The conference drew more than 200 participants from 19 countries, and brought together a range of specialists (from volcanologists to sociologists and emergency managers) to discuss how populated areas in active volcanic regions can cope with the increasing threat of volcanic eruptions.

Auckland was a suitable venue for two main reasons. Firstly because it has 50 youthful basaltic volcanoes in the city area, and secondly because there are concerns about how the next eruption from this polygenetic volcanic field could affect Auckland and its population.

The conference had some excellent speakers. Well-received presentations included those by Richard Zias (City Manager, Yakima, Washington State) on the aftermath of volcanic ash falls on his city after the May 1980 Mount St Helens eruption, and Bill McGuire (Benfield Greig Hazard Research Centre, London) on volcanic insurance.

Other speakers presented papers in three parallel sessions that covered volcanic processes, volcano surveillance, volcanic risk evaluation and mitigation, emergency management, lessons from recent New Zealand eruptions, education and public health, agricultural and social impacts, volcanic heritage, and the 1350 Kaharoa eruption in New Zealand. AGSO's Dr Wally Johnson chaired the South Pacific volcanic hazard management workshop.

The first Cities on Volcanoes conference was held in Rome and Naples, Italy, in 1998. The third will be held in 2002 in Hilo, Hawaii—a city frequently threatened by lava flows from Moana Loa.

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Expenditure down, but *Australia leads with* GOLD

AGSO's Mike Huleatt and Lynton Jaques visit Toronto in March to promote Australian mineral exploration at PDAC 2001 (Prospectors & Developers Association of Canada conference). They summarise the Australian situation in readiness for an international audience.

Australian mineral exploration expenditure fell by 19 per cent in 1999–2000 to $676.3 million, according to the Australian Bureau of Statistics. In current dollar terms, this was the lowest expenditure since 1992–93. In constant 1999–2000 dollars it was 17.5 per cent less than that in 1998–99, reflecting the continuing depressed state faced by exploration worldwide.

Exploration expenditure fell for all major commodity groups in Australia in 1999–2000. Gold remained the principal target with just over 55 per cent of total spending (58% in 1998–99). Base metal (copper, silver, lead, zinc, nickel and cobalt) expenditure was $156.8 million, 11 per cent lower than in 1998–99 even though its share of total expenditure rose from 21 per cent to 23 per cent. Western Australia was the leading state with expenditure of $415 million (a reduction of $108.1 million on 1998–99 figures).

In 1999–2000 almost 6.5 million metres of exploration drilling was completed, 25 per cent less than in 1998–99. Of the total, almost 1.8 million metres were on production leases compared with 2.4 million metres the previous year. Spending on drilling was $256.6 million.

AUSTRALIA LEADS

Australia remained the leading country for exploration expenditure. It attracted 17.3 per cent (18.7% in 1999) of global exploration expenditure according to a report in the *Mining Journal* on the latest Metals Economics Group survey.

Interest from major international mining houses increased. Joint ventures between them and junior explorers provide an important stimulus to grass-roots exploration. Examples include Platsearch NL joining Inco to explore properties in New South Wales, South Australia and Queensland. Pilbara Mines reached agreement with Inmet Mining Corporation for Inmet to farm exploration around Pilbara's Teutonic Bore base metal project in Western Australia. And Homestake Mining expanded its Australian interests with the purchase of a 7.5 per cent share of Tanami Gold NL, giving Homestake a presence in the prospective Tanami–North Arunta region.

Exploration highlights of the year

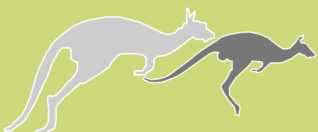
- Australia attracts more exploration spending than any other country (17.3% of world expenditure).
- Gold was the main target, accounting for more than 55 per cent of total spending.
- Western Australia was the leading state with expenditure of $415 million.
- Significant nickel–copper intersections were encountered in Proterozoic layered mafic-ultramafic rocks at WMC's West Musgrave project.
- Goldfields Ltd and others reported a 1 Moz gold resource (average grade of 41.7 g/t) at Raleigh, near Kalgoorlie, in an area with 100 years of gold exploration and mining.
- Dalrymple Resources & Lionore Mining International announced an initial resource of 30 Mt at 2.2 g/t Au (2.1 Mozs) at the Thunderbox gold deposit.

OUTLOOK HEALTHY

The outlook for junior companies has improved with successful listings of more than a dozen new mineral floats on the Australian Stock Exchange. These companies have concentrated on base metals and nickel, with gold, mineral sands and PGMs also of interest. There is renewed interest in greenfields exploration by major companies, particularly due to the scarcity of advanced projects. Further strategic alliances between junior companies and larger overseas companies are expected to boost exploration.

While exploration is likely to focus on the major mineral provinces—Yilgarn, Mount Isa, Lachlan Fold Belt, Broken Hill–Olary—emerging provinces like the Tanami–Arunta and Murray Basin will see increased activity. The main interest is expected to be gold, nickel, zinc, copper, mineral sands and diamond in known provinces under cover and in greenfields areas. High palladium prices should see continued interest in PGMs.

The Australian Bureau of Agricultural and Resource Economics (ABARE) expects most minerals and metal prices to firm in 2000–01 with increases averaging between three and six per cent. However, they also forecast that gold price rises will average just one per cent and that zinc and nickel prices will fall by one and four per cent respectively.



EXPLORATION SUCCESSFUL

In one of the most important finds in several years, WMC Resources announced the intersection of nickel–copper mineralisation at its West Musgrave project. This mineralisation is associated with the Giles Complex (~1100 million-year-old mafic and ultramafic rocks in Western Australia near the South Australian border). The Giles Complex, which includes layered gabbro, troctolite and pyroxenite, is one of the largest of its type in the world. The mineralisation is speculated to be similar in style to the Voisey's Bay deposit in Canada.

Successful gold exploration continued in the Eastern Goldfields of Western Australia, despite production and exploration for more than a century. The Raleigh gold deposit, reported by Goldfields Ltd to have more than one million ounces at an average grade of 41.7 g/t Au, is only 22 kilometres from Kalgoorlie. Other prominent discoveries were WMC's Belleisle discovery near its St Ives operations, and Dalrymple Resources and Lionore Mining International's Thunderbox deposit near Leinster.

High levels of exploration were maintained in the new Murray Basin mineral sands province in south-eastern Australia. Further prospects were identified and new resources delineated at some deposits. The Douglas and Gingko deposits moved into feasibility studies.

Gold

The Archaean greenstones of Western Australia's Eastern Goldfields continued to yield new mineralisation. Successful deep drilling (e.g. Kanowna Belle and Wallaby) highlights its potential at depth. Deeper resources are likely to be an important factor in the industry's long-term future in Australia, which is generally under-explored at depth. The importance of new geological models and improved understanding of the geological environment was demonstrated by the discovery of new mineralisation at some existing deposits, including the Palaeozoic slate-belt deposits at Bendigo in Victoria.

WMC Resources announced that its Belleisle discovery near Kambalda, Western Australia, has the potential to add substantially to the global resource of the St Ives system, which exceeds 11 million ounces. Results include: 43.1 metres at 18.41 g/t Au, 4.8 metres at 15.01 g/t Au and 34 metres at 2.20 g/t Au. Belleisle is 12 kilometres north of the St Ives processing plant.

Dalrymple Resources NL (40%) and Lionore Mining International (60%) reported the first resource estimate for the Thunderbox deposit 60 kilometres south of Leinster, Western Australia. An initial resource of 30 Mt at 2.2 g/t Au for 2.1 million ounces was estimated. The deposit has a 1800–metre strike length, occurs to a depth of 450 metres, is open in two directions and has high-grade zones open at depth.

Goldfields Ltd announced discovery of the Raleigh high-grade gold deposit, 2.5 kilometres south of its Kundana operation near Kalgoorlie. Combined, indicated and inferred resources are 0.747 Mt at 41.7 g/t Au for a resource of more than one million ounces. An 800 by 50 metre anomaly two kilometres south of Raleigh gave results including: two metres at 10.24 g/t

Au, two metres at 17.73 g/t Au, one metre at 10.90 g/t Au and one metre at 2.77 g/t Au. Raleigh straddles the boundary of two tenements.

Bendigo Mining found mineralisation that repeats at depth. Drilling at Bendigo intersected unmined ribbons below the Deborah and Sheepshead line of reefs and on the New Chum line of reef, six kilometres away and 200 metres below previous workings. Traditionally gold has been sought in anticlinal crests at Bendigo, but attention has focused on synclines following the Swan Decline intersecting a gold-bearing reef in the Deborah Syncline between the Deborah and Sheepshead Anticlines. Sampling of this reef gave values to 1.3 metres at 7.6 g/t Au.

Copper, lead, zinc & silver

Exploration continued to focus on the Broken Hill–Olary region (Fe-oxide Cu-Au deposits, Broken Hill style Zn-Pb-Ag deposits), the Mount Isa province (sediment hosted Zn-Pb-Ag, Fe-oxide Cu-Au) and the Lachlan Fold Belt (porphyry Au-Cu). There was renewed interest in massive sulphide (VMS) deposits with increased exploration in the Yilgarn and the Lachlan Fold Belt.

Noranda Pacific completed a feasibility study into the Lady Loretta Zn-Ag-Pb project in the Mt Isa Inlier, 130 kilometres north-west of Mt. Isa. Drilling resulted in a 60 per cent increase in resources to:

- measured 9.1 Mt at 16.7 per cent Zn, 6.2 per cent Pb, 99 g/t Ag;
- indicated 4.0 Mt at 18.0 per cent Zn, 5.4 per cent Pb, 94 g/t Ag; and
- inferred 0.5 Mt at 15.6 per cent Zn, 5.1 per cent Pb and 91 g/t Ag.

Noranda subsequently exercised its option to purchase a 75 per cent share in the project.

Nickel

The discovery of the West Musgrave Ni-Cu mineralisation in the Giles Complex rekindled interest in the Proterozoic mafic-ultramafic complexes in the East Kimberley and elsewhere as potential hosts for Voisey's Bay style Ni-Cu mineralisation. These and other layered intrusions were also the focus of renewed interest in PGMs following from the high precious metal prices. Exploration for Archaean komatiite-hosted nickel sulphide in the Yilgarn and for lateritic nickel deposits continued strongly.

WMC Resources announced the intersection of Ni-Cu mineralisation at its West Musgrave project in the Giles Complex. WMC's initial announcement in May 2000 reported both massive and disseminated mineralisation. Subsequently, three prospects were identified—Nebo, Babel and Gerar. The following intersections were reported:

- at Nebo, 26.55 metres at 2.45 per cent Ni, 1.78 per cent Cu and 0.74 g/t PGMs+Au;
- at Babel, 148.9 metres at 0.3 per cent Ni, 0.42 per cent Cu, 0.01 per cent Co and 0.29 g/t PGMs+Au was intersected.

Mineral sands

The focus of activity continued to be the strandline deposits of late Miocene–Pliocene marine sand sequences of the Murray Basin in New South Wales, Victoria and South Australia. As some projects moved into feasibility studies, new deposits were being delineated. In Western Australia, strandlines near Shark Bay have potential for substantial resources.

Resource estimates were upgraded by Basin Minerals for the Douglas project near Horsham, Victoria. Total inferred resources rose to 20.8 Mt of concentrates containing 11.31 Mt of ilmenite, 1.26 Mt of rutile and 1.62 Mt of zircon. A bankable feasibility study is in progress with the aim of starting production in 2004. Resource definition drilling totalling 60 000 metres on two deposits at Douglas aimed at outlining measured resources for an initial five-year production period will be completed in the first half of 2001.

Bemax Resources NL announced that resources at its Gingko deposit in New South Wales, total 252 Mt at 2.8 per cent heavy minerals (HM). The deposit has a high-grade core of 123 Mt grading 4.2 per cent HM. A pre-feasibility study is in progress.

Diamond

Diamond exploration centred on the Kimberley region of Western Australia, particularly the North Kimberley. But there was a minor pegging rush during the year, with large areas of the North Australia Craton in the Northern Territory now under application.

Ashton Mining announced encouraging results from deep drilling at the Argyle Pipe, 120 kilometres south-west of Kununurra, Western Australia, with a high-grade intersection of 4.7 cts/t over 392 metres of lamproite. This confirms the extension of the Central Vent to greater depths than previously inferred.

Deep drilling at Merlin, 80 kilometres south of Borroloola, Northern Territory, aimed at testing depth extensions of diamond-bearing pipes showed that two of the main pipes joined at about 120 metres into one larger pipe. Ashton reported the recovery at Merlin of a 42-caret diamond, the second largest ever found in Australia. Ashton also reported the recovery of diamonds in bulk sampling of drainages on one of its tenements in the Batten Trough near the Merlin mine.

RISK REDUCED

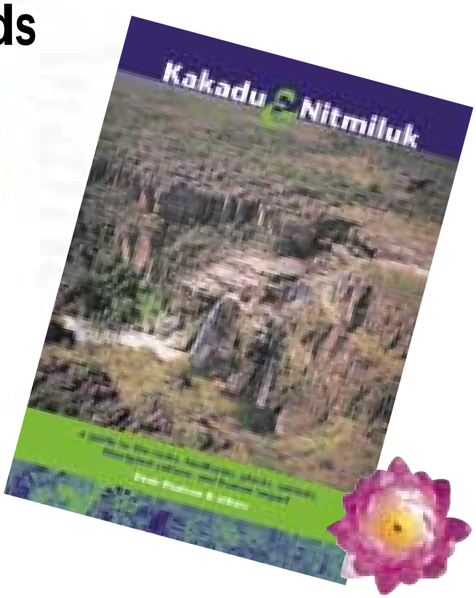
The federal government has allocated $52.6 million to three Cooperative Research Centres whose activities include research to aid mineral exploration in areas of substantial cover, prediction of the location and quality of ore deposits, and coal research.

AGSO is involved in the first two of these activities and, under the National Geoscience Agreement (NGA) with state and territory surveys, provides geoscientific data for proven and greenfield mineral provinces. This year NGA projects are being conducted in the Yilgarn province, the Carpentaria–Mount Isa belt, southern Northern Territory, the Gawler Craton, and the Broken Hill–Olary province.

Access to Australian geoscience data and information will improve when a geoscience web portal becomes operational this year. It will provide information and links to the various geological surveys. Online access to national geoscience datasets and databases is already available via AGSO's website.

For more information about Australian mineral exploration or material prepared for the Australian booth at PDAC phone Mike Huleatt on +61 2 6249 9087 or e-mail mike.huleatt@agso.gov.au

Kakadu guidebook *wins bronze* in National Print Awards



Spend five minutes leafing through this beautiful guidebook and you'll realise why 'Kakadu & Nitmiluk' beat an impressive commercial field to win a bronze medal at Australia's 18th National Print Awards in Melbourne in March.

One of 1307 entries, and in the category 'limp-bound books', it was awarded a bronze with Courier Newspaper winning gold *(Reflections of Double Bay)* and First National Real Estate *(Creating your home)* and Litchfield *(Cape to cape)* the silver medals.

Pages of stunning photographs allow the guidebook to claim 'coffee-table' status, but its text and cartography make it far more useful. The guidebook's detailed, but refreshingly easy to understand text and painstakingly meticulous diagrams and maps add hugely to reader value.

The guidebook has two main parts. The first describes Kakadu and Nitmiluk national parks—the climate, facilities, Aboriginal heritage and rock art, European exploration, mining activities, the geological history of rocks and landforms, and habitat types. The second part provides details of the 48 trails, tracks and cruises available for anyone (from the fit to the flabby) planning an excursion in either park. There are maps, diagrams of geological cross sections, aerial photos, and excellent photos of features along walking trails and four-wheel-drive tracks.

The 120-page guidebook titled *Kakadu & Nitmiluk: A guide to the rocks, landforms, plants, animals, Aboriginal culture and human impact* was 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. It was printed and bound by Gillingham Printers in South Australia. Colour reproduction was by Command E, South Australia.

For a copy of this beautifully crafted award winner phone the AGSO Sales Centre on +61 2 6249 9519 or e-mail sales@agso.gov.au. The guidebook costs $24.75 (includes GST), plus postage and handling.

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

EVENTScalendar

Compiled by Steve Ross

Australian Science Festival
Australian Science Festival Ltd
27 April to 7 May, **Canberra**
Contact: Australian Science Festival, PO Box 193, Civic Square ACT 2608
phone +61 2 6205 0588
fax +61 2 6205 0638
www.sciencefestival.com.au

NSW Mineral Exploration & Investment 2001
NSW Department of Mineral Resources
17 and 18 May, **Hilton Hotel, Sydney**
Contact: Stacey Hutchins, Dept Mineral Resources, PO Box 536, St Leonards NSW 1590
phone +61 2 9901 8654
fax +61 2 9901 8493
e-mail hutchins@minerals.nsw.gov.au

AAPG 2001—An Energy Odyssey
American Association of Petroleum Geologists Annual Meeting and Exhibition
3 to 6 June, **Denver, Colorado, USA**
Contact: American Association of Petroleum Geologists, PO Box 979, Tulsa Oklahoma 74101-0979 USA
phone 0011 1 918 560 2679
fax 0015 1 918 560 2684
e-mail convene@aapg.org

Fourth International Dyke Conference
Interaction Conferencing, University of Natal
26 to 29 June, **Ithala Game Reserve, KwaZulu-Natal, South Africa**
Contact: Jacqui Ingram-Klopper, Interaction Conferencing, University of Natal, Durban 4041, South Africa
phone 0011 27 31 260 1584
fax 0015 27 31 260 1606
e-mail klopperj@nu.ac.za

COGS 2001 Marine Geology Conference
Consortium for Ocean Geosciences of Australian Universities
27 to 29 June, **University of Tasmania, Hobart**
Contact: Peter Harris, Antarctic CRC, GPO Box 252–80, Hobart Tas 7001
phone +61 3 6226 2504
e-mail P.Harris@utas.edu.au

Changes in the Marine Environment
Australian Marine Sciences Association & New Zealand Marine Sciences Association
3 to 6 July, **Jupiters, Townsville**
Contact: Ms Raewyn Dooley, Conference & Events Management, PO Box 771, Townsville Q 4810
phone +61 7 4721 2377
fax +61 7 4721 4936
e-mail C.E.M.A.@bigpond.com

Deep-ocean drilling results from the submarine Kerguelen Plateau, a very large volcanic area in the middle of the southern ocean, are causing a flutter among geoscientists. Results show continental crust lies under the plateau. The extent of this crust is crucial for gauging the area's petroleum prospects. Irina Borissova describes the plateau's structure and the region's evolution.

KERGUELEN PLATEAU—a **new look** at its basins

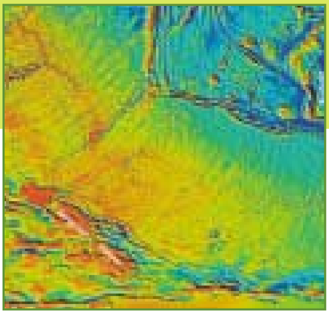


Figure 1. Location of the Kerguelen Plateau in the southern ocean. The Australian EEZ is shown by a green line.

The Kerguelen Plateau is one of the largest submarine plateaus in the world. It is nearly three times the size of Japan or four times the size of the British Isles. It lies in the southern ocean about 3000 kilometres to the south-west of Fremantle (Western Australia) near the Antarctic margin. A large part of the plateau lies within Australia's Exclusive Economic Zone (AEEZ; figure 1) and its 'extended continental shelf'—the area of seabed/subsoil jurisdiction beyond 200 nautical miles. The total area of the AEEZ around Heard and McDonald Islands and the extended continental shelf is about 1.4 million square kilometres.

In 1997 AGSO conducted two surveys over the southern Kerguelen Plateau and the Labuan Basin (surveys 179 and 180) acquiring more than 4600 kilometres of high-resolution deep (16 second) seismic data. Interpretation of this data, together with previously collected seismic data, formed the basis of a two-year AGSO framework study of the region.[1] The surveys and the framework study were conducted as part of AGSO's Law of the Sea project to support definition and understanding of the Kerguelen Plateau region. The study integrated available geological and geophysical information, including recent ODP drilling results (leg 183) with interpretation of the seismic reflection data. The outcome improves understanding of the plateau's structure, tectonic history and petroleum potential.

Past environments

Geological investigations of the Kerguelen Plateau reveal a dramatic history over the past 120 million years. Oceanic volcanic activity built up edifices that eventually stood above the waves. Plants colonised the new volcanic islands initially with tree ferns, followed by a climax community of podocarp forest consistent with the mild, wet climate of the mid-Cretaceous even at these high southerly latitudes. The pollen recovered from ODP drilling sites records this history along with abundant charcoal fragments that point to raging forest fires, perhaps started by volcanic eruptions.[2]

Volcanic activity waned and the lonely islands subsided as the hotspot that gave birth to the Kerguelen Plateau moved north. Albian terrestrial sediments, such as the red-brown clastic sediment with reworked coal fragments intersected in ODP 750, were overlain by marine deposits. These included shales and carbonates and,

Expressions of interest_Scientific exploitation of AASOPP data

Join a consortium to develop a science plan for AASOPP (Australian Antarctic Southern Ocean Profiling Project) data.

Major areas of likely research include:

- Plate kinematics and spreading history;
- Antarctic margin structure, subsidence and sequence stratigraphy for comparison with the southern Australian margin;
- Antarctic slope and rise sedimentation related to palaeooceanography and ice sheet history; and
- Antarctic seafloor morphology and processes.

The major research partners are Australian institutions (e.g. AGSO and Australian universities), but international collaboration is welcome and encouraged.

The AASOPP undertakes research that will enable the Australian Government (if it wishes) to prepare a submission to the United Nations Commission on the Limits of the Continental Shelf delineating the 'extended continental shelf' off the Australian Antarctic Territory.

For more information or to lodge an expression of interest phone Neville Exon on +61 2 6249 9347 or e-mail neville.exon@agso.gov.au

unexpectedly, bioclastic limestones forming mounds.

A drape of fine-grained pelagic sediments covered the mounds in the Palaeogene as a rain of calcareous microfossils formed oozes across the deepening submarine plateau. In the past few million years, the carbonate oozes have been replaced by silica-rich diatom oozes as the grip of ice intensified in neighbouring Antarctica.

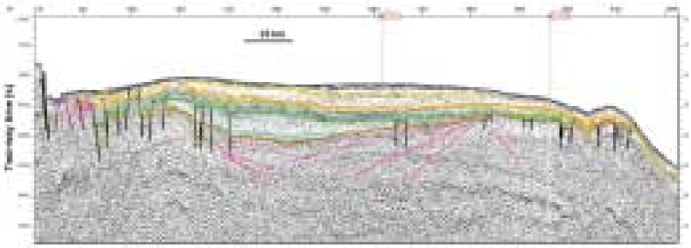


Figure 3. A typical seismic section through Raggatt Basin showing dipping sequences within basement (pink) and interpreted sedimentary sequences.

Origin

Due to its large size and remote location, the crustal structure of the plateau is poorly understood. ODP drilling revealed that the plateau is underlain mostly by magmatic crust generated in the Barremian–Cenomanian (119–95 Ma) by excessive volcanism attributed to a large hotspot. The plateau is often described in the literature as a Large Igneous Province (LIP).[3] Examples of LIPs include Iceland, Hawaiian Ridge and the Ontong–Java Plateaus.

The oceanic origin of the plateau has been recently challenged by ODP drilling results on the Elan Bank (figure 2; site 1137, leg 183[4]). Gneissic metamorphic and felsic igneous clasts recovered in volcanoclastic conglomerate deposited in a fluvial environment provide unambiguous evidence of its continental origin. This recent discovery, together with geochemical evidence pointing to the presence of continental lithosphere under the southern part of the plateau,[5,6] may indicate a more significant involvement of continental crust in the foundations of the plateau than was previously assumed.

High-resolution seismic data collected by AGSO shows considerable stucturing beneath the lava flows ('volcanic basement') on some lines. Poorly defined faulted blocks have been mapped beneath the 'volcanic basement' west of the 77 degree graben on line 179/07. This structuring is similar to that within basement east of site 1137 on the Elan Bank, which has proved to be continental. It seems likely that the plateau is floored by a combination of different crustal blocks, including continental fragments and magmatic crust.

Kerguelen Plateau basins

There are two major sedimentary basins on the plateau itself (figure 2): Kerguelen-Heard Basin in the north (mostly in the French Exclusive Economic Zone) and the Raggatt Basin in the south. A large, mostly unexplored deep-water basin, Labuan Basin, adjoins the eastern margin of the plateau.

The basins of the Kerguelen Plateau may be potentially prospective for petroleum.

There is sufficient thickness of sediment for hydrocarbon generation to have occurred, especially in the Labuan Basin. However, the thickest sedimentary accumulations tend to be in deep water, often in excess of four kilometres. The structural and stratigraphic complexity of the Kerguelen Plateau may host potential hydrocarbon traps within the extensive basin areas. There are some lines of evidence to indicate the existence of organic rich rocks, but reservoir quality remains a fundamental problem on a LIP.

Raggatt Basin

Raggatt Basin is located in the southern part of the plateau. The basin area is approximately 58 000 square kilometres, and contains at least 2000 metres of Cainozoic sediments and possibly up to 1000 metres of Mesozoic sediments. Seismic data show that the eastern flank of the basin is underlain by a north-west–south-east trending intra-basement igneous ridge that marks the eastern limit of the basin. It is characterised by prominent reflectors dipping away from the ridge axis (figure 3). These reflectors can be traced for up to 120 kilometres westwards beneath the Raggatt Basin, and the sequence is at least four to five kilometres thick. These dipping reflector sequences are likely to represent sub-aerial lava flows.

The western and northern boundaries of the basin are less clearly defined. It appears that the basin extends generally in the north-west–south-east direction to at least 56°S, being intersected almost in the middle by a 77-degree graben (figure 4).

In the southern Raggatt Basin, prominent mound features can be seen in the Late Cretaceous–

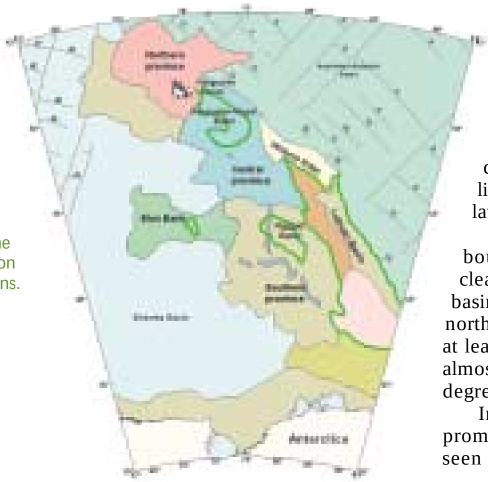


Figure 2. Tectonic provinces of the Kerguelen Plateau showing the location of the main sedimentary basins.

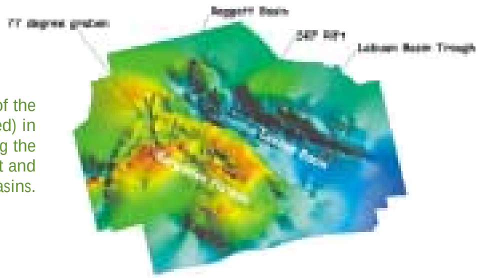


Figure 4. Perspective image of the basement (sediments removed) in the study area, revealing the structure of the Raggatt and Labuan basins.

Palaeocene section (the top green reflector in figure 3). ODP 748 intersected 246 metres of upper Campanian and Maastrichtian glauconitic coarse-grained biogenic carbonates, made up of bryozoan, inoceramids and other bioclastic grains. Watkins et al. interpreted these limestones as having been deposited in shallow water (<20 m), in a benthic bank complex.[2] The mounds are all within the same stratigraphic level, which is consistent with a biogenic rather than a volcanic origin. Seismic interpretation indicates that these mounds were growing until the Palaeocene.

The occurrence of a petroleum system or systems in the Raggatt Basin is possible but unproven. There appear to be potential source, reservoir and seal facies, and trapping mechanisms. Prospective areas occur in water depths of around two kilometres. The most viable play may be Cretaceous limestone reservoirs. These are in biogenic mounds sealed by the drape of Palaeogene fine-grained sediments, and sourced from mid-Cretaceous marine shales or Early Cretaceous terrestrial coaly sediments. Setting aside economic and engineering considerations, the major geological risk is the existence and maturity of any source facies.

Labuan Basin

The Labuan Basin flanks the eastern margin of the Kerguelen Plateau and is the largest sedimentary basin in the region. It is about 1000 kilometres long, 250 kilometres wide and contains three to five kilometres of sediment.

The nature of the crust underlying the Labuan Basin and the age of its sedimentary fill are very poorly constrained. Its basement has never been sampled. Most interpretations are based on current understanding of the regional plate tectonic history of the region and comparisons between it and the seismic sequences on the Kerguelen Plateau.[7] There is a remarkable similarity in the gravity signature between the Labuan Basin and its conjugate margin—the Diamantina Zone. Plate tectonic reconstructions of the southern ocean show that prior to the onset of Eocene fast spreading between Australia and Antarctica, the Labuan Basin reconstructs against the Diamantina Zone. Both features therefore are likely to have the same origin.

AGSO survey 180 was the first seismic survey to provide a regional coverage of high-quality seismic data in this basin. Interpretation of the new seismic data shows that structural style and sedimentary fill of the basin are extremely variable (figure 5). The Labuan Basin can be sub-divided into three distinctly different provinces.

The western part of the basin is highly faulted and is likely to represent extended and down-faulted Kerguelen Plateau crust, which may include continental fragments. Large basement ridges and deep troughs of the eastern part of the basin (figure 5) are very similar to the ridge/trough topography of the Diamantina Zone. Although none of these ridges has been sampled in the Labuan Basin, it seems likely that each will have a similar composition to the corresponding ridges in the Diamantina Zone, where sampling recovered basalts and peridotites. Peridotite exposure is often associated with extreme crustal thinning and unroofing of the mantle. The southern part of the Labuan Basin is underlain by the basement with a smooth seismic character that is largely unaffected by faulting. It may be floored by oceanic crust of Valanginian age formed during the early stages of separation between India, Australia and Antarctica.

There are no direct or indirect indicators of hydrocarbons known from the deep water (> 4 km) Labuan Basin. Its petroleum prospectivity is speculative. However, one positive indicator has been noted on seismic: a bottom-simulating reflector that may indicate the presence of gas hydrates. If present, the hydrates could be of biogenic, thermogenic or mixed origin. A likely possible source rock could be Late Cretaceous marine shales in the lower (pre-uplift) megasequence of Rotstein and others.[7] Basal and near-basal Late Cretaceous sandstones and younger turbidites provide possible reservoir facies. These potential reservoirs would be predominantly in the west of the basin, close to the Kerguelen Plateau proper.

Exploration drawbacks

The Kerguelen Plateau is located in deep and remote waters that experience severe weather conditions. And its location near Antarctica elicits fears that petroleum exploration could be a

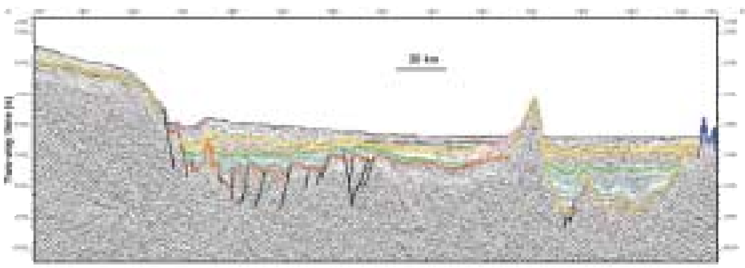


Figure 5. A typical seismic section through the Labuan Basin that demonstrates the difference in structural style between its western and eastern part.

risk to environmental values. For these reasons, as well as geological ones, the Kerguelen Plateau is ranked towards the bottom of any list of future hydrocarbon exploration targets around Australia. Despite this, the basins of the Kerguelen Plateau are important in unravelling the tectonic development of the Australian–Antarctic conjugate margin system.

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Prices SLASHED!

Information on North Queensland prospects is very affordable with a huge price reduction on two key publications produced jointly by AGSO and the Queensland Department of Mines and Energy.

- Bulletin 240/Geology 9: North Queensland Geology (1997), including a 1:1 million geology map of north Queensland, was $215.80, now $148.50
- Atlas of North Queensland Geology 1:3 million scale (1997) was $107.90, now $77.00

EVEN BETTER: BUY BOTH FOR JUST $165.00

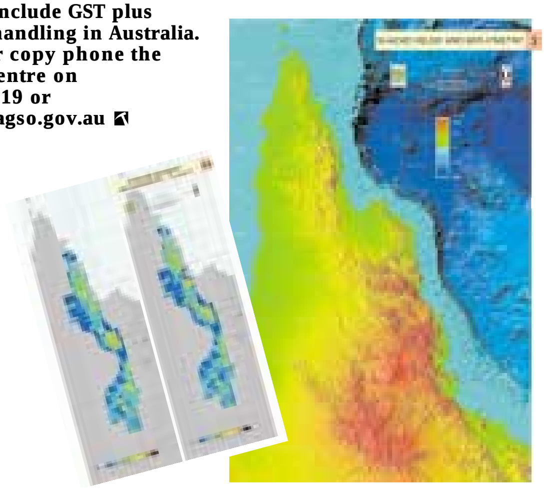
Bulletin 240/Geology 9 covers the northern half of Queensland east of 141°E and parts of the Gulf of Carpentaria and Coral Sea. The book is 612 pages with numerous summary tables and 64 pages of colour plates. The chapters provide:

- an overview of the geological and geophysical framework
- descriptions for nine regional geologies that make up the area
- discussion of the regolith of Cape York Peninsula
- consideration of applied isotope geochronology and geochemistry
- a review of relationships among the geological provinces and basins
- discussion of the mineral and energy deposit styles and potential resources
- a brief geological history.

The atlas comprises 45, A3-size full-colour plates and foldouts that cover the following themes:

- relief, climate, vegetation, culture and land categories
- geology (regions, basins, provinces, time slices)
- regolith, groundwater and surface geochemistry
- mineral deposits
- geophysical images.

Prices listed include GST plus postage and handling in Australia. To order your copy phone the AGSO Sales Centre on +61 2 6249 9519 or e-mail sales@agso.gov.au



PRODUCTnews

North West Shelf ALF surveys reinterpreted

Six ALF (airborne laser fluorosensor) surveys of the Bonaparte and Browse basins, northern Australia, have been reprocessed and re-interpreted and released as AGSO records. Using ALF Explorer software, it has become possible to compare surveys and optimise information about hydrocarbon seepage levels and patterns over several geological regimes including the Yampi Shelf, Vulcan Sub-basin and Nancar Trough.

ALF detection

Natural petroleum seepage is a direct indication of the generation and leakage of hydrocarbons from thermally mature basins and, in some cases, helps locate significant accumulations. ALF surveys detect and map hydrocarbon seepage occurring in the marine environment by inducing characteristic fluorescence in the resulting oil films that form on the sea surface. Such evidence of leakage can be used to identify oil migration pathways and accumulations. In frontier areas, the detection of hydrocarbon seepage can reduce exploration risk by indicating potential hydrocarbon provinces.

Interpretations released

The six ALF surveys flown on the North West Shelf are shown in figure 1. AGSO and World Geoscience Corporation (now Fugro Airborne Surveys) acquired these surveys in 1996 and 1998. The following reports by Robert Cowley document the latest interpretations of each survey.

- AGSO record 2000/28: 1996 Nancar Trough, Northern Bonaparte Basin Airborne Laser Fluorosensor survey interpretation report [WGC AC/P16 survey number 1248.3].
- AGSO record 2000/29: 1996 Laminaria High, Northern Bonaparte Basin Airborne Laser Fluorosensor survey interpretation report [WGC AC/P8 survey number 1248.2].
- AGSO record 2000/30: 1998 Yampi Shelf, Browse Basin Airborne Laser Fluorosensor survey interpretation report [WGC Yampi survey].
- AGSO Record 2000/31: 1996 Yampi Shelf, Browse Basin Airborne Laser Fluorosensor survey interpretation report [WGC Browse Basin survey number 1248.1].
- AGSO record 2000/32: 1996 Vulcan Sub-basin/Browse Basin Transition Airborne Laser Fluorosensor survey interpretation report [WGC Haydn survey number 2051].
- AGSO record 2000/33: 1996 Vulcan Sub-basin Airborne Laser Fluorosensor survey interpretation report [WGC Vulcan Graben Survey Number 1113].
- AGSO record 2000/27: Comparison of AGSO North West Shelf Airborne Laser Fluorosensor survey interpretations. This is an additional report that compares the relative abundance of fluorescence anomalies (fluors) and their spectral response from each survey.

The records (each includes a CD-ROM) can be purchased for $200 a copy from the AGSO Sales Centre by phoning +61 2 6249 9519 or e-mailing sales@agso.gov.au. For further information about the reports phone Dianne Edwards on +61 2 6249 9782 or e-mail dianne.edwards@agso.gov.au

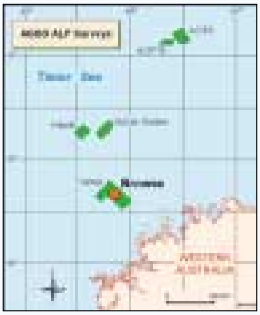
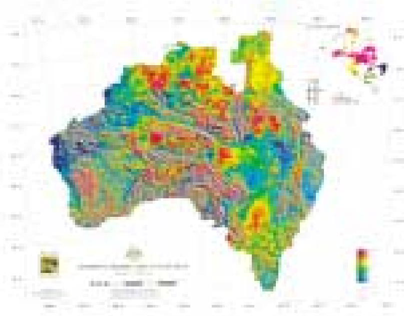


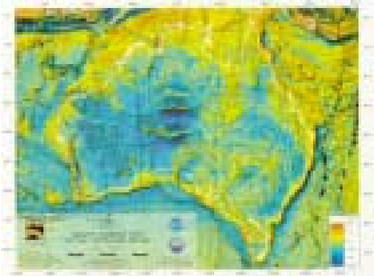
Figure 1. Location map for the AGSO ALF surveys

Special!

NATIONAL SCALE MAP SET



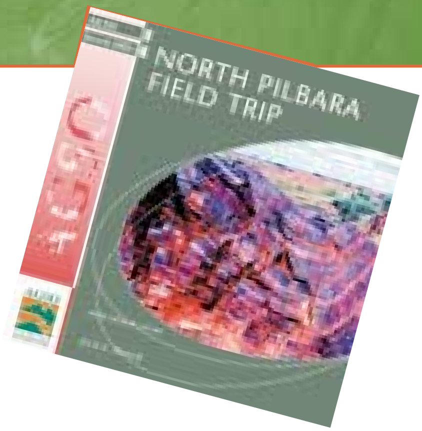
More than 35% off



Buy a set of Australian 1:5 million scale (A0 poster size) maps and save! Included in the set of four maps are geology, magnetic anomaly, gravity anomaly, and elevation. These colourful, informative maps normally retail for $123.60. But until June 30 the set is selling for just $79.20 (includes GST) plus $7.50 postage and handling. There are only 200 sets available at this special price, so don't delay your order.

Contact the AGSO Sales Centre on +61 2 6249 9519 or e-mail sales@agso.gov.au for your set.

Regional, *virtual* but specific products about North Pilbara *on offer*



A new look at tin and rare element pegmatites, a virtual field trip, and a regional synthesis in a convenient digital form are the latest products offered as the North Pilbara project completes its output.

Record 2000/44: *Characteristics of Sn-Ta-Be-Li-industrial mineral deposits of the Archaean Pilbara Craton, Western Australia*

Since 1889, tin, tantalum, beryllium and associated minor rare metals, together with non-metallic industrial minerals (feldspar and mica) have been produced sporadically from pegmatite orebodies, related hydrothermal veins and secondary alluvial/eluvial deposits. Production from the Pilbara Craton, Western Australia, has been significant for a number of these commodities.

Record 2000/44 is a comprehensive report (58 pages including figures) documenting these deposits, as well as the world class Wodgina Sn-Ta deposit which is in current production.

The record updates Blockley's work on the tin deposits of Western Australia, and re-interprets the geological and mineralogical characteristics of the rare element pegmatites (given recent advances in their understanding). Most attention is given to the geological characteristics of the pegmatite deposits of tin-tantalum-beryllium-lithium-industrial mineral deposits, because of their economic significance and exploration interest. Associated vein deposits, alluvial and eluvial deposits are also discussed in detail separately.

Record 2000/45: *North Pilbara 'virtual' field trip*

Record 2000/45 on CD-ROM reports the results of specialist structural geological studies in the North Pilbara from 1997–2000. It provides, for the first time, a comprehensive synthesis of the structural evolution of the resource-rich region.

Traditionally, the science of structural geology is presented in a one-dimensional printed text format with accompanying maps, drawings and images cross-referenced in the text. This approach is problematic because structural geology is four dimensional (three spatial dimensions and time). To overcome this problem, the report is structured so that new information can be accessed in three ways:

1. in the 'standard' way where the text is arranged chronologically and the user skips to sections of interest by embedded hyperlinks;
2. by geographical regions on a map with hyperlinked text explanations, maps and images; and
3. via a time-based break up of the text (by structural events, e.g. D1, D2, etc.) so the same event can be compared across regions.

More than 200 scanned photographs are located spatially on active maps so the user can see the geology described in their correct spatial position and in relation to other areas. This provides a 'virtual' field trip for users, who can decide where they want to go in the report.

The report can be viewed with a standard web browser. A printable version is available on the CD-ROM.

AGSO records 2000/44 and 2000/45 cost $35 each (includes GST) plus postage and handling.

North Pilbara geographical information system (GIS)

The North Pilbara GIS packages AGSO's primary data holdings for the entire region into a convenient digital form that can be manipulated and integrated with proprietary data in standard mapping applications. It provides different views of the same area, allowing correlation, comparison and analysis at a broad scale.

The GIS provides many new digital data sets, including variations of the magnetics, gravity and gamma-ray spectrometry. It complements the 1:1.5 million scale colour atlas released mid-2000. New aspects of the GIS include:

- the under-cover shape of prospective rocks with a new digital solid geology map;
- all the images generated by the project (magnetics, gravity, Landsat and radiometrics);
- the imaging of several large shear zones, and complexity in granites;
- a compilation of geochemistry and geochronology;
- a new chemical map based on radiometrics; and
- the identification of the source regions of transported regolith.

Access to the GIS will be invaluable to exploration companies considering North Pilbara prospects. Industry commonly has restricted data holdings over leases. The regional synthesis data sets in the North Pilbara GIS will provide a context and framework for exploration decisions.

The GIS costs $4000 (includes GST) plus postage and handling. It comprises two CDs that contain ArcInfo export files, ArcView project, and MapInfo workspace.

To order copies of the North Pilbara products phone the AGSO Sales Centre on +61 2 6249 9519 or e-mail sales@agso.gov.au

Web site upgrade speeds access to resource data

The most visited part of AGSO's web site has been substantially upgraded. The National Datasets Online GIS (geographic information system) generates more than 3000 maps a week for web visitors. It is the most comprehensive visualisation tool for generating Australian geoscience maps on the internet.

Features

The new web site features more than 70 different spatial geoscience datasets and provides snapshots of Australia's onshore and offshore mineral and petroleum resources and their geological and geophysical contexts. Themes include national scale geophysical images—such as aeromagnetics, gravity and crustal heat flow—which can be overlain with data drawn directly from AGSO's national databases (including those for earthquakes, geochemistry and geochronology).

Users can create tailor-made maps by selecting and combining themes from a large range of geoscience elements. They have the option of zooming to geological regions, mines and towns, in addition to general pan, zoom and query capabilities.

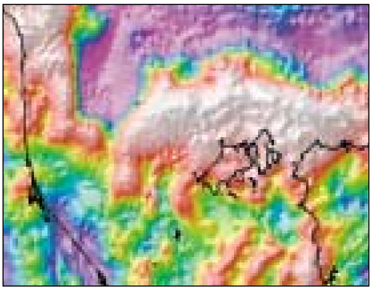
Faster access

Newly combined with the online GIS, the 'Latest national geoscience datasets' facility allows users to quickly and conveniently download available datasets from AGSO's web site (many at no charge) and obtain free to print images. The result is a substantially better service for those wanting to create their own geoscience maps or look for information online.

The major impact of the upgrade is improved access to spatial geoscience relevant to resource issues. The web site will interest resource companies, emergency managers, land managers, and the education sector.

For further information phone Bruce Kilgour on +61 2 6249 9610 or e-mail bruce.kilgour@agso.gov.au; web page www.agso.gov.au/geoscience/national/

GRIDS OF EASTERN AUSTRALIAN MARGIN COMPLETE THE PICTURE



Digital bathymetry, gravity and magnetic grids for Australia's continental margin east of 140°E are being released by AGSO. The grids, with resolutions of 250–1000 metres, are a major upgrade of marine ship-track potential field and bathymetry data in Australian waters.

Data from many sources have been integrated, requiring levelling techniques to correct crossover and other errors. Ship-track data (see figure 1) have been merged with satellite and high-resolution onshore sources. Pre-existing compilations have been superseded by the addition of:

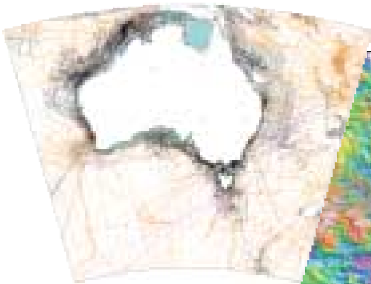
- bathymetric data on the shelf digitised from Australian Hydrographic Service charts;
- bathymetric data from swath surveys in deep water by AGSO, Scripps Institute of Oceanography and Woods Hole Oceanographic Institute; and
- shiptrack bathymetry from numerous exploration surveys obtained under the Petroleum Submerged Lands Act.

Grids covering the north-west and south-west parts of the continent west of 140°E were released in 1999 and 2000 (refer to: http://www.agso.gov.au/front/data_release.html). To complete the coverage of the Australian margin east of 140°E, grids of the eastern and south-eastern regions should be released in April/May 2001. (See figures 2 and 3 for examples.)

The grids will be used in AGSO's regional-scale interpretation projects for modelling crustal structure and defining province boundaries, and for developing a better understanding of seafloor environmental processes. The data will be particularly useful for petroleum exploration and engineering activities.

The grids were produced by AGSO, in cooperation with Desmond Fitzgerald and Associates and the Australian Hydrographic Service.

For further information phone Peter Petkovic on +61 2 6249 9278 or e-mail peter.petkovic@agso.gov.au



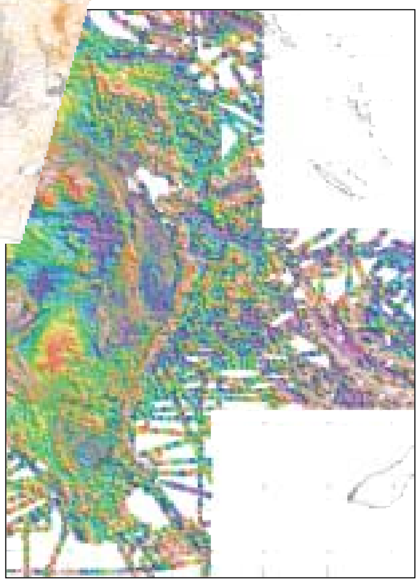


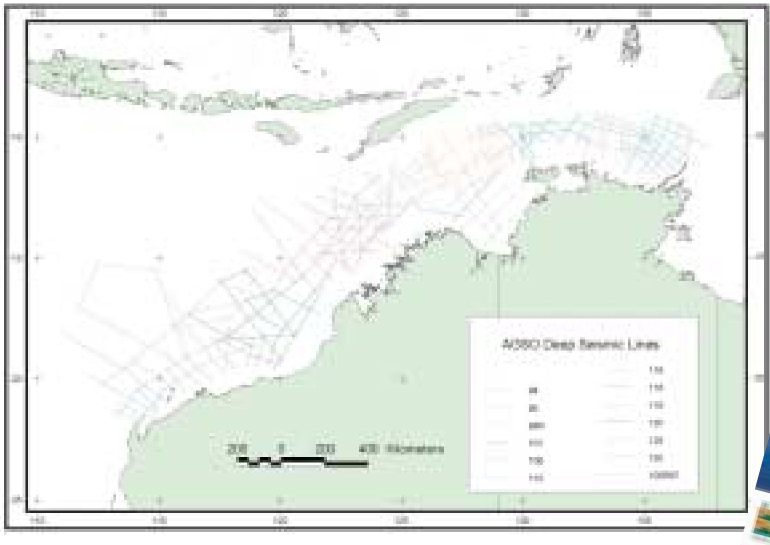
Figure 1 (above). Data included in bathymetry, gravity and magnetic grids around Australia, and basin boundaries. The black lines are from the AGSO database.

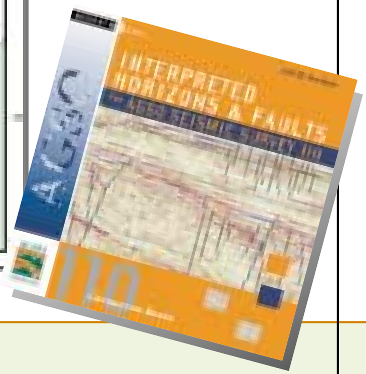
Figure 2 (top right). Gravity field over Bass Strait

Figure 3 (right). Magnetic anomaly map for eastern and south-eastern Australia, combining levelled ship-track data and the AGSO magnetic anomaly map of Australia.

BASIN ARCHITECTURE CDS

exploration tool for northern Australian margin





As an aid to oil and gas exploration off northern and north-western Australia, AGSO's Petroleum and Marine Division has released 13 CDs that give an overview of the region's structural architecture and basin fill.

The CDs contain interpreted horizon and fault data for approximately 35 000 kilometres of regional, mostly deep (commonly 15+ seconds two-way time), seismic reflection data. The data was acquired by AGSO between 1990 and 1994 over Australia's continental margin from North West Cape to the Arafura Sea (see map).

The deep-seismic data commonly image features and structures that are deeper than conventional industry seismic data and thus provide a valuable insight into the region's geological evolution. In many places, the deep structures influence the development of younger, shallower features that may be prospective for hydrocarbons.

The seismic data are interpreted on the following 13 CDs (one survey per CD):

- survey 94 Arafura Basin (AGSOCAT 35232),
- survey 95 Carnarvon & Roebuck basins (AGSOCAT 35234),
- survey 98 Vulcan Sub-basin (AGSOCAT 35237),
- survey 100 Petrel Sub-basin (AGSOCAT 35239),
- survey 101 Carnarvon Basin (AGSOCAT 35240),
- survey 106 Arafura Basin (AGSOCAT 35241),
- survey 110 Carnarvon Basin (AGSOCAT 35242),
- survey 116 Bonaparte Basin (AGSOCAT 35249),
- survey 118 Money Shoal & Bonaparte basins (AGSOCAT 35243),
- survey 119 Browse Basin (AGSOCAT 35244),
- survey 120 Roebuck & offshore Canning basins (AGSOCAT 35245),
- survey 128 outer Carnarvon, Roebuck & Browse basins (AGSOCAT 35247), and
- survey 130 Browse Basin (AGSOCAT 35248).

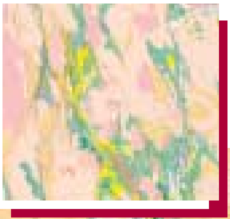
Seismic trace data are not included, but can be purchased from Perth-based TGS-Nopec (phone +61 8 9480 0000). The interpreted data on the CDs are in ASCII format for use with standard seismic mapping and interpretation packages.

Horizons that are consistently interpreted through the grid include: water bottom, late Miocene and base Miocene, mid-Oligocene, base Eocene, base Tertiary, Turonian, Aptian, Valanginian, base Cretaceous, Callovian, base Jurassic/top Triassic, mid-Triassic, near-top Permian, late Carboniferous, and 'basement'.

Additional horizons have also been interpreted as appropriate through parts of the grid—for example, mid-Carboniferous (late Visean), intra-Devonian and mid- to late Cambrian in the Arafura Basin; and mid-Carboniferous (late Visean) and early Carboniferous (late Tournaisian) in the Petrel Sub-basin.

For further information about the CDs phone Jim Colwell on +61 2 6249 9346 or e-mail jim.colwell@agso.gov.au. Copies can be bought from the AGSO Sales Centre by phoning +61 2 6249 9519 or e-mailing sales@agso.gov.au

New solid geology map increases depth of Yilgarn products



More than 80 per cent of the eastern Yilgarn Craton is either deeply weathered or covered by transported materials of various depths, commonly several tens of metres thick. To reveal the bedrock geology of the eastern Yilgarn, a new 1:500 000 solid geology map has been produced. It incorporates outcrop geology, with interpretation of 400-metre line spacing aeromagnetic data that has been supplemented, in some areas, with interpretation of detailed aeromagnetic and geological data from the minerals industry.

The map shows the greenstone belt distribution, the main greenstone lithologies within those belts, and a 'limited' granitoid subdivision. It also shows major folds, faults and shear zones that probably affected fluid migration and the distribution of hydrothermal gold deposits.

Rock types

Mafic and ultramafic rocks are the dominant greenstone rock types. For mafic rocks, mapped units include undivided greenstones, metabasalt, high-Mg metabasalt, greenstones of intermediate composition, greenstones interleaved with granitic rocks, metadolerite and metagabbro. Ultramafic rocks are abundant in the Agnew–Wiluna greenstone belt, in the areas north of Mt Clifford, around Murrin Murrin, in the western and southern parts of the Duketon greenstone belt, and in the areas north-east and east of Yundamindra and east of Sunrise Dam in the Laverton greenstone belt.

Felsic volcanic/volcaniclastic rocks are a major component in the Yandal greenstone belt, as well as the Melita, Mertondale, Welcome Well and Edjudina areas. Metasedimentary rocks (clastic and banded iron formation) are abundant in the Duketon and Laverton greenstone belts. The Jones Creek and Yilgangi conglomerates are the youngest sequences in greenstone belts. Sandstones in the Jones Creek Conglomerate have sourced granite 2667±6 Ma old. Although stratigraphic sequences have been proposed for parts of the map area (e.g., Leonora–Laverton, Wiluna and northern Yandal), regional greenstone stratigraphy and correlations are yet to be established.

Mineral abundance

The region hosts numerous mineral deposits, particularly nickel and gold. Many nickel deposits have been discovered in areas of abundant ultramafic rocks. For example, the Agnew–Wiluna greenstone belt hosts several major magmatic sulphide nickel deposits at Honeymoon Well, Mount Keith, Yakabindie, Cosmos, Perseverance and Rocky's Reward. Nickel deposits are also found in the north-western (around Windarra) and the western (Pyke Hill) parts of the Laverton greenstone belt. A large laterite nickel deposit occurs at Murrin Murrin in the greenstone belt. Ultramafic rocks are a minor component of the Yandal, Malcom and southern Laverton greenstone belts. Nickel prospectivity is probably low in these areas.

Several world class gold deposits (>100 t) occur in the north-eastern Yilgarn Craton, including Wiluna, Jundee–Nimary, Bronzewing, Tarmoola, Sons of Gwalia, Wallaby and Sunrise Dam/Cleo. Seven of these deposits were discovered in recent years, making the region (in particular, the Yandal and Laverton greenstone belts) currently among the most productive areas for gold in Australia.

Other products

Over the past decade the northern part of the highly mineralised late-Archean (2760–2635 Ma) granitoid-greenstone terrain of the eastern Yilgarn has been mapped in detail by AGSO and the Western Australian Survey. This has resulted in a series of 1:100 000 and 1:250 000 outcrop geology maps.

The solid geology map is a valuable addition to these earlier maps for anyone involved in resource evaluation, target generation and planning exploration programs in the north-eastern Yilgarn. As well, for those interested in the area, there are two derivative products to watch out for in coming months.

One is a structural map at 1:500 000 scale showing mineral deposit distribution. The second is a 1:1 million scale two-panel map comprising a simplified solid geology map and a composite image of Bouguer gravity (in colour) draped on the greyscale first vertical derivative of total magnetic intensity.

For more details phone Songfa Liu on +61 2 6249 9522 or e-mail songfa.liu@agso.gov.au. Phone the AGSO Sales Centre on +61 2 6249 9519 or e-mail sales@agso.gov.au to purchase a copy.