Australian Government

Geoscience Australia

ENERGY SECURITY PROGRAM

ACHIEVEMENTS

Towards Future Energy Discovery

DEPARTMENT OF RESOURCES, ENERGY AND TOURISM
Minister for Resources and Energy: The Hon. Martin Ferguson, AM MP
Secretary: Mr Drew Clarke PSM

GEOSCIENCE AUSTRALIA
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GEOSCIENCE AUSTRALIA

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ACKNOWLEDGEMENTS

The Energy Security Program involved many individuals and project teams in Geoscience Australia's Petroleum and Marine Division and Onshore Energy and Minerals Division. Above all, their collective contributions are acknowledged and thanks are extended here.

Organisations that collaborated in the Energy Security Program are acknowledged in parts of the text and contractors and partnerships are listed at the end of the report. Without their collaboration and support it would not have been possible to deliver the program.

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FOREWORD

Martin Ferguson AM MP

Minister for Resources & Energy

The work of Geoscience Australia in providing world class pre-competitive geoscience information plays a vital role in ensuring the future of Australia's energy resource developments. The significant value of this work to Australia's economy was recognised earlier this year in a government review conducted by the Department of Finance and Deregulation.

This publication, along with the Australian Energy Resource Assessment released in March 2010, are strategically important, science-based inputs to government policy. I commend the high standard of Geoscience Australia's work and look forward to its continuing input to Australia's energy future.

Toward Future Energy Discovery is the culmination of five years of offshore and onshore data acquisition and regional studies to encourage further exploration for energy resources. In this catalogue of achievements, Geoscience Australia not only summarises the work completed under its Energy Security Program, but also identifies new opportunities and potential for energy and mineral discovery in under-explored regions.

The data and results from the Energy Security Program are yielding dividends already, and stimulating investment in the exploration for energy and mineral resources with:

- expenditure of more than $600 million offshore in the first 3-year term of permits and additional onshore exploration expenditure estimated to be in excess of $300 million;
- discovery of a world-class source rock in the Bight Basin, which has led to the largest work program bid ever received for frontier basin exploration in Australia;
- large tenement packages taken up by companies seeking to explore for energy commodities in southern and northern parts of Australia;
- discovery of the Millungera Basin in north Queensland, which has potential for petroleum, geothermal and other resources;
- data and new knowledge in the Mentelle, North Perth, Southern Carnarvon and offshore Canning basins resulting in large frontier acreage blocks being offered to the petroleum exploration industry;
- release of deep crustal data and interpretations stimulating interest and leading to development of new models and conceptual frameworks by industry for energy exploration;
- initial assessments of the hydrocarbon prospectivity of the deepwater Otway, Sorell, Capel and Faust basins completed in preparation for future acreage release;
- the Radiometric Map of Australia, the first for an entire continent, being used widely by energy and mineral explorers;
- establishment of a technical capability in geothermal energy in support of the Government's Clean Energy Initiative.

The policy framework relevant to energy security has continued to change rapidly over the past five years. We remain committed to achieving energy security for ourselves from primary and renewable energy sources and contributing to the energy security of our trading partners.

CONTENTS

ACKNOWLEDGEMENTS ii
FOREWORD iii
CONTENTS v
EXECUTIVE SUMMARY vii
INTRODUCTION ix

OFFSHORE

REGIONAL SURVEYS

Capel and Faust Basins Marine Reconnaissance Survey 3
Bass, Otway and Sorell Aeromagnetic Survey 5
Southwest Margin Marine 2D Geophysical Survey 7
Southwest Margin Marine Reconnaissance Survey 9
Offshore Canning Basin Aeromagnetic Survey 11
Reprocessing and Analysis of 2D Marine Seismic Data 13

REGIONAL PROSPECTIVITY ASSESSMENTS

Capel and Faust Basins Prospectivity Assessment 15
Deepwater Otway and Sorell Basins Prospectivity Assessment 17
Bight Basin Prospectivity Assessment 19
Mentelle Basin Prospectivity Assessment 21
Vlaming Sub-Basin Prospectivity Assessment 23
Offshore North Perth Basin Prospectivity Assessment 25
Southern Carnarvon Basin Prospectivity Assessment 27
Wallaby Plateau Prospectivity Assessment 29
Offshore Canning Basin Prospectivity Assessment 31
Joseph Bonaparte Gulf Seabed Environment Study 33

INFORMATION MANAGEMENT

Timescales Project 35
Robotic Storage and Delivery of Seismic Data 37
Petroleum Databases and Information Management 39

ONSHORE

NATIONAL SURVEYS

Radiometric and Magnetic Maps of Australia 43
Gravity Map of Australia 45
National Geochemical Survey of Australia 47

REGIONAL SURVEYS

Deep Crustal Seismic and Magnetotellurics 49
Airborne Electromagnetics 51
Geothermal Energy—Heat Flow 53

REGIONAL ASSESSMENTS

Mount Isa–Georgetown–Charters Towers (Queensland) 55
Gawler–Curnamona–Arrowie (South Australia) 57
Gawler–Officer–Musgrave–Amadeus (South Australia–Northern Territory) 59
Georgina–Arunta (Northern Territory) 61
Paterson (Western Australia) 63
Pine Creek (Northern Territory) 65
Frome (South Australia) 67

COMMODITY STUDIES

Onshore Petroleum 69
Uranium and Thorium 71
Geothermal 73

PUBLICATIONS 75
Offshore 75
Onshore 84

CONTRACTORS, PARTNERSHIPS AND WORKSHOPS 99

EXECUTIVE SUMMARY

Under a five-year Energy Security Program, established to attract investment in offshore and onshore energy exploration, Geoscience Australia engaged widely with the State and Northern Territory governments, industry and other stakeholders to select frontier regions for pre-competitive data acquisition and investigation.

The offshore program targeted frontier basins with a long term objective aimed at attempting to locate a new hydrocarbon province for Australia. The program focused on the southern and southwest continental margin off Western Australia in the Mentelle, Vlaming, Perth, Southern Carnarvon, Canning and North Perth basins and the Wallaby Plateau.

Off eastern Australia, the focus was on the remote Capel and Faust basins and the Bass, deepwater Otway and Sorell basins west of Tasmania and south of Victoria.

In addition to basin analysis and prospectivity assessment work, extensive seabed mapping was undertaken along the southern continental margin and the remote eastern parts of Australia's marine jurisdiction, in support of resource management.

As a result of the Offshore Energy Security Program, exploration companies have guaranteed expenditure of more than $600 million in the first three-year term of granted permits. In addition, indicative expenditure approaching $1 billion has been proposed during the second three-year permit period.

The focus of the onshore program was to provide a national synthesis of and stimulate exploration for energy resources, including non renewable resources such as hydrocarbons, uranium and thorium and renewable geothermal energy sources. The Onshore Energy Security Program was carried out under the National Geoscience Agreement between the Australian, State and Northern Territory governments. Australia-wide activities involved acquisition and processing of airborne radiometric and magnetics data and collecting more than 1300 geochemical samples. Regionally, deep seismic and airborne electromagnetic surveys were undertaken in most States and the Northern Territory.

In addition to delivering an extensive suite of new precompetitive geoscience information, the onshore program produced the first national radiometric map of a continent, discovered a new sedimentary basin in north Queensland with the potential to host energy resources, and delivered a number of regional assessment studies and syntheses, which identified favourable areas for uranium, geothermal and mineral exploration.

Data and results from the Onshore Energy Security Program have stimulated tenement take-up, design of drilling programs and led to the discovery of mineralisation as well as the development of new models and frameworks for energy exploration. The use of data and products released by Geoscience Australia during the onshore program is estimated to have resulted in additional exploration expenditure by industry in excess of $300 million.

INTRODUCTION

In economic terms, the resources sector makes a substantial contribution to gross domestic product, export earnings, employment, exploration expenditure and capital expenditure on new projects, including infrastructure as well as government revenue through royalties and taxation. The export performance of the mining and energy resource sectors is critical for the long term maintenance of Australia's current account position and the strength of the economy. In this context, the government has an interest in ensuring the continued viability and health of the mining and energy resource sectors.

The provision of pre-competitive geoscience information is fundamental to attracting the exploration investment needed to ensure the discovery and development of the next generation of mineral and energy resources. Pre-competitive information is used by government to identify areas suitable for exploration by industry and to promote the offshore and onshore exploration potential of Australian basins and provinces.

Comprehensive pre-competitive data are directly comparable to the supporting data provided in a prospectus for the sale of an asset.

While known oil reserves are declining, much of Australia remains under-explored and large areas of remote frontier provinces are essentially unexplored. Current exploration is largely in previously investigated areas, or 'brownfields' rather than in the higher risk 'greenfields', where exploration is aimed at identifying new energy resource provinces.

To address this situation the Australian Government in 2006 expanded Geoscience Australia's program of seismic acquisition, data enhancement and client access through the commitment of almost $134 million over five years to its Energy Security Initiative. A total of $75 million was allocated to focus on new frontier offshore areas and $58.9 million was appropriated to identify potential onshore energy resources such as petroleum, uranium and geothermal. The objective of the initiative has been to provide pre-competitive information to encourage exploration in greenfields by improving the chances of discovery and reducing risk to investors.

This report provides an overview of the Energy Security Initiative achievements on completion of the program in mid-2011. Although data, products and assessments have been released progressively, the report is the first unified compilation of the activities undertaken during the course of the program. The report is designed to inform stakeholders of new opportunities and key products embodied in a range of datasets, regional studies, assessments, maps and publications, most of which can be accessed online.

OFFSHORE ENERGY SECURITY PROGRAM

The objective of the program was to address the challenge of finding a new hydrocarbon province with similar impact on the nation's petroleum inventory as the Gippsland Basin discoveries achieved in the 1960s. The vast under-explored offshore sedimentary basins on Australia's continental margin, broadly ranked, and internationally regarded as prospective frontier regions, hold significant promise for further similar opportunities.

Australia remains relatively under-explored for conventional oil and gas deposits, with less than 10 200 wells on and offshore. Australia's offshore jurisdiction covers 13.5 million square kilometres, including 2.56 million square kilometres of extended continental shelf confirmed by the United Nations Commission on the Limits of the Continental Shelf in April 2008. There are about 40 offshore sedimentary basins which range from mature areas producing hydrocarbons to remote frontiers which have never been drilled but may have hydrocarbon potential.

Frontier regions of prime interest were selected in consultation with petroleum exploration companies and the Australian Petroleum Production and Exploration Association. Projects to investigate these regions under the program were developed and implemented at a rapid pace building on outcomes of the New Petroleum Program (2003–2007). In addition to standard petroleum basin analysis of hydrocarbon source rocks, reservoir, seal and trap, seabed mapping within the frontier areas was undertaken. Marine reconnaissance surveys included bathymetric and video imaging of the seafloor, sediment sampling for geological and ecological analysis and sampling of the benthic flora and fauna.

About 10 000 line kilometres of industry-standard 2D seismic data were acquired along the southern and south-western continental margin. These new data sets cover parts of the under-explored Bremer, Mentelle, Vlaming, Perth and Southern Carnarvon basins and the Wallaby Plateau (Fig. 1). More than 11,000 line kilometres of older, open-file seismic data from the North Perth Basin were reprocessed to consistent, modern standards and released in 2010. In the Capel and Faust basins, a remote frontier region off the east Australian coast, an additional 6000 line kilometres of 2D seismic data were acquired and processed prior to release. To facilitate access to these data sets, Geoscience Australia loaded more than 500 Terabytes of quality controlled seismic data into a newly commissioned Robotic Data Store which was purchased with Energy Security Initiative funds.

In addition to the seismic data, about 200 000 line kilometres of new aeromagnetic data covering extensive areas of the offshore Canning, Bass, deepwater Otway and Sorell basins, were acquired to assist in the assessment of the geology and petroleum potential of these areas prior to the release of exploration acreage.

To complement the seismic imaging of the sub-surface geology, more than 250 000 square kilometres of the seabed (an area about the size of Victoria), along the southwest continental margin and the remote eastern parts of Australia's marine jurisdiction, was mapped using a variety of techniques, including multi-beam sonar, sub-bottom profiling, magnetics, gravity, video imaging and still photography. Geological and biological samples also were collected by dredge. In addition to assisting in exploration, this seabed mapping will underpin regional marine planning.

During the program, exploration acreage in frontier areas was released progressively as the assessment of each area's petroleum prospectivity was completed. Specifically, acreage was released in the Arafura Basin (2006), offshore Canning Basin (2007), Vlaming Basin (2008), Bight Basin (2009), Mentelle and Duntroon basins (2010), culminating in the release of three large frontier blocks in the North Perth and southern Carnarvon basins in 2011. Data and knowledge from the program will underpin future releases of additional acreage in the Otway, Sorell, Bight, Perth, and Capel and Faust basins.

As a result of the Offshore Energy Security Program, exploration companies have guaranteed expenditure of more than $600 million in the first three-year term of the permits granted. The companies also have proposed additional expenditure of close to $1 billion during the second, three-year permit period. The program underpinned frontier petroleum acreage releases from 2007 to 2011 and will continue to do so in future years.

ONSHORE ENERGY SECURITY PROGRAM

The Onshore Energy Security Program was carried out under the National Geoscience Agreement between the Australian, State and Northern Territory governments. This involved a high degree of consultation between Geoscience Australia and the State and Northern Territory geological surveys, industry and other stakeholders.

The focus of the onshore program was to provide a national synthesis of and stimulate exploration for energy resources, including non renewable resources such as hydrocarbons, uranium and thorium and renewable geothermal energy sources.

At a national level, the program acquired and processed 145 000 kilometres of airborne radiometric (gamma-ray spectrometric) and magnetics data, 6500 line kilometres of deep seismic crustal data, 215 000 kilometres of airborne electromagnetic data and collected and processed more than 1300 geochemical samples. The expanded and enhanced datasets provide an increased understanding of Australia's geology, structure, geochemistry and geomorphology.

The benefits of the radiometric and magnetics datasets are many. Broadly, they will help to identify favourable areas for energy, geothermal and mineral resources, and aid in the mitigation of geological hazards.

The seismic acquisition program provided a whole-of-crust, structural understanding of regions with enhanced potential for petroleum, natural gas and other energy sources and for mineral resources. The program targeted basins with perceived petroleum and natural gas potential where seismic data and interpretations were required to encourage exploration. In other regions it was used to investigate provinces considered to have potential for uranium and/or high heat producing granites as possible sources of geothermal energy. A striking success from the seismic work was the discovery of the Millungera Basin, a previously unknown sedimentary basin which may be prospective for petroleum. In addition, several granites are interpreted to occur immediately below the Millungera Basin which suggests potential for geothermal energy systems.

Airborne electromagnetic data were acquired in areas considered prospective for uranium and other energy sources, and will assist with exploration for other minerals and resources including groundwater.

Regional energy and mineral assessment studies and syntheses were completed in areas where seismic and airborne electromagnetic data were acquired. These areas are shown in Figure 1. Activities with a specific energy focus were undertaken for petroleum, geothermal, uranium and thorium and are reported under these headings. These include miscellaneous activities, such as funding the reprocessing of existing open-file seismic data to encourage hydrocarbon exploration of onshore areas in the Otway Basin.

Although the financial impact of the Onshore Energy Security Program is difficult to quantify at this time, energy and mineral exploration companies commented favourably during the program on the importance and value of data and products released by Geoscience Australia. Exploration companies acknowledged the program's influence on their acquisition of tenement and on the design of drilling programs. In one example, a company linked regional geophysical data obtained under the program to successful drilling results. The program's results also led to the development of new models and frameworks for energy exploration. From feedback, the use of data and products released by Geoscience Australia during the program is estimated to have resulted in additional exploration expenditure by industry in excess of $300 million.

ENERGY SECURITY PROGRAM: REGIONAL SURVEYS AND ASSESSMENTS

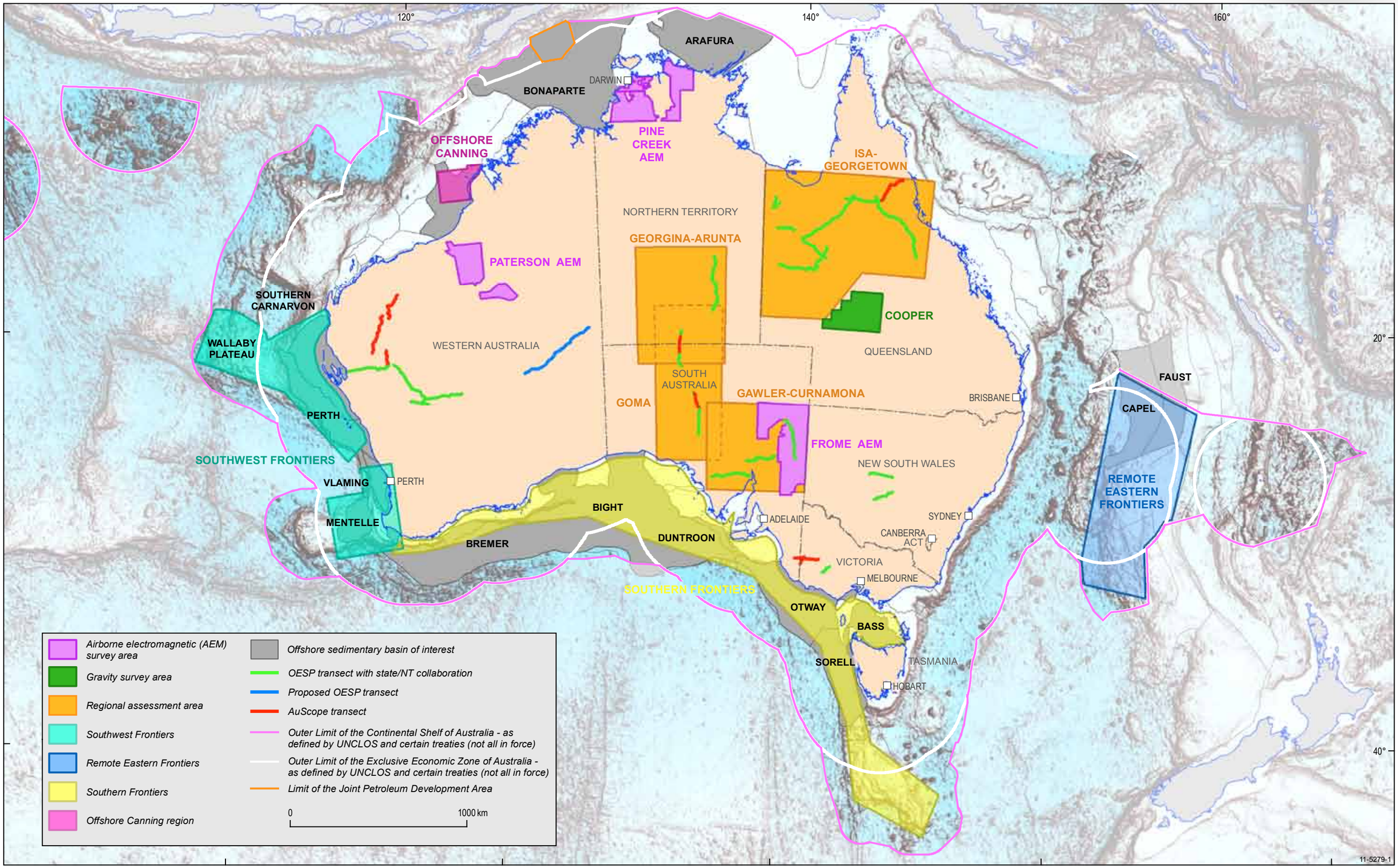


Figure 1

OFFSHORE

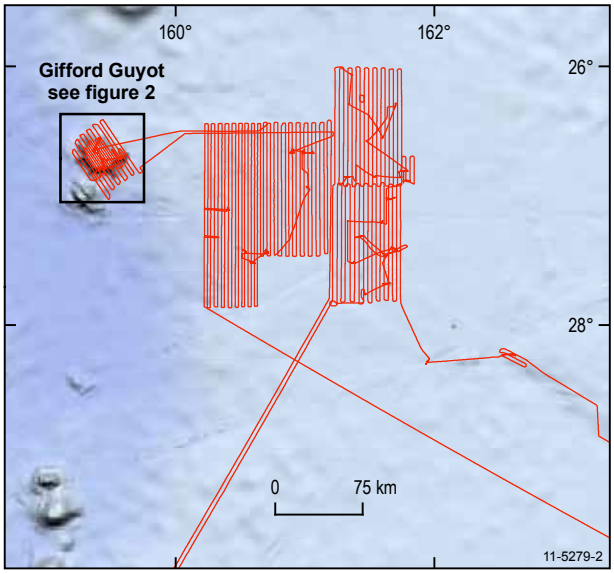
Regional Surveys

Regional Prospectivity Assessments

Information Management

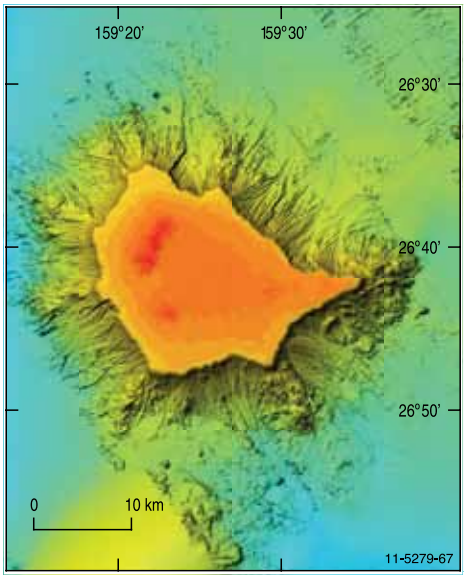
OFFSHORE *Regional Surveys*

1



GA-2436 Tangaroa survey (2007)

2



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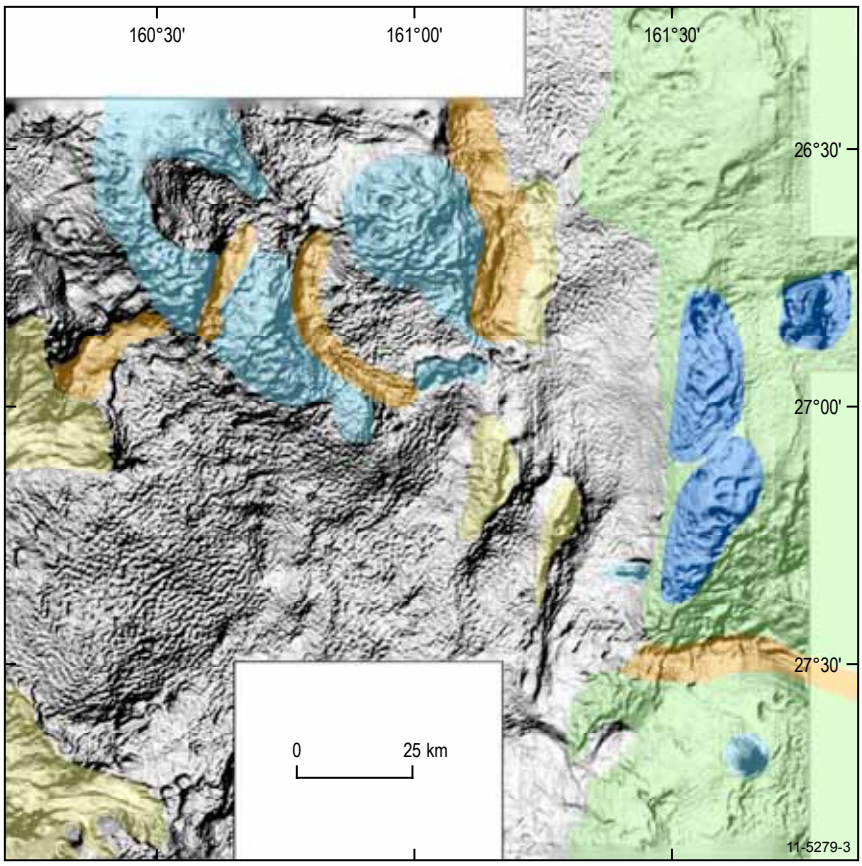


Bathymetric Provinces

- *Pliocene Volcanism Complex*
- *Forced fold*
- *Eastern Plateau*
- *Scarp and slope failure*
- *Polyforms zone*
- *Valley*

1: Location of marine reconnaissance survey lines over the Capel and Faust basins, and the Gifford Guyot.

2: High resolution multibeam bathymetry image of the flat-topped Gifford Guyot.

3: Detailed bathymetry of the seafloor of the Capel and Faust basins relates closely to the nature of the underlying geological strata and structure.

CAPEL & FAUST BASINS MARINE RECONNAISSANCE SURVEY

The 47 day Survey conducted during October and November 2007, using the New Zealand marine research vessel *RV Tangaroa,* was designed to further assess the petroleum prospectivity and seabed environment of this remote eastern frontier. Data acquisition targeted the deepest parts of the Capel and Faust basins. The areas had been indentified from previous surveys completed under the Australian Government's New Petroleum Program, in an initial petroleum prospectivity assessment of these unexplored frontier basins. In addition, multi-beam bathymetry data, seabed samples and camera footage were acquired over the basins and Gifford Guyot, as part of a program to systematically map Australian marine benthic environments.

In total, 16 081 line kilometres of multi-beam bathymetry was acquired over 39 870 square kilometres, as well as 14 145 line kilometres of gravity, 13 843 line kilometres of magnetic and 3280 line kilometres of sub-bottom profiler data. The survey also acquired seabed samples and video footage at 46 sites. The bathymetry, gravity and magnetic data have been levelled and merged with pre-existing data to improve the regional data coverage. All data sets are available to interested parties at the cost of transfer.

The data sets have underpinned the prospectivity assessment of the Capel and Faust basins by supplementing seismic, gravity, magnetic and seafloor sampling data previously acquired under the New Petroleum Program. The improved knowledge of the basin architecture has allowed an assessment of the hydrocarbon generation, migration and accumulation potential of the basins and identification of risks for potential hydrocarbon exploration. Seabed mapping data will inform decisions regarding the management and use of offshore natural resources in the region. The data sets will also guide identification of targets in the event of future data acquisition or petroleum/natural resource exploration in the region.

ACHIEVEMENTS:

- **An integrated geophysical data set of high resolution multi-beam bathymetry, gravity, magnetic and sub-bottom profiler data as well as seabed samples and video footage from 46 seafloor sites over the Capel and Faust basins, and Gifford Guyot for use in marine zone management and hydrocarbon resource assessment.**

NEW OPPORTUNITIES:

- **Data released to the public in 2008 represents the best coverage of geophysical and seabed data in the area, and will help inform future decisions on resource and environmental management in the region. The integrated datasets and new knowledge will underpin hydrocarbon prospectivity assessments of this region and subsequent acreage releases.**

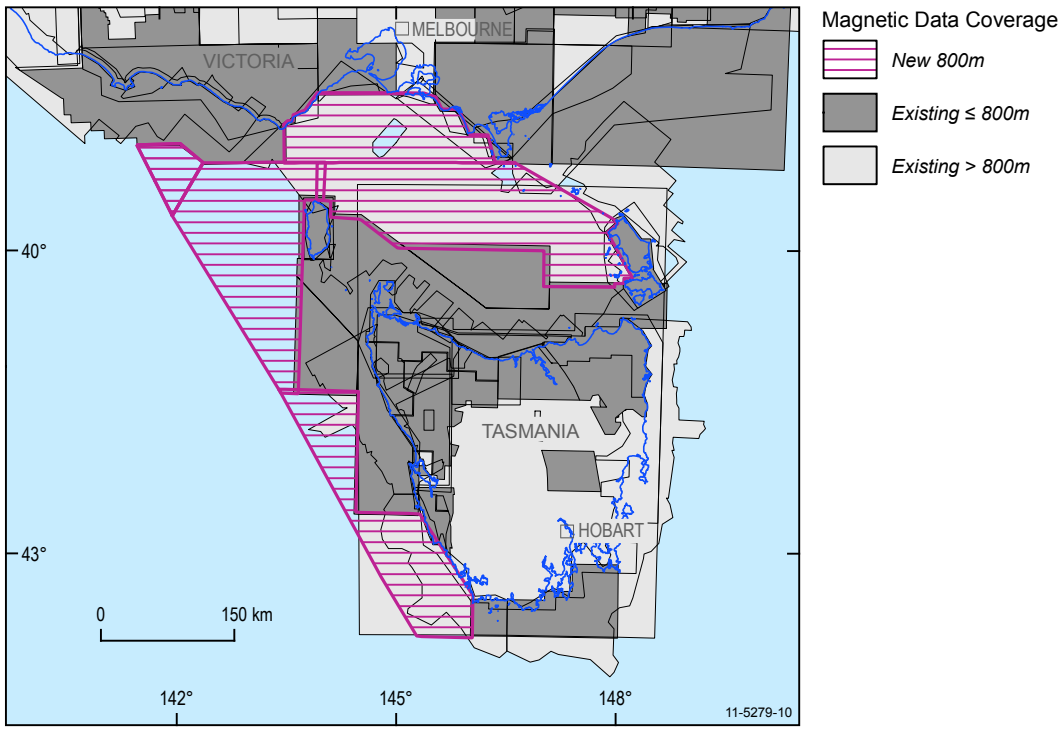
KEY PRODUCTS:

Seabed environments of the Capel and Faust basins and Gifford Guyot, eastern Australia, TAN0713 post-survey report. *Geoscience Australia Record 2009/22.*

Potential-field data covering the Capel and Faust Basins, Australia's Remote Offshore Eastern Frontier. *Geoscience Australia Record 2010/34.*

OFFSHORE *Regional Surveys*

1



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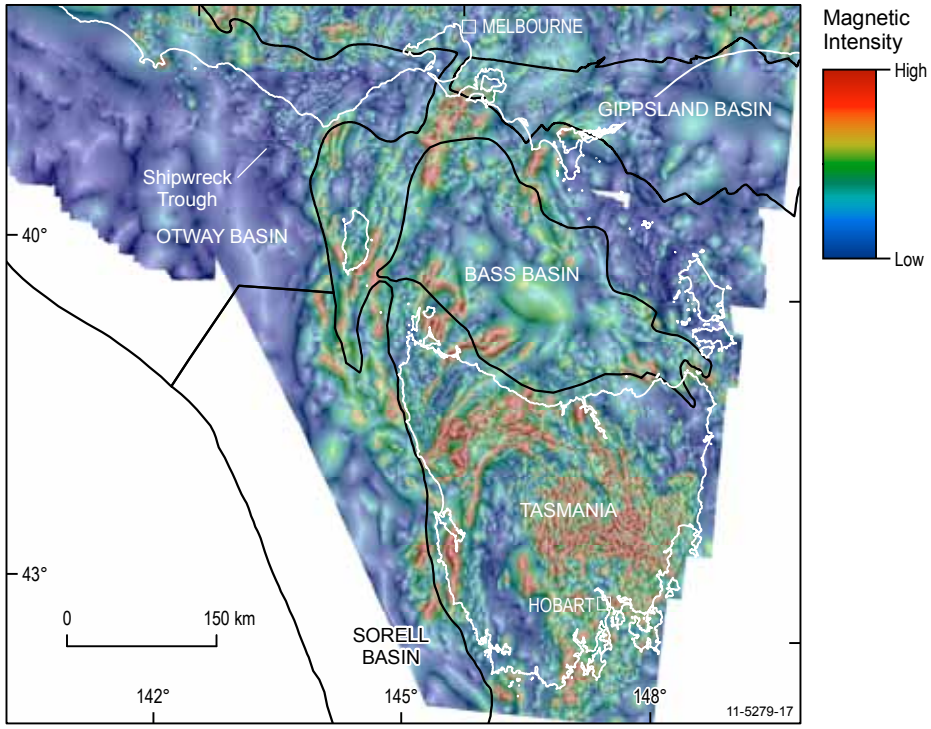


1: Aeromagnetic data coverage for the Bass, southern Otway and Sorell basins, combining results of recent and earlier surveys.

2: Aeromagnetic image showing continuity of the submerged and sub-surface geological units between Tasmania and Victoria, and adjacent offshore regions.

BASS, OTWAY AND SORELL AEROMAGNETIC SURVEY

Previous aeromagnetic coverage over parts of the Bass, deepwater Otway and Sorell basins needed to be upgraded to gain a better understanding of basin architecture and the underlying distribution of basement and igneous rocks. As a result, Geoscience Australia carried out an industry-standard aeromagnetic survey over these areas in early 2008 in collaboration with Mineral Resources Tasmania and GeoScience Victoria. The data acquisition was carried out by Fugro Airborne Surveys Pty Ltd and Thompson Aviation. The Offshore Energy Security Program funded part of the survey cost.

More than 141 000 line kilometres of new data, covering 90 000 square kilometres, were acquired with a consistent line spacing of 800 metres, and 4000 metre tie-line spacing. After processing of the raw data by the respective acquisition companies, the results were merged by Geoscience Australia to produce a seamless end-product which is available to interested parties at the cost of transfer.

Combined with other datasets, the new aeromagnetic data has contributed to the development of a revised basement terrane map in which the re-activation of pre-existing structures and faults can be seen to have played a major role in the formation, architecture and distribution of the main sedimentary depocentres. Understanding the structural framework of these depocentres has been critical in assessing the hydrocarbon prospectivity of this frontier region. These new results demonstrate that the tectonic setting and basin architecture of these depocentres is strikingly similar to those along the ocean-continent transform boundary off the coast of Ghana, which currently is the focus of intense activity by petroleum exploration companies.

Following completion of these integrated studies in mid-2011, this information will be used to underpin future acreage release in these frontier areas. Results are being widely promoted through peer-reviewed scientific articles and presentations at national and international conferences.

ACHIEVEMENTS:

- **Development of a single, merged aeromagnetic dataset which, for the first time, provides the means to rigorously test and constrain geological modelling between Victoria and Tasmania.**
- **Acquisition of new, high resolution aeromagnetic data over parts of the Bass, deepwater Otway and Sorell basins.**

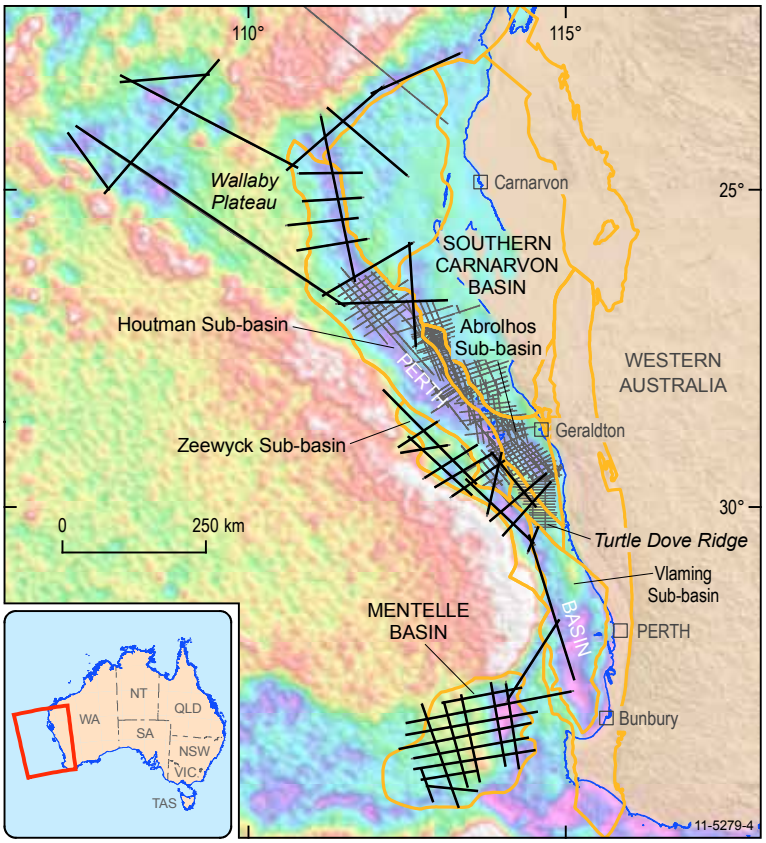
NEW OPPORTUNITIES:

- **The new data sets allow for a better understanding of basement and basin architecture and can be applied to a holistic assessment of basin resources which include oil and gas, and carbon storage potential.**

KEY PRODUCTS:

High quality, merged and levelled aeromagnetic data covering parts of the Bass, deepwater Otway, and Sorell basins and the Torquay Sub-basin. www.ga.gov.au/gadds/

1



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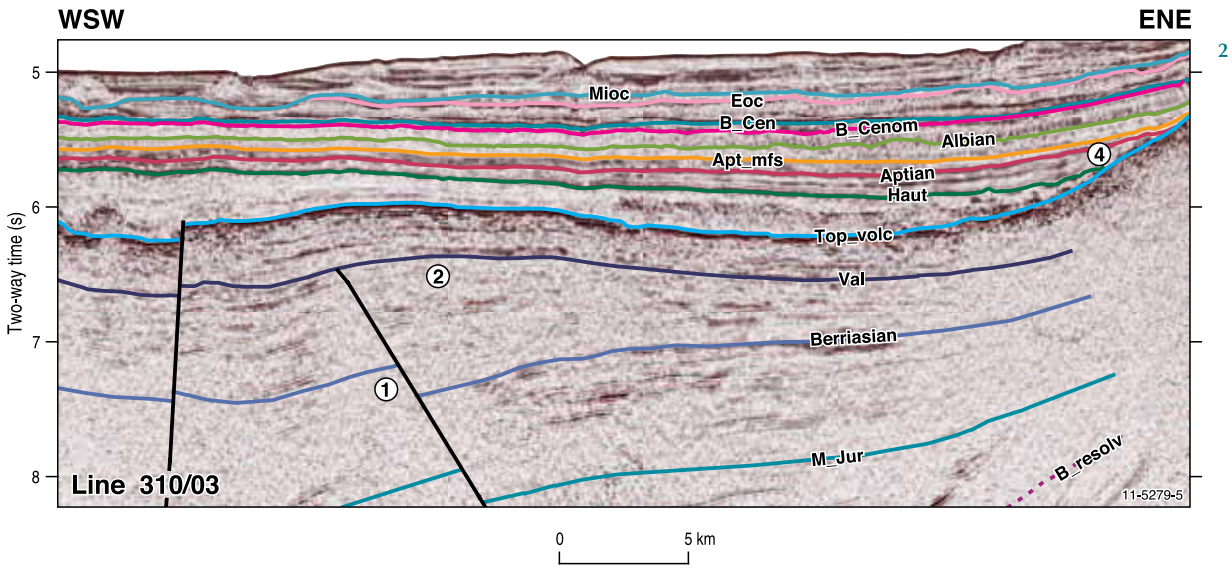


2

1: Location of the southwest margin marine seismic survey with inset photos (a and b) of marine acquisition operations.

2: Interpretation of a newly acquired seismic line across the Mentelle Sub-basin, giving new insights into the geology and hydrocarbon potential of the area.

SOUTHWEST MARGIN MARINE 2D GEOPHYSICAL SURVEY

As part of a project to assess the petroleum prospectivity of the unexplored Mentelle Basin, deep water areas of the northern part of the Perth Basin, Southern Carnarvon Basin and the Wallaby Plateau, Geoscience Australia acquired 7300 line kilometres of 2D seismic, gravity and magnetic data using the commercial supplier CGG Veritas. The survey took place between October 2008 and February 2009 in an area extending from Cape Range in the north to Cape Leeuwin in the south.

Key acquisition parameters included an eight kilometre solid streamer with 12.5 metre hydrophone groups (giving 106-fold data), 4290 cubic inch airgun source array and 12 second record length. These parameters are designed to give good depth penetration and resolve features within the sedimentary section, such as seismic character and structure, which are used in the assessment of hydrocarbon potential.

In addition to the new data collected, a selection of 11 700 line kilometres of older, open-file company 2D seismic data within the survey area was also reprocessed by Fugro Seismic Imaging to a consistent, industry-standard. This data provides links to most of the existing wells in the Abrolhos and Houtman sub-basins.

These data sets are being used to build a geological framework for the previously unexplored parts of the south-west continental margin and assess the petroleum potential of these frontier regions. Selected acreage has been released to industry in the Mentelle and northern Perth basins, and additional areas are being assessed to meet industry demand in the future.

ACHIEVEMENTS:

- **A comprehensive regional understanding of the southwest margin through the acquisition of industry-standard 2D seismic reflection data, marine gravity and magnetics over parts of the Mentelle, northern areas of the Perth Basin, Southern Carnarvon Basin and the Wallaby Plateau. The Wallaby Plateau interpretations include an initial assessment of this extended continental shelf area.**

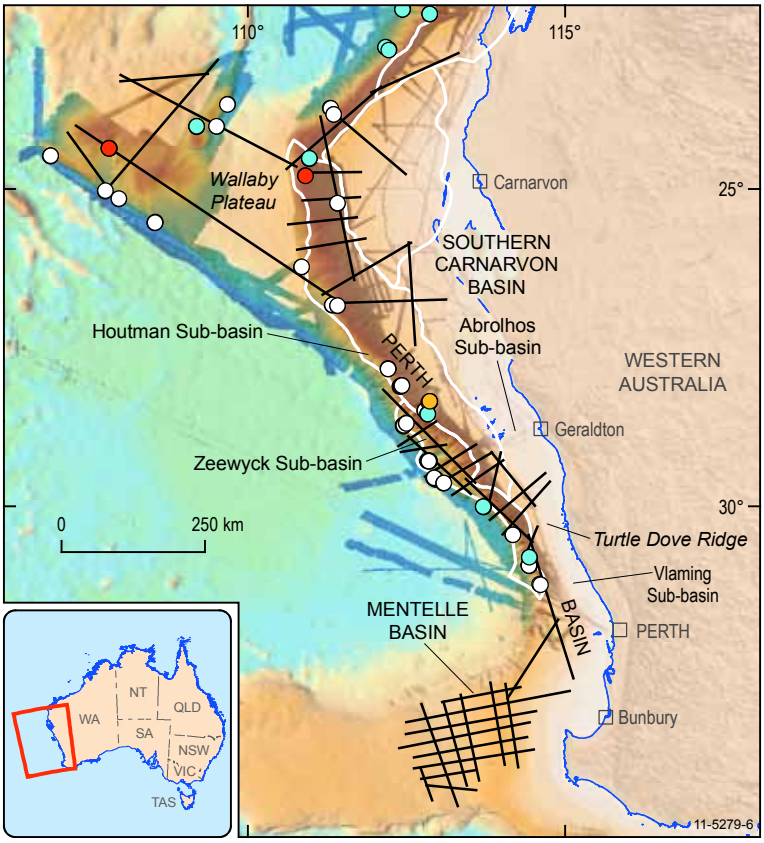
NEW OPPORTUNITIES:

- **These data sets will continue to provide a primary source of information to assess the petroleum potential of the southwest continental margin. The data sets have already underpinned the release of new exploration acreage in the Mentelle Basin (2010), the Southern Carnarvon Basin (2011) and the North Perth Basin (2011). Further acreage releases will be made in response to industry demand.**

KEY PRODUCTS:

SW Margin Data Package.
www.ga.gov.au/products/servlet/controller?event=GEOCAT_DETAILS&catno=70292

1



s310 Southwest margins seismic survey

Sedimentary basin outline

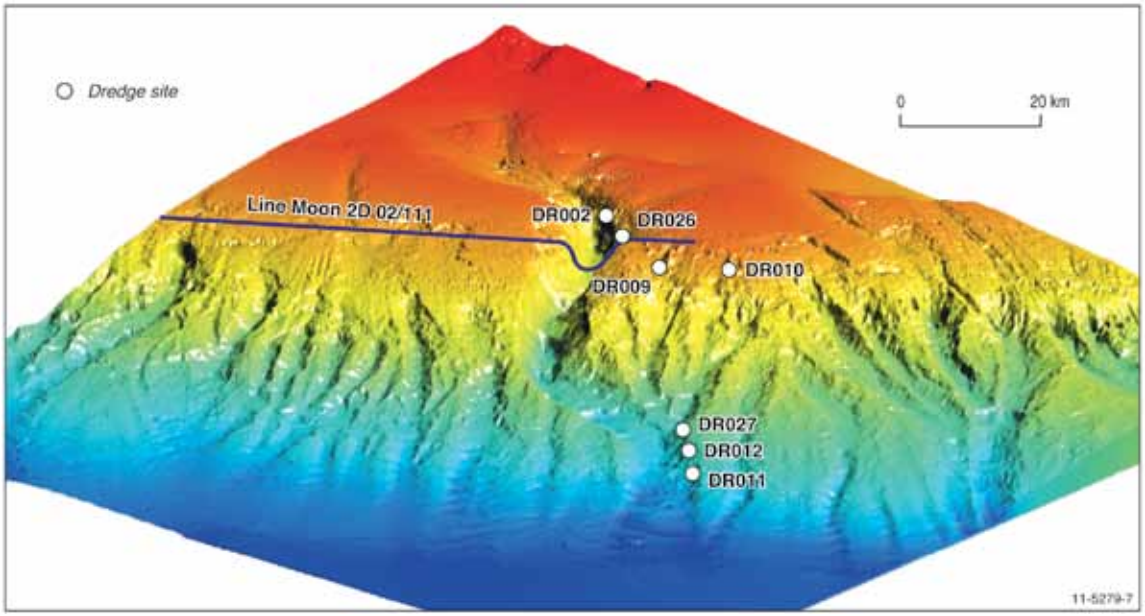
Rock Recovery Operations

Grab (BODO) *Box core*

Benthic trawl *Dredge*

a

2



1: Location of southwest margin marine reconnaissance survey showing high resolution bathymetry and seabed sampling sites with inset photo of seafloor samples being retrieved from a rock dredge.

2: Bathymetry of Houtman Canyon showing location of dredged rock samples and the seismic line used to control the locations of sample sites.

SOUTHWEST MARGIN MARINE RECONNAISSANCE SURVEY

To complement the data acquired in the Southwest Margin Marine 2D Seismic Survey, Geoscience Australia undertook a marine reconnaissance survey along Australia's southwest continental margin to improve understanding of the petroleum prospectivity and environmental significance of these frontier basins. The German research vessel *RV Sonne* conducted the survey between October 2008 and January 2009. The survey mapped an area of 229 000 square kilometres (roughly the size of Victoria) within the Australian Exclusive Economic Zone and Extended Continental Shelf. Data sets acquired included geophysical and oceanographic information as well as geological and biological samples.

The survey was conducted in three legs of one month each and involved scientists and technical staff from Geoscience Australia, the Geological Survey of Western Australia, the Australian Institute of Marine Science, and 21 students and staff from the University of the Sea. Three key areas were targeted: the Zeewyck and Houtman sub-basins of the Perth Basin, the Southern Carnarvon Basin and the Wallaby Plateau. A total of 25 000 line kilometres of multi-beam sonar, sub-bottom profiler, gravity and magnetic data were collected over these underexplored areas.

Multi-beam sonar mapping revealed that Australia's western margin is characterised by a large number of previously unmapped submarine canyons. On the perimeter of the Wallaby Plateau, in the newly recognised extended continental shelf area, scarps and seamounts have relief from hundreds to thousands of metres and extend for tens to hundreds of kilometres.

Geological and benthic ecology samples were obtained from 62 sites, covering a range of seabed features identified from a preliminary analysis of the multi-beam sonar data and pre-existing seismic sections. For the geological samples, the main focus was on dredging the deeply incised canyons which provided the best opportunity to sample older strata. Analysis of these rock samples has yielded valuable new information about the age, depositional environment and hydrocarbon source potential of these sediments. This information will be used to help define areas for future acreage release.

The survey has provided the first observations of deep-water benthic habitats and biota over a depth range from 640 metres to 4825 metres. Generally, the samples contained extremely low numbers of marine organisms.

ACHIEVEMENTS:

- **Comprehensive and complementary data sets over a vast frontier region of 229 000 square kilometres of Australia's western continental margin using multi-beam sonar, sub-bottom profiler, magnetic and gravity techniques.**
- **Geological and biological samples obtained from 62 sites have yielded significant new information about the age and petroleum prospectivity of the sedimentary basins as well as the biota and benthic habitats of the region.**

NEW OPPORTUNITIES:

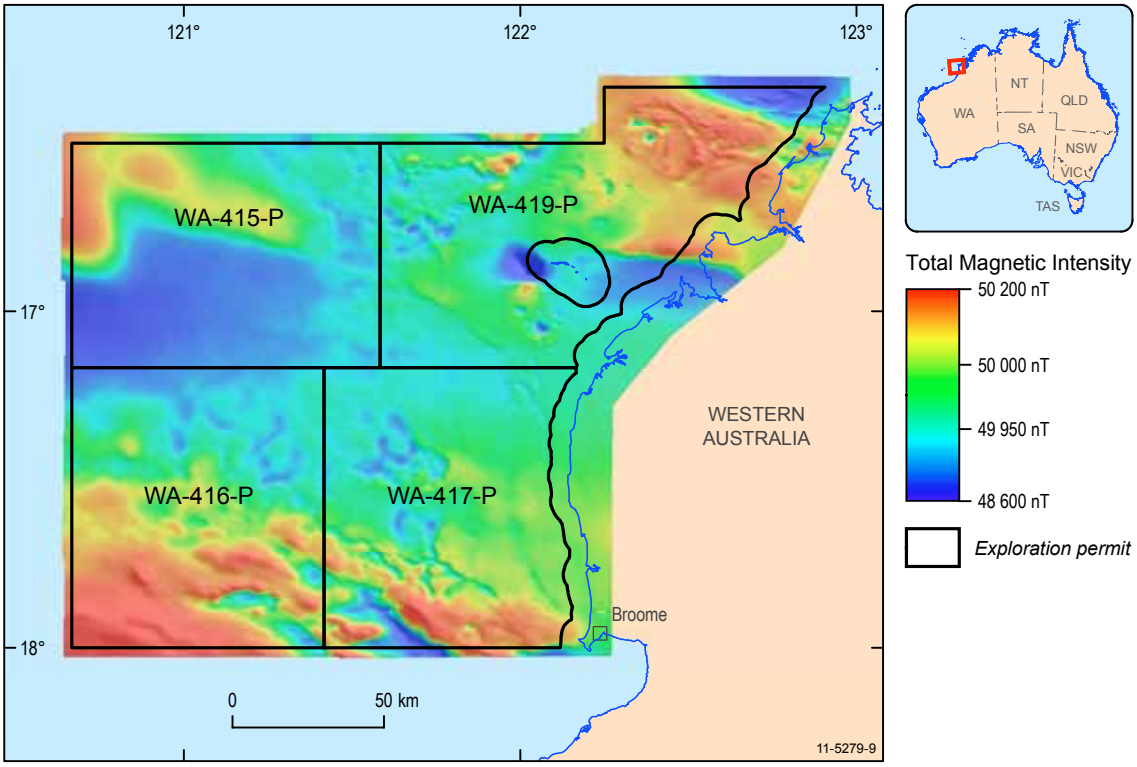
- **These data have been used to support the 2011 acreage release and will be used to improve resource and marine zone management in offshore Western Australian waters.**

KEY PRODUCTS:

Frontier Basins of the West Australian Continental Margin: Post-survey Report of Marine Reconnaissance and Geological Sampling Survey GA2476. *Geoscience Australia Record 2009/38.*

OFFSHORE *Regional Surveys*

1



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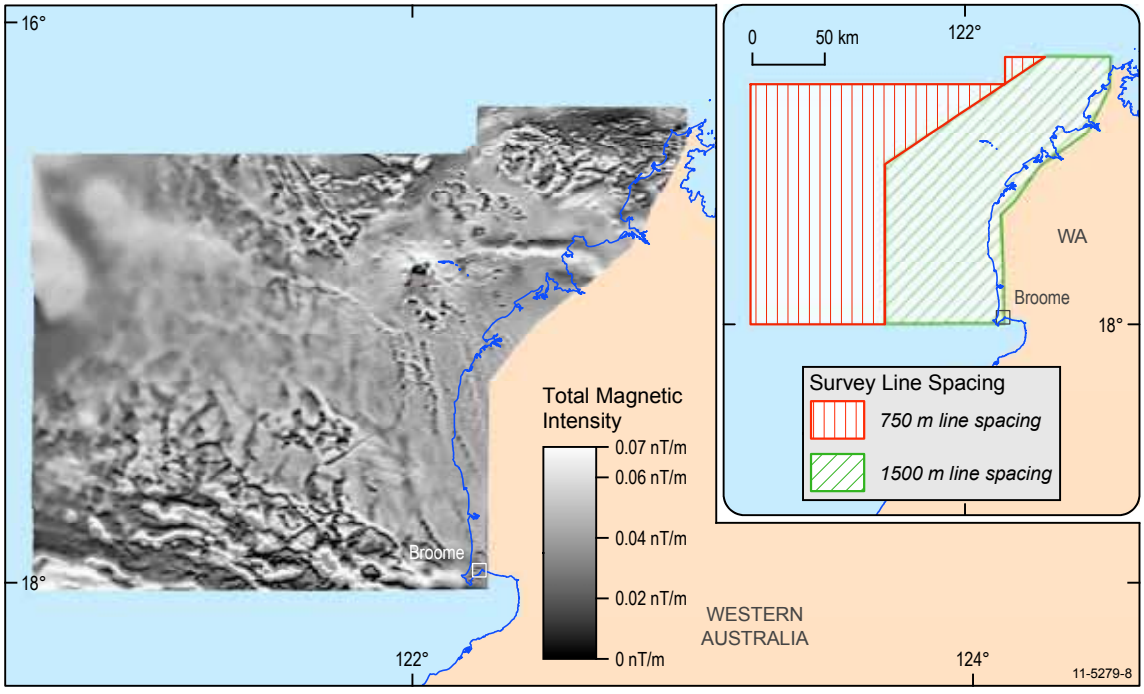


1: Colour image of Total Magnetic Intensity data obtained by the offshore Canning Basin aeromagnetic survey. The sharp field variations in the north-east and southern parts are due to shallow igneous intrusions.

2: Example of a derivative magnetic image used to map linear trends, terminations and displacements in the magnetic field that are associated with faults and other subsurface geological structures.

OFFSHORE CANNING BASIN AEROMAGNETIC SURVEY

Assessment of the petroleum potential of the offshore Canning Basin has been hampered by the incomplete knowledge of igneous intrusions within the section. In an attempt to address this, Geoscience Australia commissioned Fugro Airborne Surveys Pty Ltd in 2007 to undertake a systematic regional magnetic survey of the area at 750 metres line spacing, with the eastern half in-filling an existing survey with line spacing of 1500 metres.

The survey data covers approximately 31 770 square kilometres and consists of a total 56 500 line kilometres made up of 44 630 line kilometres of new data and 11 870 line kilometres of previously acquired data. The merged and levelled data set was released to industry in October 2007 through Geoscience Australia's online geophysical data delivery system.

An interpretation of the new aeromagnetic data found that much of the magnetic signal is generated by intrusive igneous rock (dykes and sills) within the sedimentary section, which is masking signal from deeper basement sources. However, in some locations, mainly in the western part of the survey area, basement magnetic sources are evident at depths up to 11 kilometres. This means that there is sufficient sediment thickness to have generated hydrocarbons, provided that suitable source rocks are present in the sedimentary section.

This new aeromagnetic data set has underpinned the re-assessment of the prospectivity of the offshore Canning Basin and supported the release of new acreage to the exploration industry in 2007.

ACHIEVEMENTS:

- **An understanding of the distribution of igneous rocks of the offshore Canning Basin, and the recognition of basin areas with sufficient sediment thickness to generate hydrocarbons.**
- **Provision of a levelled magnetic data set to industry in October 2007 to assist in the appraisal of four acreage release areas, all of which have been awarded exploration permits.**

NEW OPPORTUNITIES:

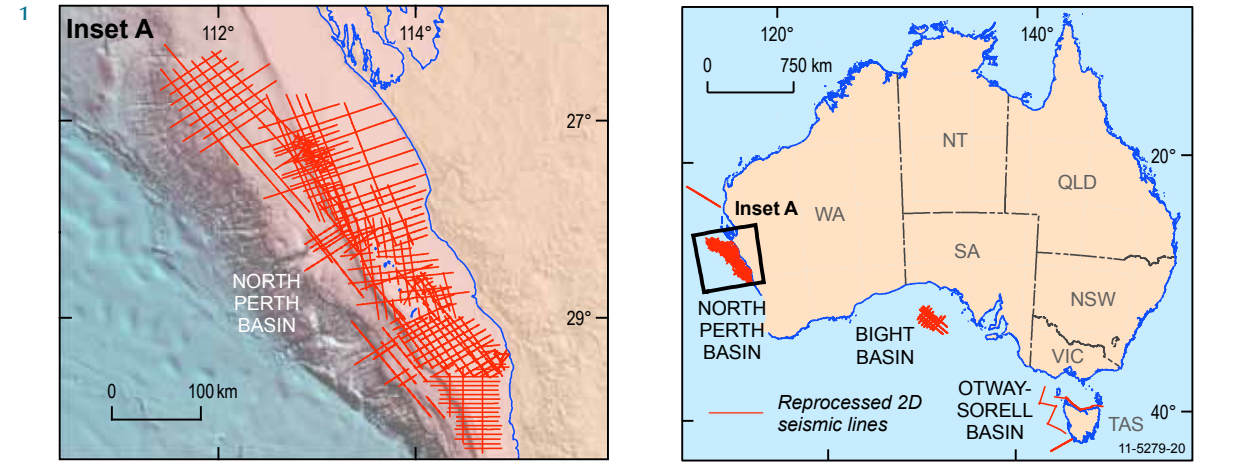
- **This work has provided an example of the value of airborne magnetic coverage in understanding the geology of the offshore Canning Basin and has set a precedent for future work in other data-poor frontier regions.**

KEY PRODUCTS:

Offshore Canning Aeromagnetic Data: 56 500 line kilometres of new and merged data.
www.ga.gov.au/gadds/

OFFSHORE *Regional Surveys*

1



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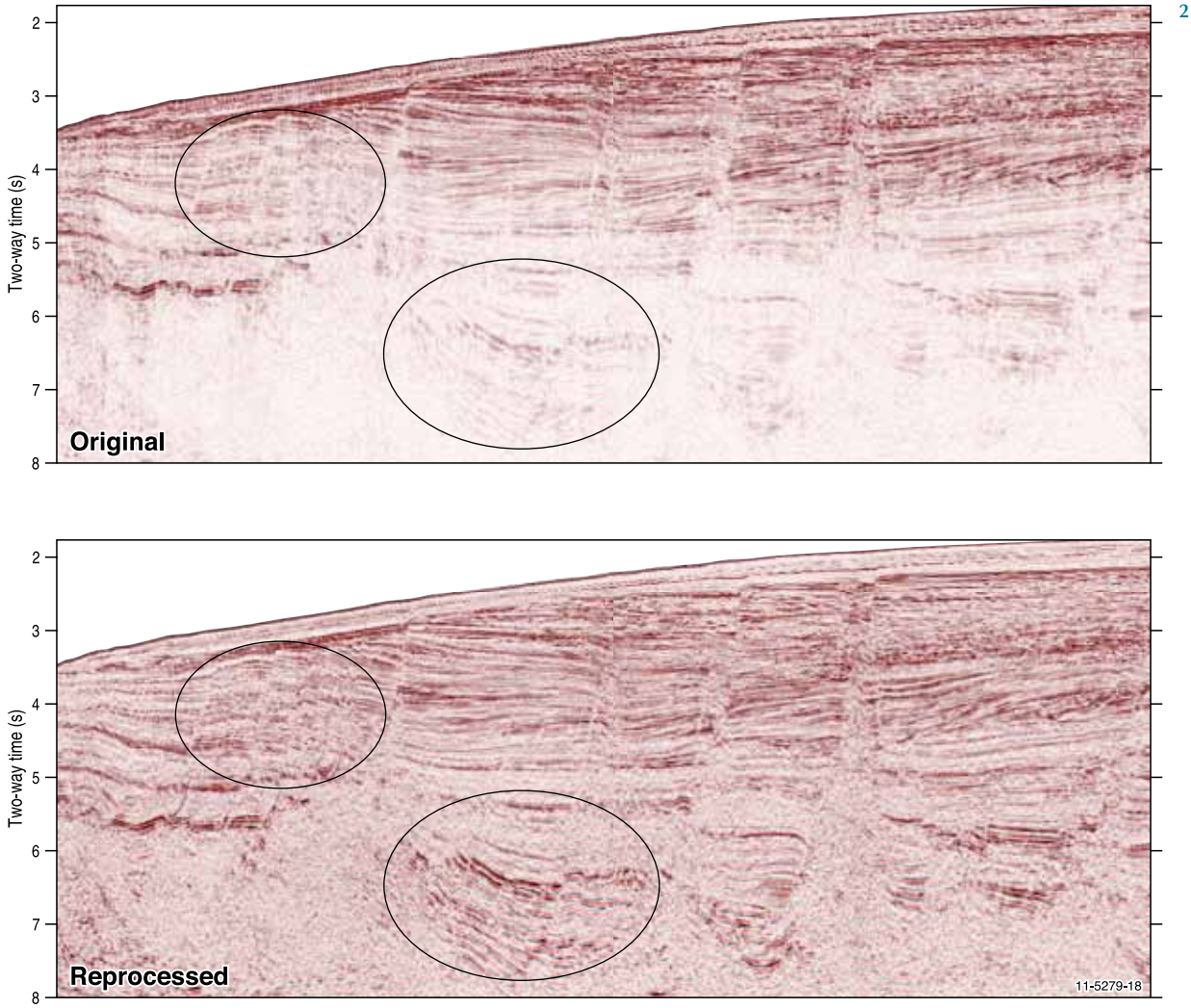


1: Location of reprocessed seismic lines in the northern Perth, Bight and Otway–Sorell basins.

2: Comparison of original and reprocessed seismic data in the Bight Basin, highlighting the significant inprovement in image quality throughout the section.

REPROCESSING & ANALYSIS OF 2D MARINE SEISMIC DATA

Previously acquired seismic data, lodged under the various petroleum acts, can be reprocessed using modern techniques to enhance basin imaging and, as a result, interpretation and geologic understanding for petroleum prospectivity assessment. Reprocessing undertaken during the Offshore Energy Security Program was to current industry-standard, to provide high quality images with good reflection continuity for optimum interpretation.

In the northern Perth Basin, 11 700 line kilometres of seismic data across 21 surveys was re-processed, including key seismic lines which permitted sub-surface stratigraphies intersected in petroleum exploration wells to be more accurately linked. These datasets are being used to build a geological framework and improve understanding of the petroleum potential of the previously under-explored parts of these sub-basins.

In addition, several locations with Amplitude versus Offset (AVO) anomalies were identified on seismic data acquired during the Southwest Margin Marine 2D Geophysical Survey. Such anomalies are regarded as being direct indications of the presence of hydrocarbons, enhancing the exploration potential of this frontier region. Geoscience Australia had these further investigated by RPS Energy using the Hampson–Russel AVO analysis software to better support acreage release.

A key component of the deepwater Otway and Sorell basins study has been the seismic reprocessing of vintage Shell Petrel survey data and that of Geoscience Australia's predecessor, the Australian Geological Survey Organisation. The reprocessed lines provide improved images of the basin succession, particularly in the southern Sorell Basin where there is extremely limited data coverage. Through the integration of seismic, geological and potential field datasets the deepwater Otway and Sorell basins study has developed an improved understanding of the petroleum prospectivity of these basins.

The Flinders Deepwater 2D seismic reprocessing provided a high quality stack product with good event continuity, frequency content and character in an area dominated by complex multiples. This provided Geoscience Australia and industry with additional seismic data to help to better define the structural complexity and hydrocarbon potential of the Bight Basin prior to offering acreage to industry.

ACHIEVEMENTS:

- **Reprocessing of 21 surveys of varying vintage totalling some 11 700 line kilometres of 2D seismic data in the northern Perth Basin.**
- **Reprocessing of 862 line kilometres of 2D seismic from the deepwater Otway and Sorell basins collected in 1972 by the Australian Geological Survey Organisation survey 159 and the Shell Petrel survey.**
- **Reprocessing of 2300 line kilometres of selected 2D seismic lines from the Flinders Deepwater Bight Basin survey.**

NEW OPPORTUNITIES:

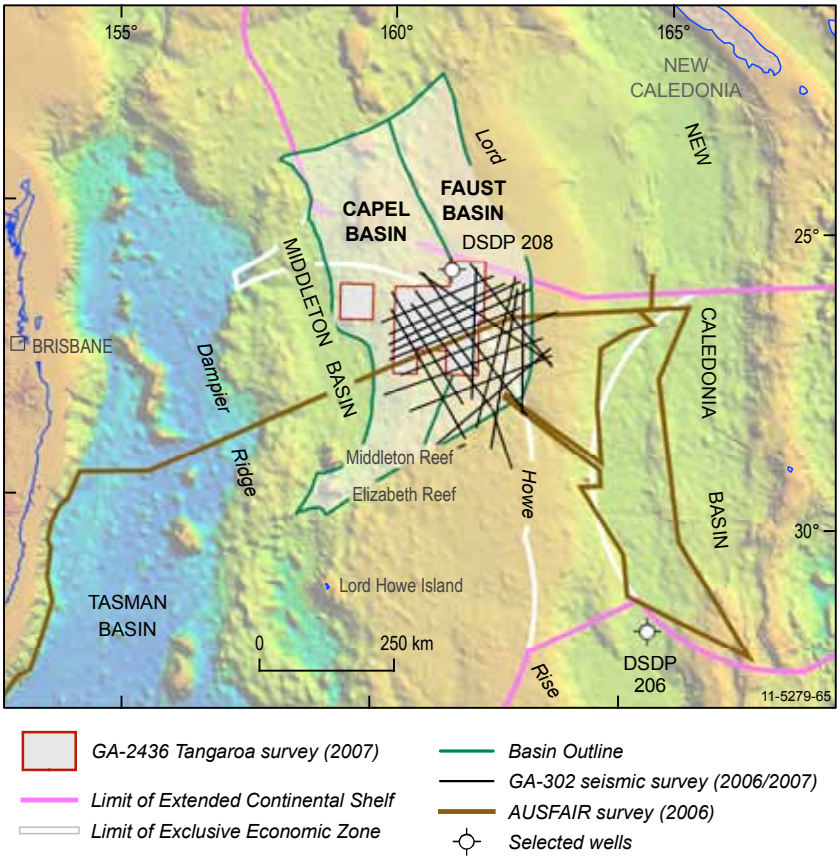
- **Analysis of these new, high quality data sets has assisted in developing new insights into the petroleum potential of these frontier regions and underpinned acreage release in the Bight and north Perth basins.**

KEY PRODUCTS:

11 700 km of reprocessed 2D SEGY 'true relative amplitude' seismic data.
https://www.ga.gov.au/products/servlet/controller?event=GEOCAT_DETAILS&catno=70292

OFFSHORE *Regional Prospectivity Assessments*

1



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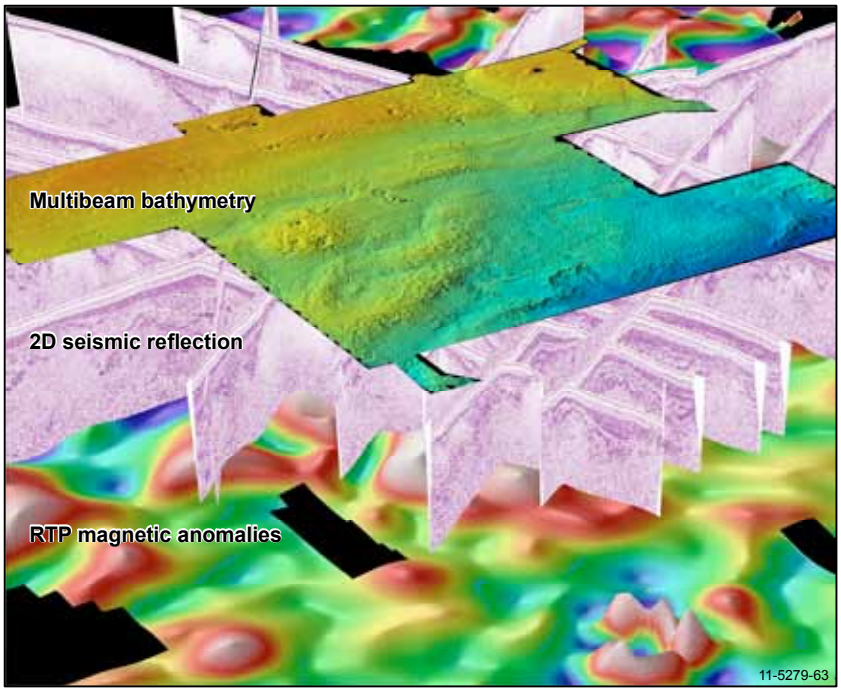

1: Location of the Capel and Faust basins, showing recent Geoscience Australia seismic and marine data acquisition surveys.

2: 3D visualisation techniques assisted data integration and analysis, leading to a much improved understanding of the geology of this under-explored frontier region.

CAPEL AND FAUST BASINS PROSPECTIVITY ASSESSMENT

This is the first detailed assessment of the petroleum prospectivity of the Capel and Faust basins. These two basins are located about 800 kilometres off the east coast of Australia and lie within a large, submerged continental fragment which extends about 1600 kilometres from the southwest of New Caledonia to the Bellona Trough west of New Zealand. Much of this fragment is located within the limits of the Australian Exclusive Economic Zone and Extended Continental Shelf (as recommended by the United Nations Convention on the Law of the Sea).

There are no petroleum exploration wells in the region and prior to investigation by Geoscience Australia, there were only limited reconnaissance seismic lines in the area. A new study commenced during the final stages of the Australian Government's 2004/07 New Petroleum Program with the acquisition of a 6000 line kilometre grid of new 2D seismic data. In addition, the Capel-Faust Marine Reconnaissance Survey between October and November 2007 acquired multi-beam sonar and other geophysical data (sub-bottom profiler, magnetics and gravity) over an area of nearly 40 000 square kilometres, together with 46 sea-floor samples.

The integrated analysis of geophysical and geological datasets in 3D space has significantly advanced the current knowledge of the petroleum potential of the Capel and Faust basins and the regional tectonic evolution of this area. The new data permits sediment thickness and basin extent to be realised and confirms the potential of these basins to generate hydrocarbons if suitable source rocks are present. Additional 2D seismic and stratigraphic drilling is required to further the regions prospectivity assessment.

ACHIEVEMENTS:

- **Confirmation of the existence of several large depocentres with sufficient sediment thickness to generate hydrocarbons within the Capel and Faust basins.**
- **An integrated 3D model which synthesises the geological evolution and petroleum prospectivity of the Capel and Faust basins through the analysis of 2D seismic, multi-beam bathymetry, shipboard gravity, magnetic data and geological samples.**

NEW OPPORTUNITIES:

- **The basins are of sufficient size to host hydrocarbon accumulations. The new data provides potential sites for stratigraphic drilling to determine basin stratigraphy and whether source rocks are present.**
- **Regional correlations carried out in collaboration with the New Zealand and New Caledonia geological surveys suggest the potential existence of petroleum systems, opening up new possibilities for future hydrocarbon exploration.**

KEY PRODUCTS:

Interpretation of Seismic Data, Capel and Faust Basins, Australia's Remote Offshore Eastern Frontier. *Geoscience Australia Record 2010/06.*

Modelling and Petroleum Prospectivity Assessment in Offshore Frontier Basins using GOCAD™: Capel and Faust Basins, Lord Howe Rise. *Geoscience Australia Record 2011/02.*

Geology and prospectivity of the Capel and Faust basins in the deepwater Tasman Sea region. *APPEA Journal 51.*

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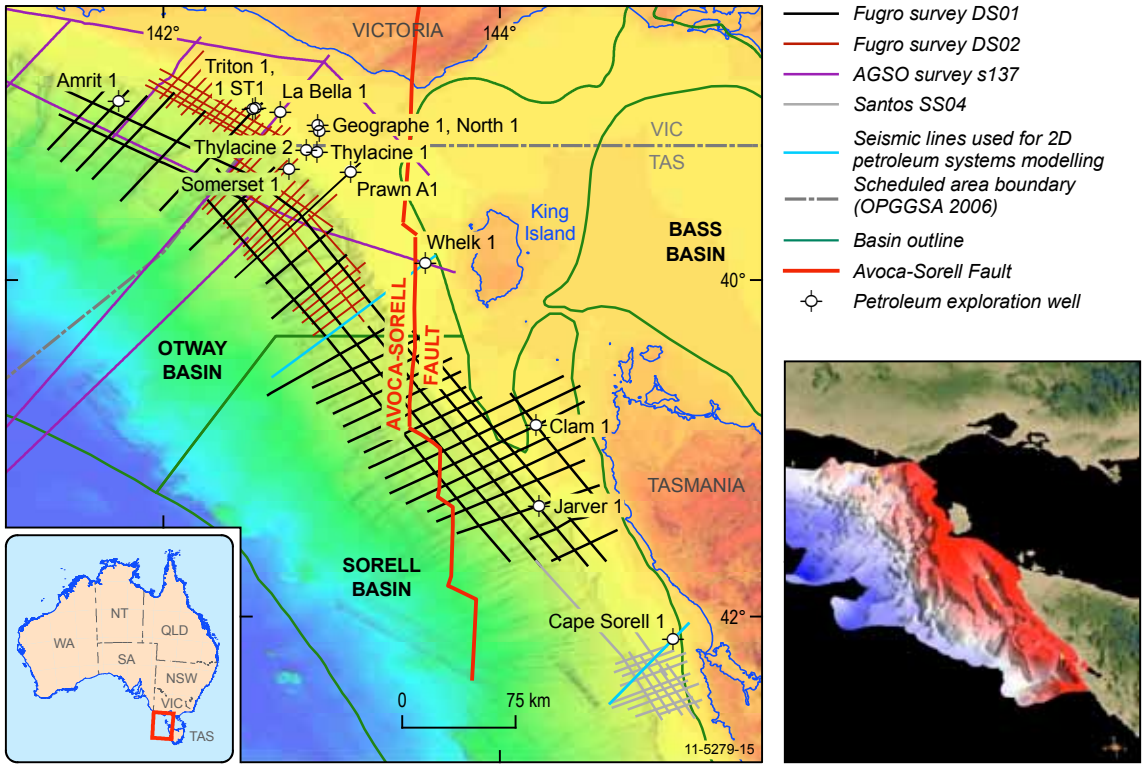

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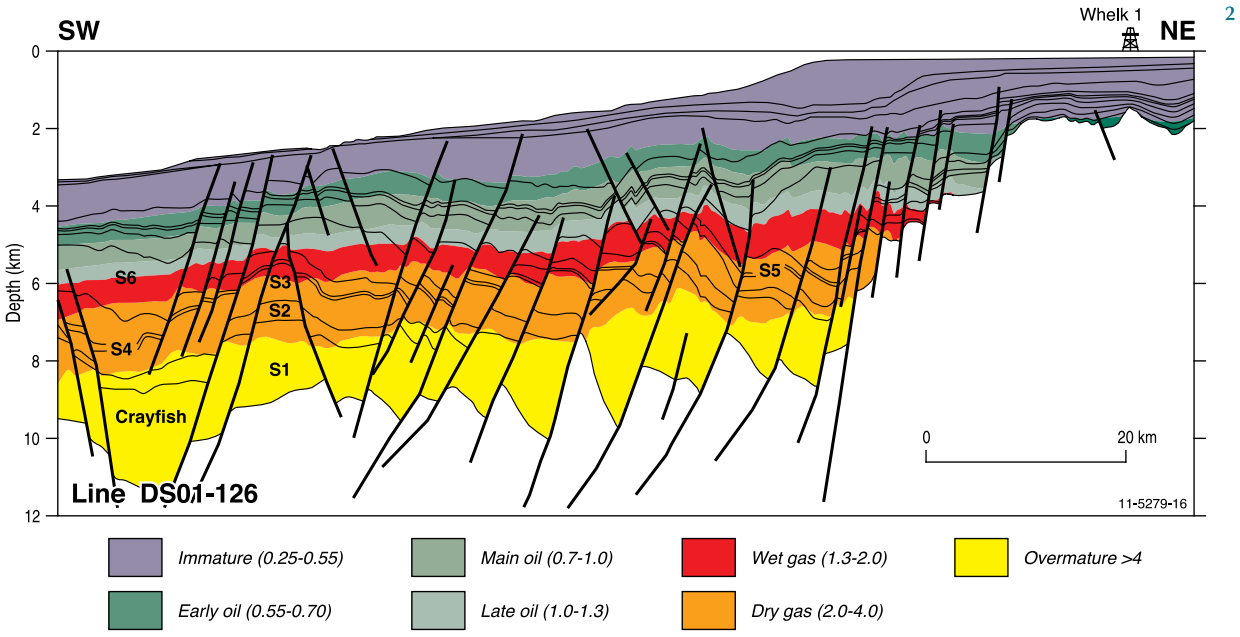

1: Regional seismic grid used for deepwater Otway-Sorell study showing Avoca-Sorell Fault. Inset image of 3D model showing configuration of basement beneath the sedimentary section.

2: Modelled present-day maturity zones for a transect across the southern Otway and northern Sorell basins, showing hydrocarbon potential beyond the shelf break.

DEEPWATER OTWAY AND SORELL BASINS PROSPECTIVITY ASSESSMENT

To renew exploration interest in the deepwater Otway and Sorell basins Geoscience Australia undertook an integrated analysis of open-file, well and seismic data together with data acquired in the Bass, Otway and Sorell Aeromagnetic Survey. This analysis was designed to acquire a better understanding of the geological evolution of the region and its hydrocarbon prospectivity.

These under-explored, frontier basins lie in water depths between 100 metres and 4500 metres, off southwest Victoria and western Tasmania. The basins contain up to 10 kilometres of Cretaceous–Cenozoic sediment and lie adjacent to hydrocarbon producing areas of the Otway Basin, including the Shipwreck Trough.

Building on previous Geoscience Australia basin studies and using an integrated approach, new aeromagnetic data, together with open-file potential field, seismic and exploration well data have been used to develop new interpretations of basement structure and sedimentary basin architecture. In addition new 2D petroleum systems models have been created from two seismic lines obtained across the southern Otway, northern Sorell and Strahan sub-basins

These investigations indicate the importance of a re-activated north–south Paleozoic shear zone in the Avoca-Sorell fault system. Depocentres to the west of this structure are large and deep, in contrast to the narrow, elongate depocentres to its east. New seismic interpretations show the depositional sequences hosting active petroleum systems in the producing areas of the Otway Basin are likely to be present also in the southern Otway and Sorell basins. Petroleum systems modelling suggests that if the equivalent petroleum systems elements are present, then they are mature for oil and gas generation, with generation and expulsion occurring mainly in the late Cretaceous in the southern Otway and northern Sorell basins, and during the Paleocene in the Strahan Sub-basin.

The results of this study highlight the complex history of these basins, addressing many of the questions regarding the geological controls on their development and petroleum prospectivity.

ACHIEVEMENTS:

- **New interpretations of basement architecture and structural fabric have resulted in the recognition of major controls on sedimentary basin development along the west coast of Tasmania, and their structural and accommodation histories. This new knowledge will assist in the definition of future exploration targets.**
- **Petroleum systems modelling of two seismic lines in the Sorell and Strahan basins shows that potential source rocks in these basins are mature for oil and gas generation.**

NEW OPPORTUNITIES:

- **New knowledge about the structural development and petroleum potential of the deepwater Otway and Sorell basins should lead to a rejuvenation of exploration interest in this frontier region and will underpin future acreage release in the area.**

KEY PRODUCTS:

Geology and hydrocarbon prospectivity of the deepwater Otway and Sorell basins. *Geoscience Australia Record 2011* (in prep.).

Insights into the geology of the deepwater Otway and Sorell basins from integrated Geophysical interpretation. *Geoscience Australia Record 2011* (in prep.).

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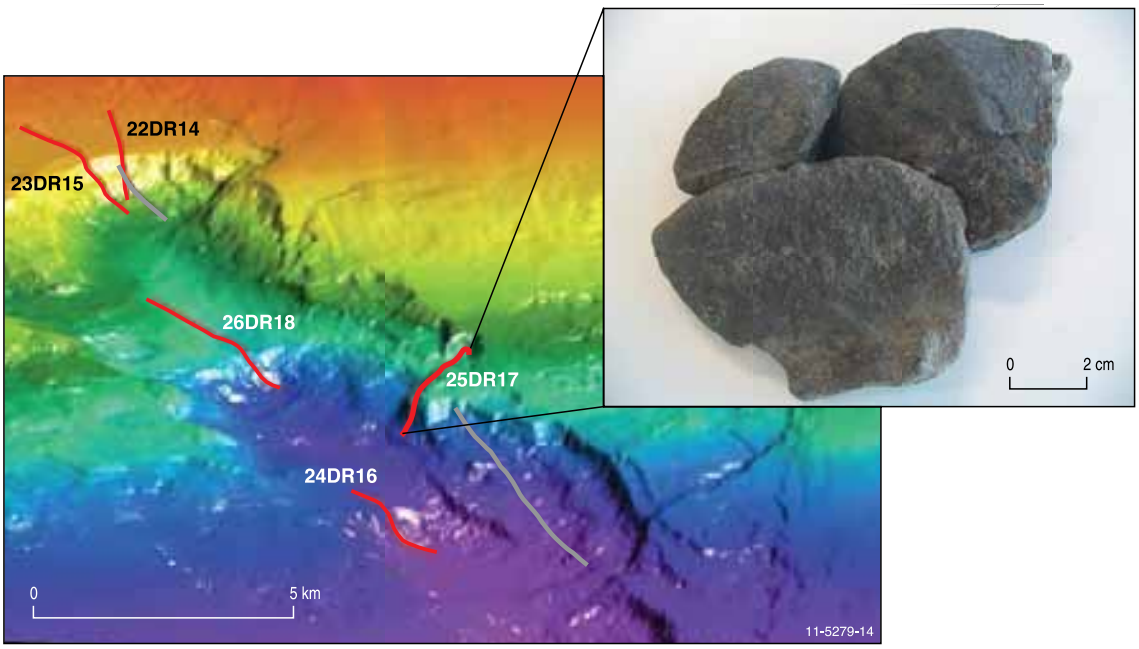

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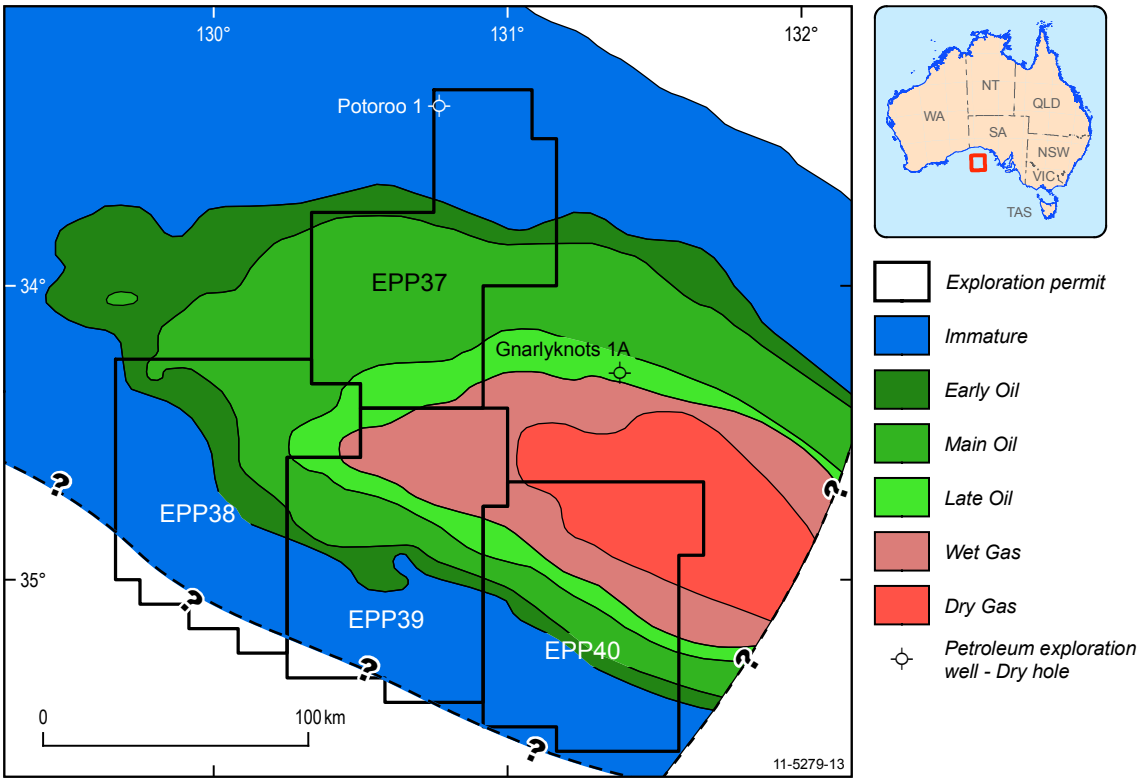

Where well symbol information is sourced from publicly available "open file" data, it has been provided by Geoscience Australia from Well Completion Reports. These symbols were generated from open file data as at 31 March 2009. Where well symbol information is not publicly available from titleholders' data, the information has been extracted from other public sources.

1: Cretaceous organic-rich marine shales (inset) recovered from the dredge site in the Ceduna Sub-basin shown on the bathymetry image of a canyon incised into the underlying strata.

2: Present-day hydrocarbon maturity map for the Cretaceous potential source rock recently discovered in the Bight Basin, leading to a new phase of exploration in four exploration permits.

BIGHT BASIN PROSPECTIVITY ASSESSMENT

Bitumen strandings, oil shows, and up to 15 kilometers of Jurassic to Cretaceous sediments in the Bight Basin make this area attractive for hydrocarbon exploration. No discoveries have been made in the area to date and the key question remains as to whether a petroleum source rock exists in this basin. However, based on previous seismic and seabed mapping, Geoscience Australia had predicted the presence of potential source rocks in canyons eroded into the Ceduna Sub-basin.

In 2007, Geoscience Australia undertook a marine sampling survey which dredged a suite of organic-rich rocks of Cenomanian-Turonian age from the northwestern edge of the Ceduna Sub-basin. Geochemical analyses characterised these samples as world-class, oil-prone, marine potential source rocks. These source rocks can be seismically mapped throughout most of the Bight Basin and modelling has shown they are mature for oil and gas generation across much of the Ceduna Sub-basin. These organic-rich rocks had not been sampled previously, and their identification changed perceptions about the source rock potential of the Bight Basin.

The discovery of a new source rock was actively promoted to Australian and international companies and attracted considerable interest across a wide spectrum of the exploration industry. In 2009, the Australian Government released six large deepwater exploration areas in the Bight Basin, which further encouraged the speculative acquisition of multi-client seismic and airborne magnetic surveys by the exploration industry. In 2011, four exploration permits were granted to BP Australia, with a guaranteed $600 million three year work program which will include four wells. The company also has committed to a secondary work program in excess of $800 million during the subsequent three years.

ACHIEVEMENTS:

- **Identification and characterisation of a world-class, marine, oil-prone Cretaceous potential source rock has changed perceptions about prospectivity and reduced exploration uncertainty in the Bight Basin.**
- **Successful release of exploration acreage resulted in four exploration permits being awarded with a guaranteed work program in excess of $600 million during the first three years, including the drilling of four wells.**

NEW OPPORTUNITIES:

- **Renewed exploration activity in the Bight Basin has attracted considerable industry interest and opened new opportunities for the release of additional acreage in an area.**

KEY PRODUCTS:

Mid–Late Cretaceous organic-rich rocks from the eastern Bight Basin: implications for prospectivity. *Eastern Australasian Basins Symposium III, Petroleum Exploration Society of Australia, Special Publication, 2008.*

Bight Basin acreage release—new exploration opportunities in a deep-water frontier. *APPEA Journal 49.*

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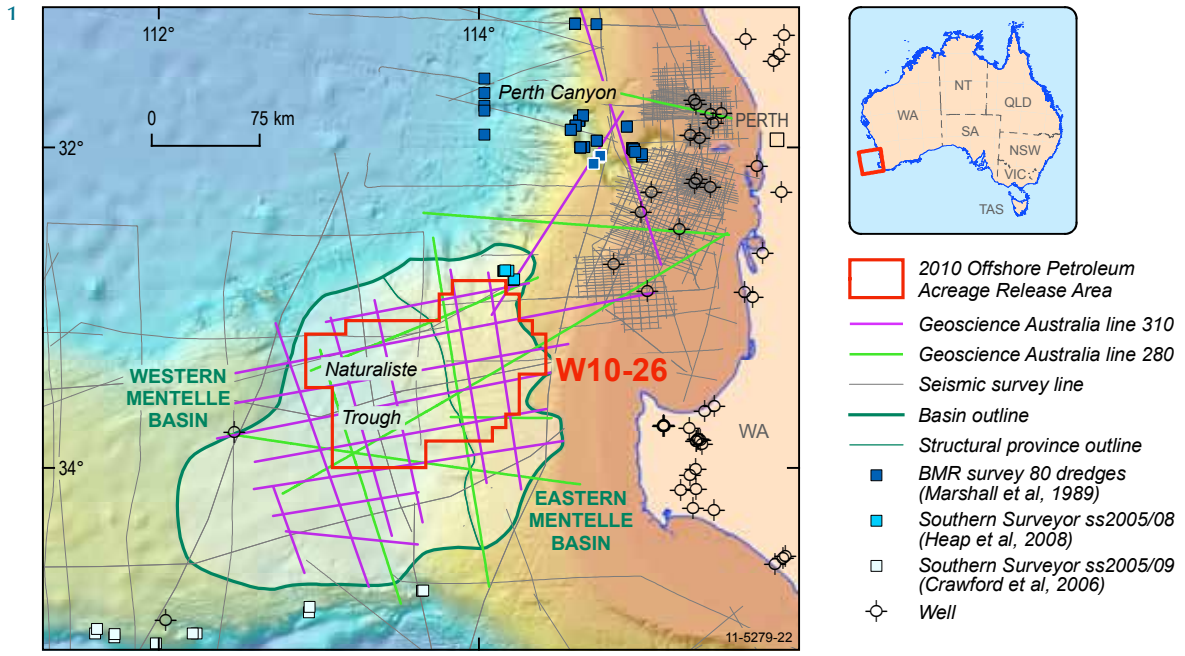

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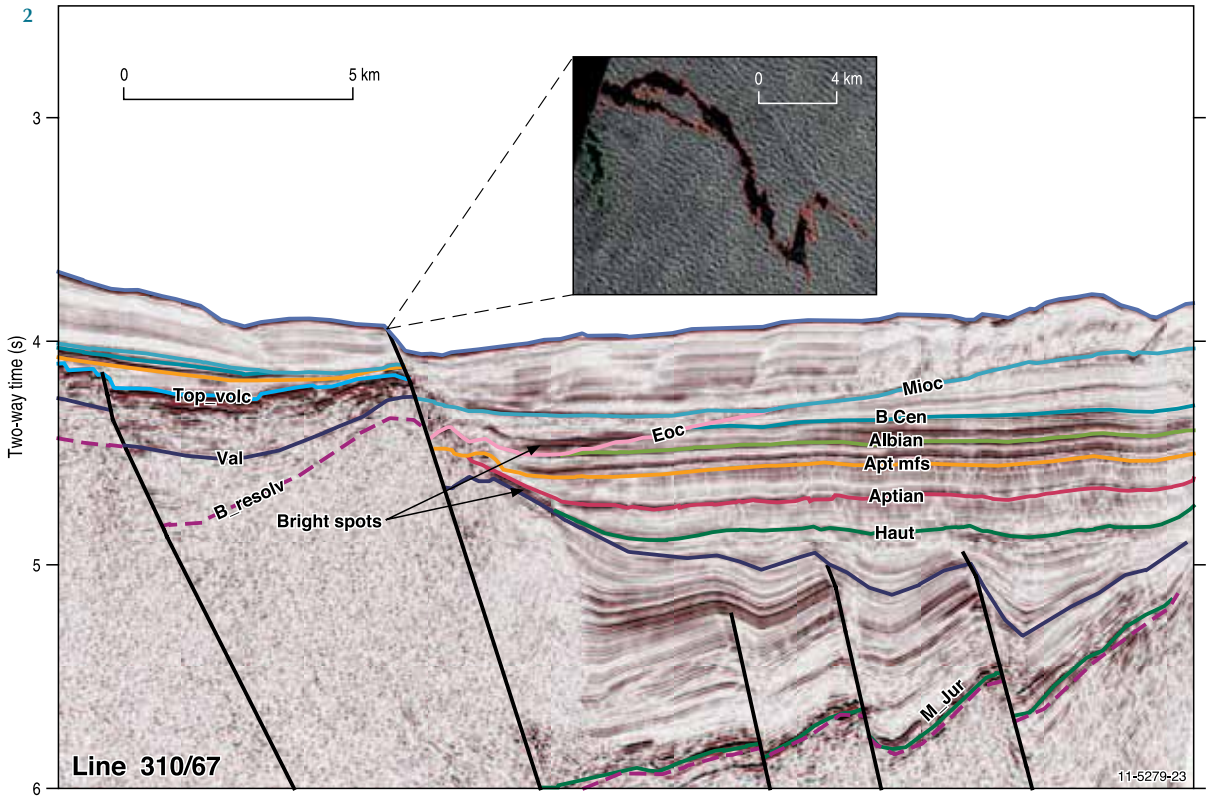

1: Location of the Mentelle Basin, showing data coverage (seismic lines and geological samples) and 2010 Acreage Release Area W10-26.

2: Interpreted seismic line in the south-western Mentelle basin showing sedimentary structure, with inset image of a 25 km long sea surface slick located above a basin margin fault.

MENTELLE BASIN PROSPECTIVITY ASSESSMENT

To stimulate the uptake of frontier petroleum acreage through the provision of new seismic and potential field data, Geoscience Australia completed a pre-competitive study of the Mentelle Basin covering 36 000 square kilometres in a deep water basin about 100 kilometres west of Bunbury off Western Australia. The exploration company Royal Dutch Shell plc acquired seismic data in 1973 which imaged a thick sedimentary succession. However, the remote location and deep-water setting inhibited subsequent exploration.

In 2004, Geoscience Australia's Southwest Frontiers Geophysical Survey collected 1060 line kilometres of new seismic data in the Mentelle Basin. These data provided a reconnaissance seismic grid, but structural complexity prevented a prospectivity assessment suitable for acreage release. In 2008/09, under its Offshore Energy Security Program, Geoscience Australia acquired an additional 2570 line kilometres of high resolution 2D seismic data to provide a grid with 20 kilometre line spacing.

Interpretation of the new seismic grid has resulted in a better understanding of the structural and depositional histories of the Mentelle Basin. The basin comprises several depocentres with an older mid-Permian to Jurassic fill in the east and a younger Jurassic to Lower Cretaceous fill in the west. These are likely to contain multiple source rock intervals associated with coals and carbonaceous shales, as well as reservoir rocks and intra-formational seals. The depocentres are overlain by Cretaceous to Holocene deposits which contain potential regional seals. A range of structural and stratigraphic traps have been identified both in the syn-rift and post-rift successions.

Burial depth and thermal maturity calibrated to data from the adjacent Vlaming Sub-basin suggest that potential source rocks are thermally mature for oil and gas generation. Petroleum system modelling predicts a range of possible accumulations at different stratigraphic levels. Petroleum prospectivity assessment confirmed that the Mentelle Basin has significant potential to become a new petroleum province.

ACHIEVEMENTS:

- **Detailed geological history of the area determined from the newly acquired data. The pre-competitive knowledge formed the basis of the 2010 Mentelle basin acreage release. Industry bids close in May 2011.**
- **For the first time mapped depocentres with sufficient sediment thickness to generate hydrocarbons were identified. Supersequence correlations to the adjacent Vlaming Sub-basin identified potential source, reservoir and seal units, enhancing the area's prospectivity.**

NEW OPPORTUNITIES:

- **The Mentelle Basin can be seen in its regional context, with the Perth Basin to the north and Bremer Basin to the east, thereby permitting improved geological correlations and prospectivity assessments for all basins.**

KEY PRODUCTS:

New exploration opportunities on the southwest Australian margin–deep-water frontier Mentelle Basin, 2010. *APPEA Journal 50.*

New exploration opportunities on the southwest Australian margin–deep-water frontier Mentelle Basin, 2010. *PESA News, October/November issue.*

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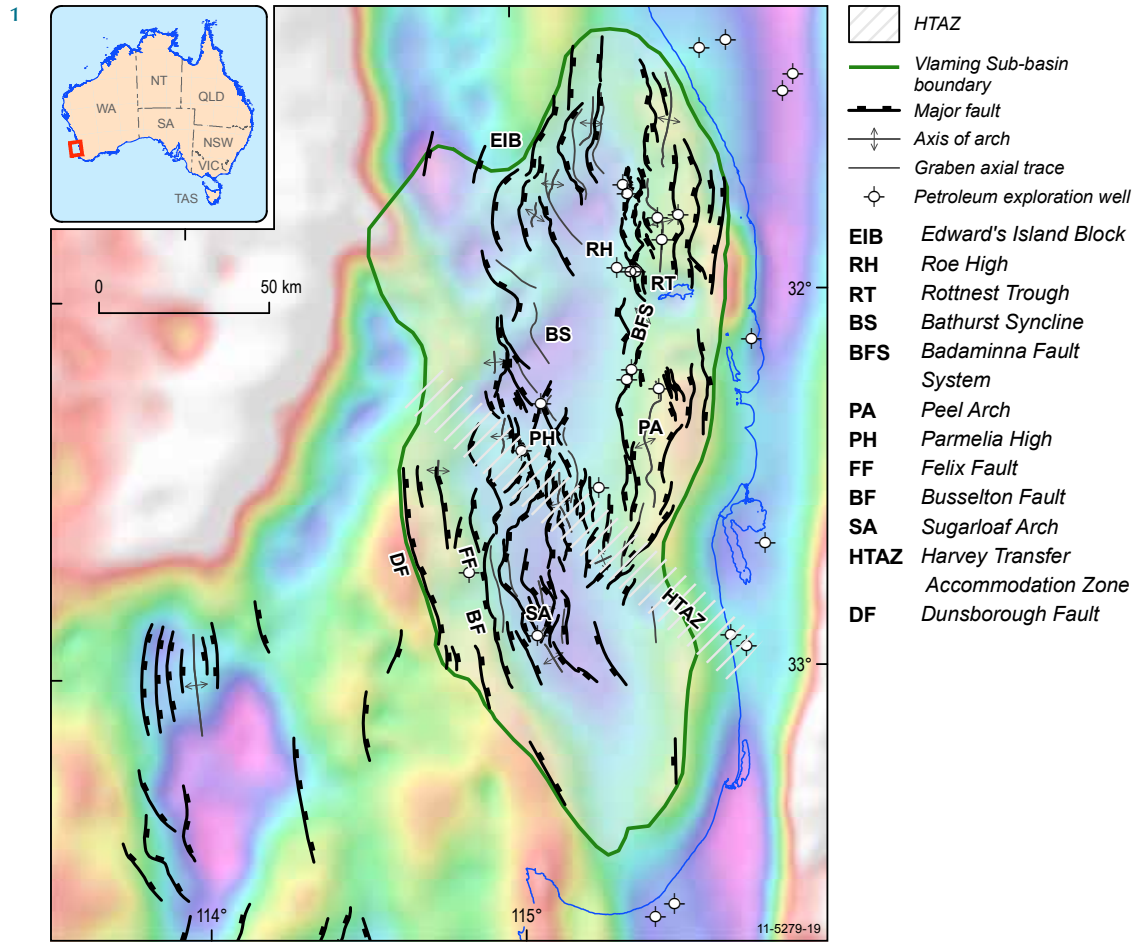

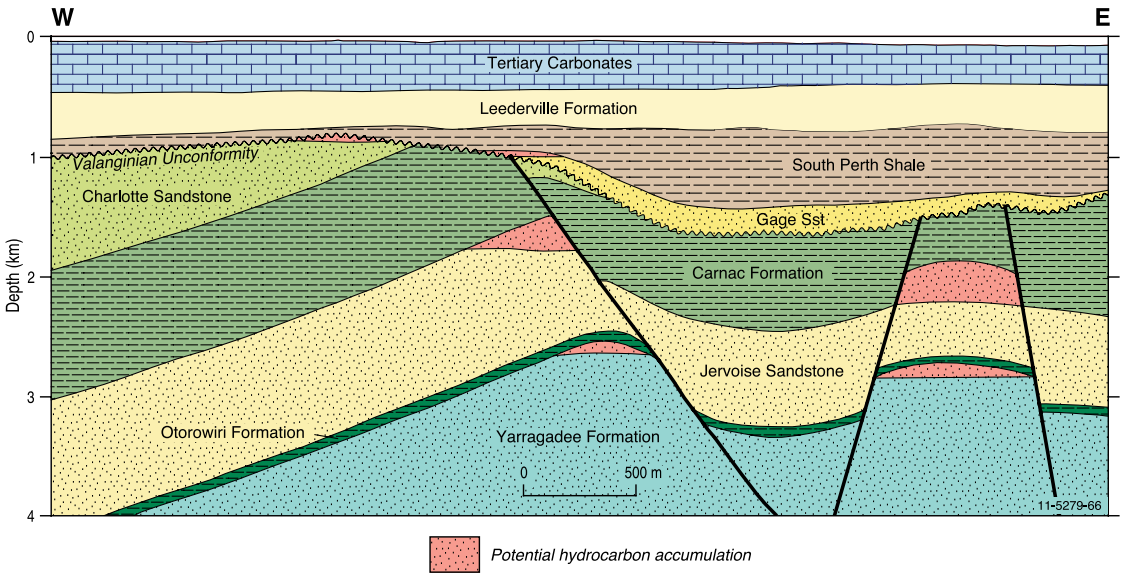

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1: Map of the structural elements of the Vlaming Sub-basin interpreted from geophysical and well data, underlain by a colour gravity image which reflects variations in rock density.

2: Conceptual model of various potential hydrocarbon traps (shown in pink) that exist at a number of stratigraphic levels in the Vlaming Sub-basin (modified from Marshall et al, 1993).

VLAMING SUB-BASIN PROSPECTIVITY ASSESSMENT

To better understand the geological evolution of the Vlaming Sub-basin and provide improved correlations to the unexplored deep water Mentelle Basin, Geoscience Australia undertook a prospectivity assessment of this sub-basin. The Vlaming Sub-basin is an elongate, north-south trending depocentre which is in water depths of between 20 and 1000 metres within the continental shelf and upper slope of the offshore southern area of the Perth Basin.

During initial exploration activity in the 1970s to early 1980s, reasonable 2D seismic coverage was acquired over most of the sub-basin and 16 wells were drilled. With the exception of a single non-commercial oil discovery, the wells were unsuccessful, which halted exploration activity for almost two decades. An uptake of acreage in the Vlaming Sub-basin in 2005 started a new round of exploration activity in the northern and central parts of the sub-basin.

Interpretations of 2D seismic data collected on the southwest margin have helped with the development of stratigraphic correlations between the Mentelle Basin and Vlaming Sub-basin. The prospectivity assessment of the Vlaming Sub-basin included biostratigraphic revisions for key wells, seismic interpretations of new and reprocessed data, geochemical assessments of key source rock intervals and liquid hydrocarbons, structural restoration of key seismic sections and 3D burial history modelling. Geoscience Australia's recent work in the Vlaming suggests that active petroleum systems are present across the entire sub-basin. In addition, the improved understanding of petroleum exploration wells drilled in the Vlaming Sub-basin enhance the prospectivity potential of the region.

The prospectivity assessments show that the Vlaming Sub-basin contains multiple source rocks for the generation of hydrocarbons from the latest Jurassic–Early Cretaceous to the present day. Good quality reservoirs are abundant and adequate seals are likely at several stratigraphic levels. Although the southern Vlaming Sub-basin is highly faulted, there are potentially good structural and stratigraphic plays. Recently completed 3D burial and maturation history modelling predicts the existence of hydrocarbon accumulations which remain untested.

ACHIEVEMENTS:

- **An improved understanding of the evolution of the Vlaming Sub-basin has provided a comprehensive assessment of its petroleum prospectivity and permitted a detailed assessment of the unexplored Mentelle Basin.**
- **3D petroleum systems modelling predicts a series of untested hydrocarbon accumulations across the basin, indicating potential for new discoveries.**

NEW OPPORTUNITIES:

- **The new assessment has improved the prospectivity of the Vlaming Sub-basin and modelling has predicted the occurrence of hydrocarbon accumulations which will underpin future rounds of acreage release.**

KEY PRODUCTS:

New exploration opportunities in the southern Vlaming Sub-basin. *APPEA Journal 48.*

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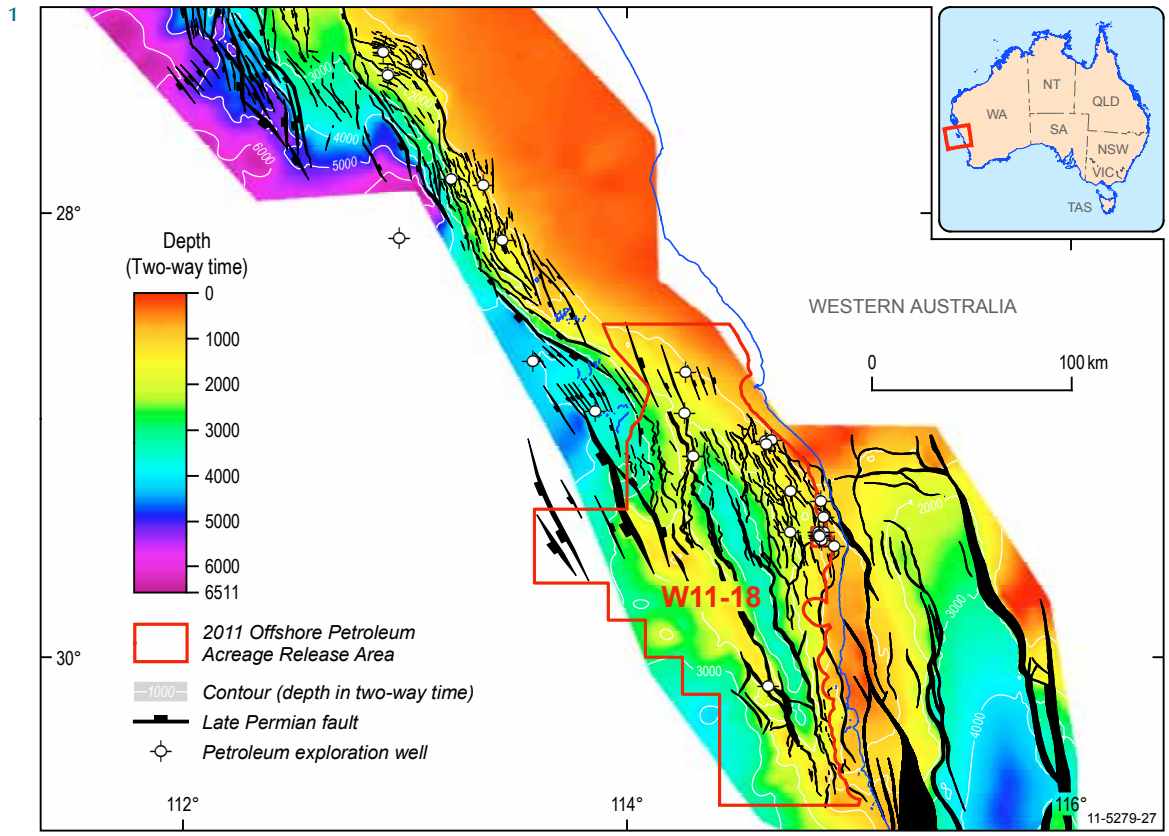

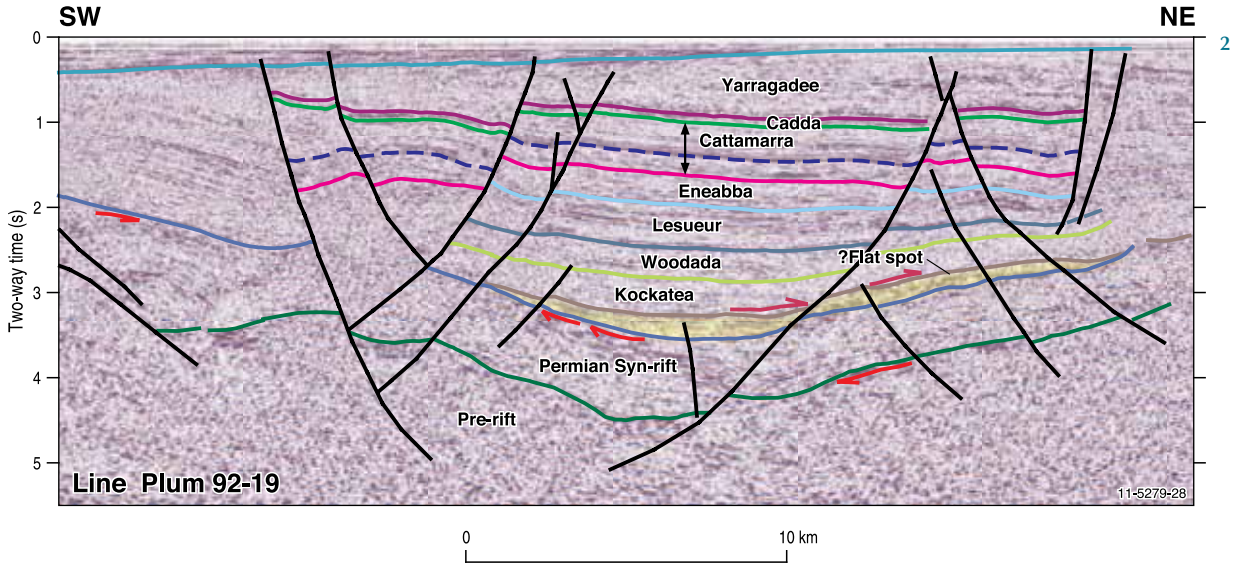

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1: Structure map of the Late Permian unconformity (primary reservoir target) in the offshore northern Perth Basin showing new Acreage Release Area W11-18.

2: Seismic line showing prospective late Permian basin floor fan (yellow) within an untested thick sedimentary section of the Abrolhos Sub-basin.

OFFSHORE NORTH PERTH BASIN PROSPECTIVITY ASSESSMENT

To stimulate renewed exploration interest in the northern Perth Basin, Geoscience Australia undertook a synthesis of open-file 2D and 3D seismic and well data to address key impediments to exploration in this region. This assessment included the first published analysis of data from 14 new exploration wells drilled since the Cliff Head 1 discovery in 2001, and the interpretation of new data acquired during Geoscience Australia's Southwest Margin Marine 2D Geophysical Survey in 2008/09. The revised stratigraphic interpretations and new knowledge of the northern Perth Basin are being used also to constrain regional assessments of the geological evolution of the entire area of Australia's southwest margin.

A new understanding of the basin history has been achieved through the integration of existing well data and the results of newly acquired seismic, geochemical and fossil data. New fossil time zonations resulted from the evaluation of an additional 123 samples of rock material from previous drilling. The integrated results led to the development of a fresh understanding of the depositional history for this part of the basin. A revised structural architecture was defined through interpretation of new and reprocessed seismic data, and key sequences were tied to the seismic grid. A refined tectonostratigraphic model for the offshore basin provided insights into basin evolution and prospectivity. Analysis of 180 new source rock samples proved there is widespread distribution of effective source rock intervals, and fluid inclusion analysis of 20 wells revealed the presence of 11 former oil columns.

Several active petroleum systems have been identified in the region on the basis of the molecular and isotopic composition of sampled oils. Proven Permian horst block plays with regional basal Triassic source/seal occur in the area and there are numerous untested leads, including an extensive late Permian basin floor fan play.

ACHIEVEMENTS:

- **The integrated synthesis of existing open-file well and seismic data and new data acquired during the Southwest Margin 2D seismic and marine reconnaissance surveys, has resulted in an improved understanding of basin evolution and the spatial distribution of key petroleum system elements.**

NEW OPPORTUNITIES:

- **New knowledge generated during the Offshore Energy Security Program has enhanced the prospectivity of the northern Perth Basin for oil and gas, resulting in the release of one large frontier block in 2011. The new knowledge and data also will underpin the release of exploration blocks in the future.**

KEY PRODUCTS:

New exploration opportunities in the offshore northern Perth Basin. *APPEA Journal 51.*

Offshore northern Perth Basin Well Folio. *Geoscience Australia Record 2011/09.*

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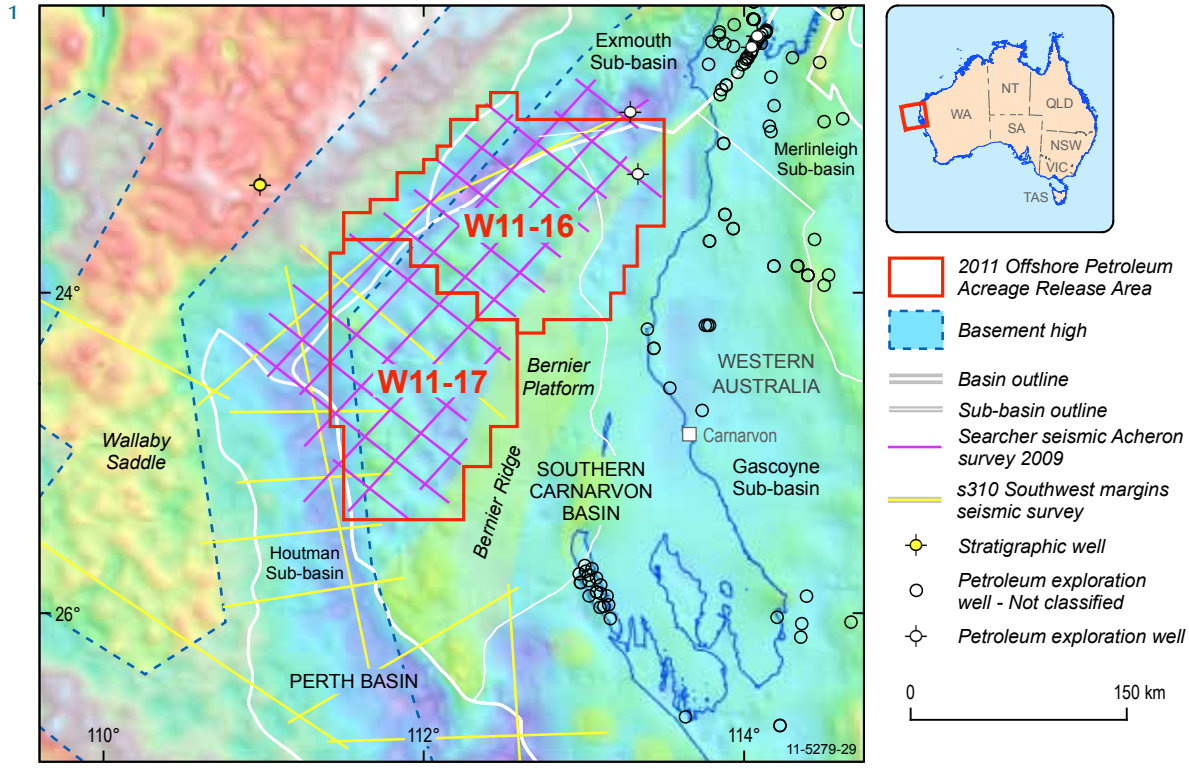

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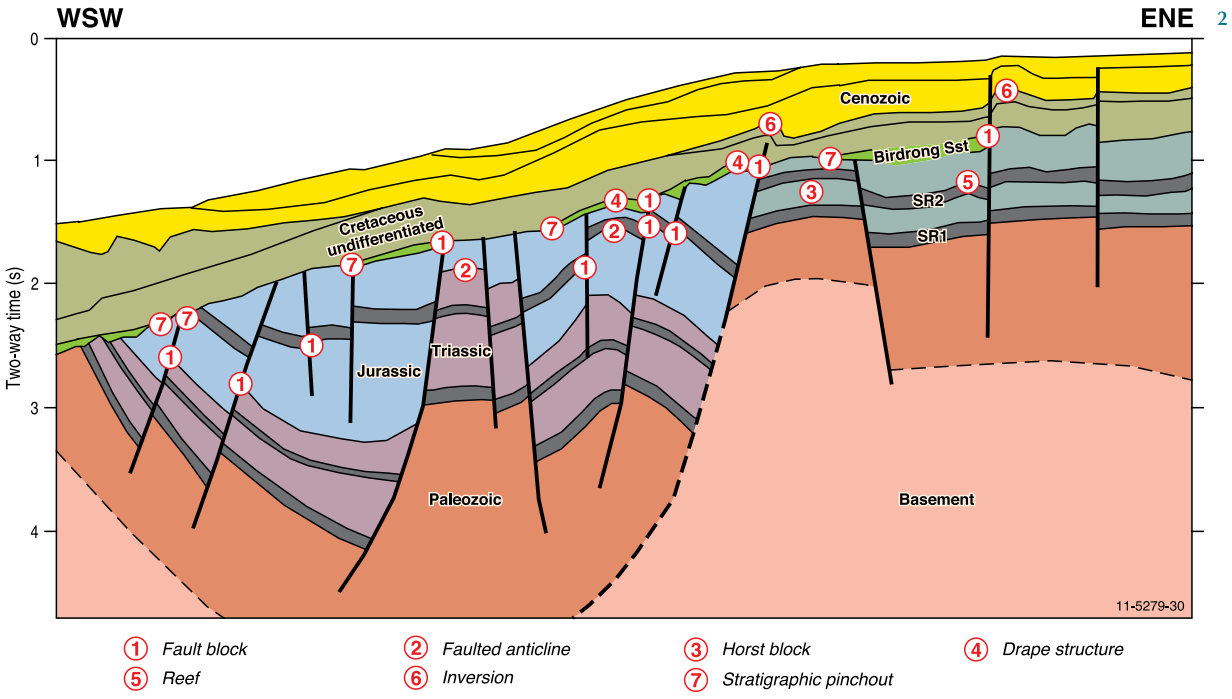

1: Location of the Southern Carnarvon Basin, showing data coverage (seismic lines and wells) and 2011 Acreage Release Areas.

2: Conceptual play diagram for the 2011 Acreage Release Areas showing potential hydrocarbon trapping mechanisms.

SOUTHERN CARNARVON BASIN PROSPECTIVITY ASSESSMENT

To renew exploration interest in this frontier region Geoscience Australia undertook a prospectivity assessment of the Bernier Platform in the Southern Carnarvon Basin and the southernmost parts of the Exmouth Sub-basin. Two wells have been drilled in this frontier area. In 1969 a single exploration well tested the petroleum prospectivity of the Bernier Platform. In 2003 a single exploration well was drilled in the southern parts of the Exmouth Sub-basin. Prior to 2009 most of this area had very limited seismic coverage with, typically, in excess of 50 kilometres between adjacent lines.

In 2008/09, under the Offshore Energy Security Program, Geoscience Australia acquired 800 line kilometres of regional seismic data in the outer part of the Southern Carnarvon Basin. Seismic lines targeted potential depocentres (areas of thickest deposition in a sedimentary basin) delineated by gravity lows, some of which extended beyond previously mapped basin boundaries. Following this, Searcher Seismic Pty Ltd acquired a regional grid in November 2009 with line spacing of 25 kilometres across the entire western Bernier Platform.

The petroleum potential of the area has been assessed using the new Geoscience Australia seismic data and existing industry data, combined with drilling information and published regional geological compilations. The study also considered preliminary findings from the new multi-client seismic survey provided to Geoscience Australia courtesy of Searcher Seismic Pty Ltd. Assessment of the data has shown that the region has two potentially active petroleum systems, one a Paleozoic system and the other a Mesozoic system. Potential hydrocarbon traps identified within the Bernier Platform include sandstones sealed by marine shales, carbonate reef complexes and inversion anticlines while in the southern part of the Exmouth Sub-basin the traps include sandstone sealed by the overlying shales or marine claystone. With a range of both Mesozoic and Paleozoic plays, this region of more than 38 000 square kilometres has significant untested hydrocarbon potential.

ACHIEVEMENTS

- **An improved understanding of the geological evolution of the deep-water Southern Carnarvon Basin based on the integrated interpretation of existing open-file well and seismic data, and new seismic data collected by Geoscience Australia.**
- **New insights into the hydrocarbon prospectivity of previously unexplored parts of the Exmouth Sub-basin and western Bernier Platform.**

NEW OPPORTUNITIES:

- **Frontier exploration acreage released in the Southern Carnarvon Basin in 2011, based on new data and upgraded prospectivity of the area, is anticipated to lead to renewed interest and activity by exploration companies searching for a new petroleum province.**

KEY PRODUCTS:

Petroleum potential of the offshore Southern Carnarvon Basin—insights from new Geoscience Australia data, 2011. *Extended abstract APPEA Conference.*

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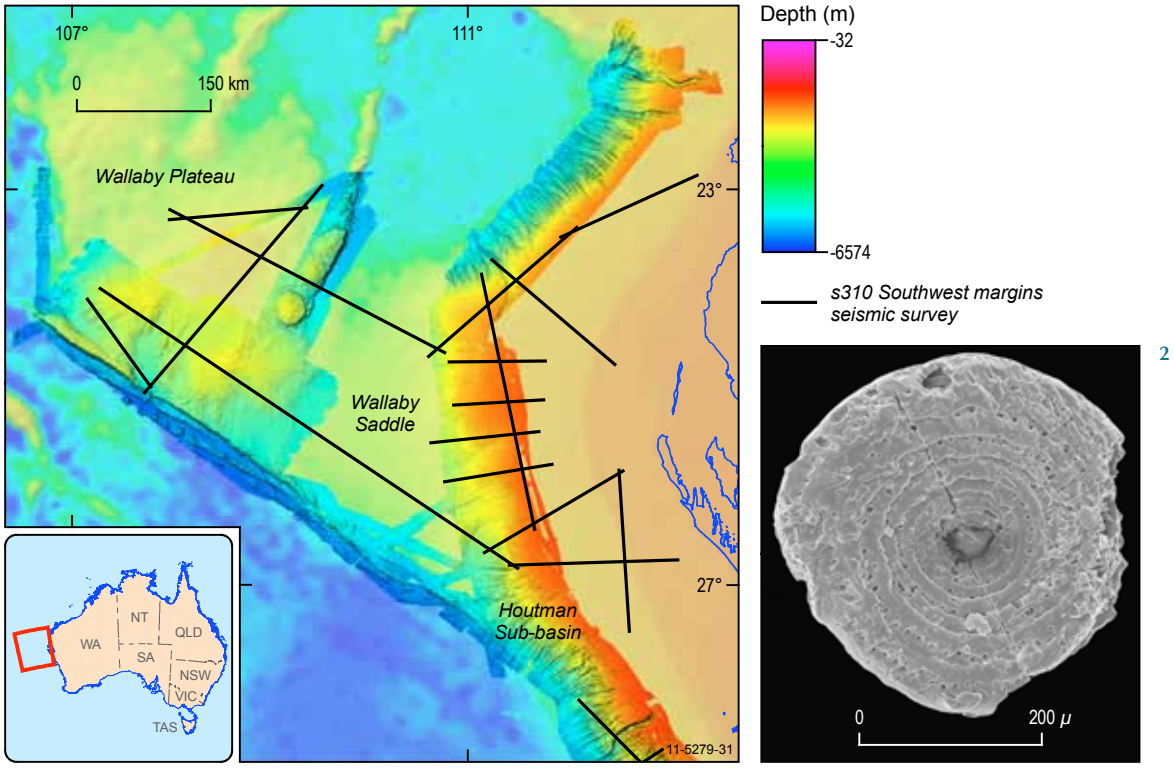

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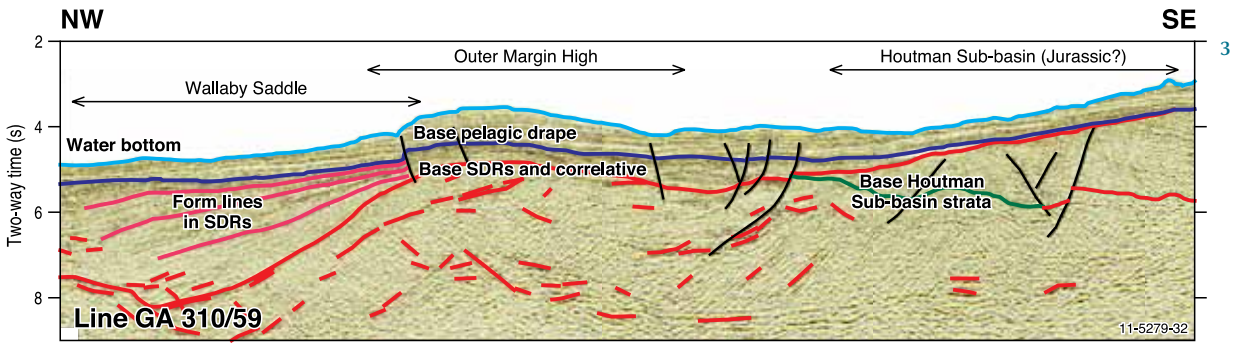

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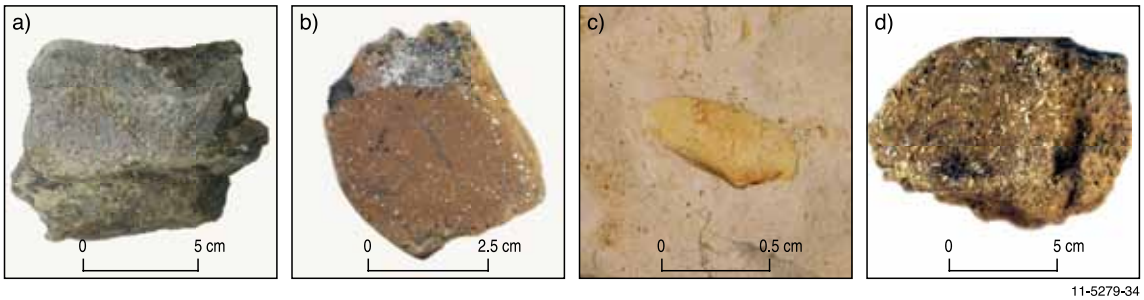

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1: Location of new bathymetry and seismic data over the Wallaby Plateau and adjacent areas.

2: Jurassic fossil foram obtained from a Wallaby Plateau sedimentary sample.

3: Seismic image showing interpreted sedimentary sections over the Wallaby Saddle and Houtman Sub-basin.

4: Dredge samples of volcanic rocks (a & b) and sediments containing fossils (c & d).

WALLABY PLATEAU PROSPECTIVITY ASSESSMENT

The hydrocarbon prospectivity of the Wallaby Plateau is unknown. However, the 2D seismic data obtained during the Southwest Margin Marine 2D Geophysical Survey in 2008/09, along with the potential field and bathymetry data and geological samples acquired under the Offshore Energy Security Program provide the necessary data to permit an initial assessment of the region's prospectivity and provide a basis for further marine planning.

The Wallaby Plateau is an extensive bathymetric high which covers about 100 000 square kilometres at water depths of 2200 metres to greater than 4000 metres, west of Carnarvon, Western Australia. The Cuvier Abyssal Plain lies to the north of the plateau and the Perth Abyssal Plain to the south. The Wallaby Saddle to the east is a bathymetric low between the Wallaby Plateau and the northern Carnarvon Terrace. Most of the plateau is within Australia's Extended Continental Shelf recommended by the United Nations Convention of the Law of the Sea.

Prior to recent investigations under the Offshore Energy Security Program, understanding of the geology and tectonic evolution of the Wallaby Plateau was limited by the quality and coverage of data. New, high quality data over the Wallaby Plateau was acquired as part of Geoscience Australia's 2008/09 south west margin 2D seismic and marine reconnaissance surveys. The latter collected 65 000 square kilometres of muilti-beam sonar, magnetic and gravity data and 31 lithologic samples, while the 2D seismic survey collected 1100 line kilometres of seismic, gravity and magnetic data.

Analysis of these data has dramatically improved the understanding of the geological structure and evolution of the Wallaby Plateau, Wallaby Saddle, and the adjacent western margin of Australia. The data have also enabled a more rigorous assessment of petroleum prospectivity for the region, which is currently considered to be low because of extensive rift-related volcanism. In addition, the characterisation of regional seabed environments will inform any future resource exploration and underpin improved marine zone management in the region.

ACHIEVEMENTS:

- **A significantly improved understanding of the structure, composition and geological evolution of the Wallaby Plateau and the first assessment of its prospectivity. The complexity of the area is indicated by the first record of Jurassic sedimentary rocks demonstrating that the area is a continental fragment of the Australian plate.**

NEW OPPORTUNITIES:

- **Thick stratified rock sequences have been identified within continental blocks on the Wallaby Plateau, but because there is evidence of extensive rift related volcanism, the petroleum prospectivity of this region is assessed as low. However, given the size of the area and the sparseness of data, further work is warranted.**

KEY PRODUCTS:

Frontier Basins of the West Australian Continental Margin: Post-survey Report of Marine Reconnaissance and Geological Sampling Survey GA2476. *Geoscience Australia Record 2009/38.*

Seismic Veolocity Insights into the Wallaby Plateau. *ASEG Extended Abstracts Volume 2010 (1).*

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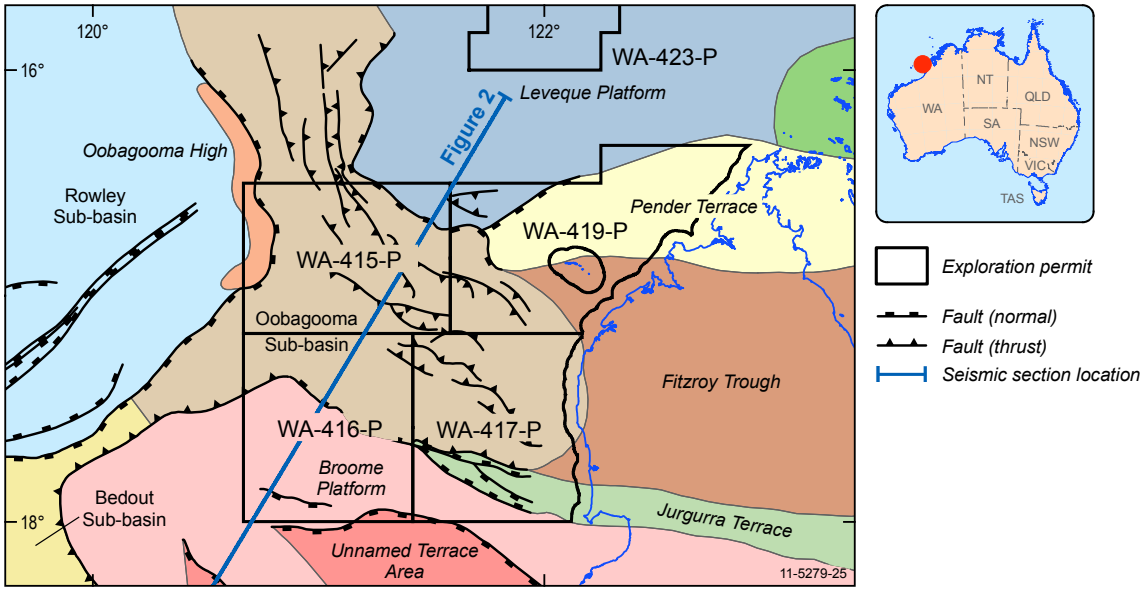

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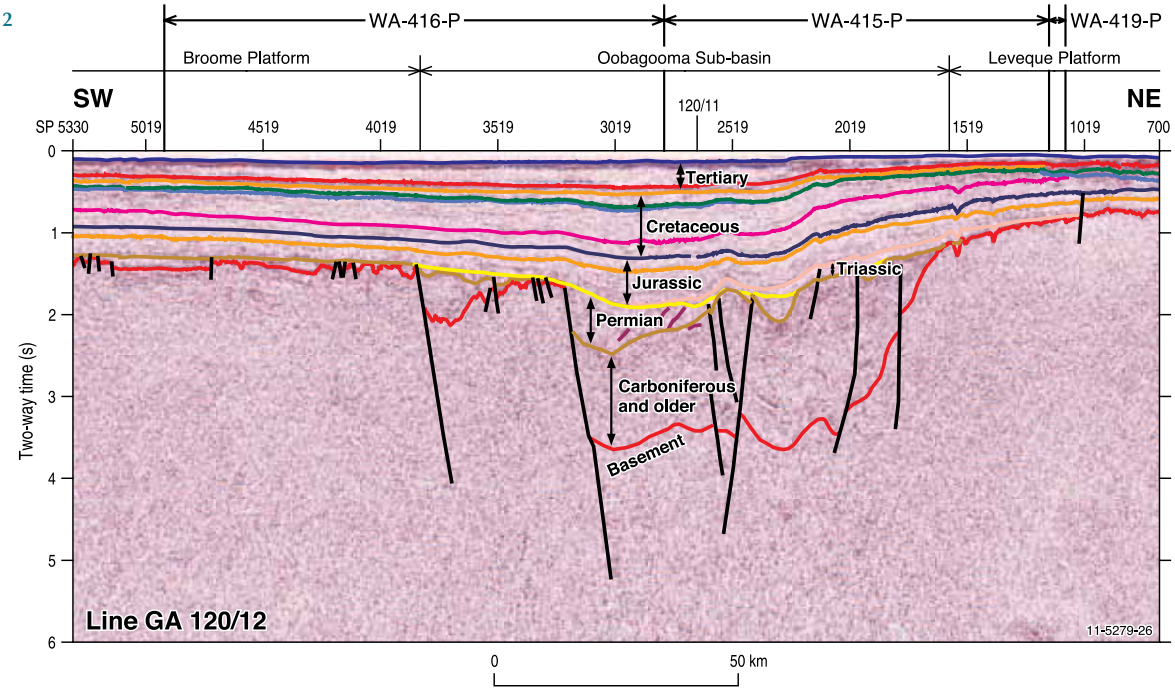

1: Structural map of the offshore Canning Basin showing newly awarded exploration permits.

2: Interpretation of GA seismic line 120/212 across the Oobagooma Sub-basin showing prospective Permian-Carboniferous succession in a deep basin setting.

OFFSHORE CANNING BASIN PROSPECTIVITY ASSESSMENT

The offshore Canning Basin is an under-explored, shallow water (less than 500 metres) extension of a proven, but small, onshore oil and gas province of northern Western Australia. To overcome negative perceptions about the prospectivity of this neglected frontier area, Geoscience Australia embarked on a program to acquire and interpret new pre-competitive data.

The first activity, which commenced during the Australian Government's New Petroleum Program in June 2006 was a survey of the central North West Shelf, by the *RV Southern Surveyor*. That survey was designed to identify potential natural hydrocarbon seeps which might be indicative of oil or gas accumulations at depth and to investigate the nature of the benthic habitats. No definitive evidence of hydrocarbon seepage was detected, suggesting that if hydrocarbon traps were present they have not been breached.

The shipboard survey was followed by an aeromagnetic survey in 2007 covering 31 770 square kilometres. The survey data, which was released in late 2007, along with an interpretation report, were designed to assist companies in assessing the petroleum potential during the bidding period for four acreage release blocks.

The interpretation of this new magnetic survey data, together with open file seismic and well data, has identified a number of potential stratigraphic and structural hydrocarbon plays in this area. It is anticipated that the work program on the four exploration permits subsequently taken up by industry in the offshore Canning Basin will investigate these opportunities and further add to the knowledge of this frontier region.

ACHIEVEMENTS:

- **A total of four acreage blocks released were subsequently awarded exploration permits with an indicative total $106 million work program over six years; $6.4 million of which is guaranteed in the first three year period.**

NEW OPPORTUNITIES:

- **The new data and pre-competitive knowledge for this area will continue to underpin future acreage releases and attract exploration attention to this under explored area.**

KEY PRODUCTS:

Aeromagnetic Interpretation and Petroleum Prospectivity Assessment—offshore Canning Basin, Western Australia. *Encom Technical Report—80750.* February 2008.

Geoscience Australia Marine Survey SS06/2006 Post Survey Report: Natural hydrocarbon seepage survey on the central North West Shelf. *Geoscience Australia Record 2007/21.*

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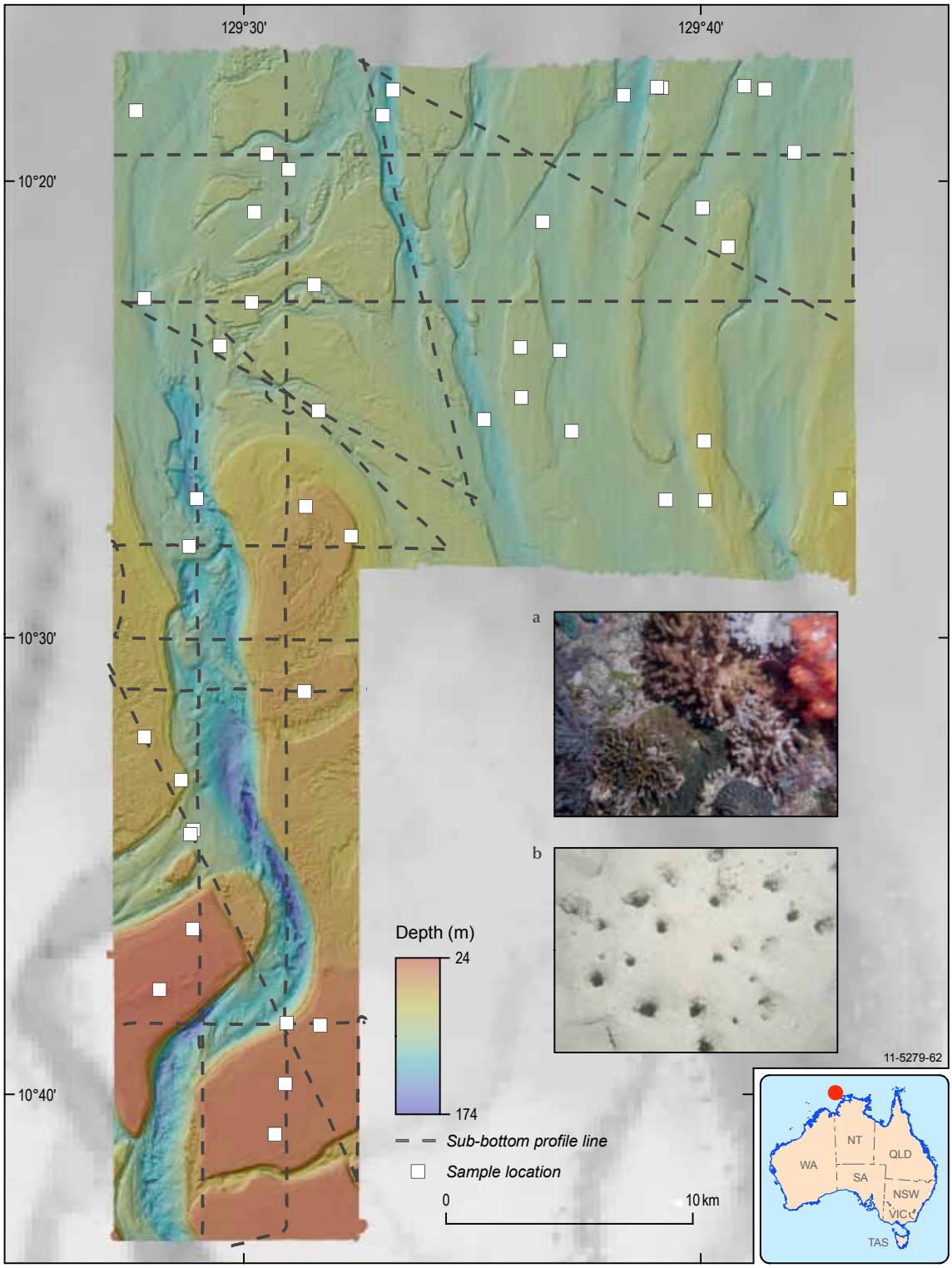

1: High resolution map (colour) of the outer continental shelf, eastern Joseph Bonaparte Gulf, showing a complex system of submarine valleys, terraces and banks superimposed on grey background map of existing data. Inset photos show examples of: (a) soft and hard corals at 25 m water depth, and; (b) heavily burrowed soft sediments at 100 m water depth.

JOSEPH BONAPARTE GULF SEABED ENVIRONMENT STUDY

The Joseph Bonaparte Gulf and Timor Sea are shallow tropical seas located to the northwest of Darwin, in the Northern Territory. The region supports significant and growing regional economic activity, including exploration for hydrocarbons and the creation of infrastructure to effectively exploit oil and gas reserves.

Prior to the recent work by Geoscience Australia, only regional seabed sediment datasets existed and these were collected more than 30 years ago by Geoscience Australia's predecessor, the Bureau of Mineral Resources, Geology and Geophysics. Although bathymetry data has been collected by Royal Australian Navy hydrographic surveys and the major seabed features are relatively well known, little data existed on the detailed nature of the Joseph Bonaparte Gulf and Timor Sea environments.

The new work in 2009 and 2010, during the final stages of the Australian Government's Offshore Energy Security Program, comprised surveys which comprehensively mapped and sampled representative seabed environments associated with shallow marine environments of the eastern Joseph Bonaparte Gulf. Overall, the surveys collected 2000 square kilometres of very high resolution multi-beam bathymetry data, 970 line kilometres of shallow sub-bottom profiler data, 340 seabed samples, 28.5 hours of video, and more than18 500 digital images on the carbonate banks, channels and soft sediment plains of the Joseph Bonaparte Gulf.

The carbonate banks comprise very complex habitats which support luxuriant sponge and coral gardens while the deeper channels are characterised by strong tidal currents with a rich array of animals within the sediment. Many new species have been identified and abundant branching coral debris was observed at one location indicating that hard corals were once more extensive than at present.

Collection and analysis of these data has significantly advanced the current knowledge of seabed environments in the region. For the first time, detailed spatial information on the type of seabed habitats and biota along with potential geohazards, including petroleum seeps, can be used to guide future resource exploration and development and improve marine zone management.

ACHIEVEMENTS:

- **Improved understanding of the types and extent of seabed environments of the eastern Joseph Bonaparte Gulf based on very high resolution multi-beam bathymetry and shallow sub-bottom profiler data coupled with seabed sampling, video footage and digital still images.**
- **Established a comprehensive inventory of physical and biological seabed properties for shallow tropical seas off northern Australia, including the discovery of new species.**

NEW OPPORTUNITIES:

- **This first detailed characterisation of seabed environments will guide future resource exploration and development and greatly enhance future marine zone management.**

KEY PRODUCTS:

Seabed Environments of the Eastern Joseph Bonaparte Gulf, Northern Australia—GA0325/SOL5117 Post-survey Report. *Geoscience Australia Record 2011/08.*

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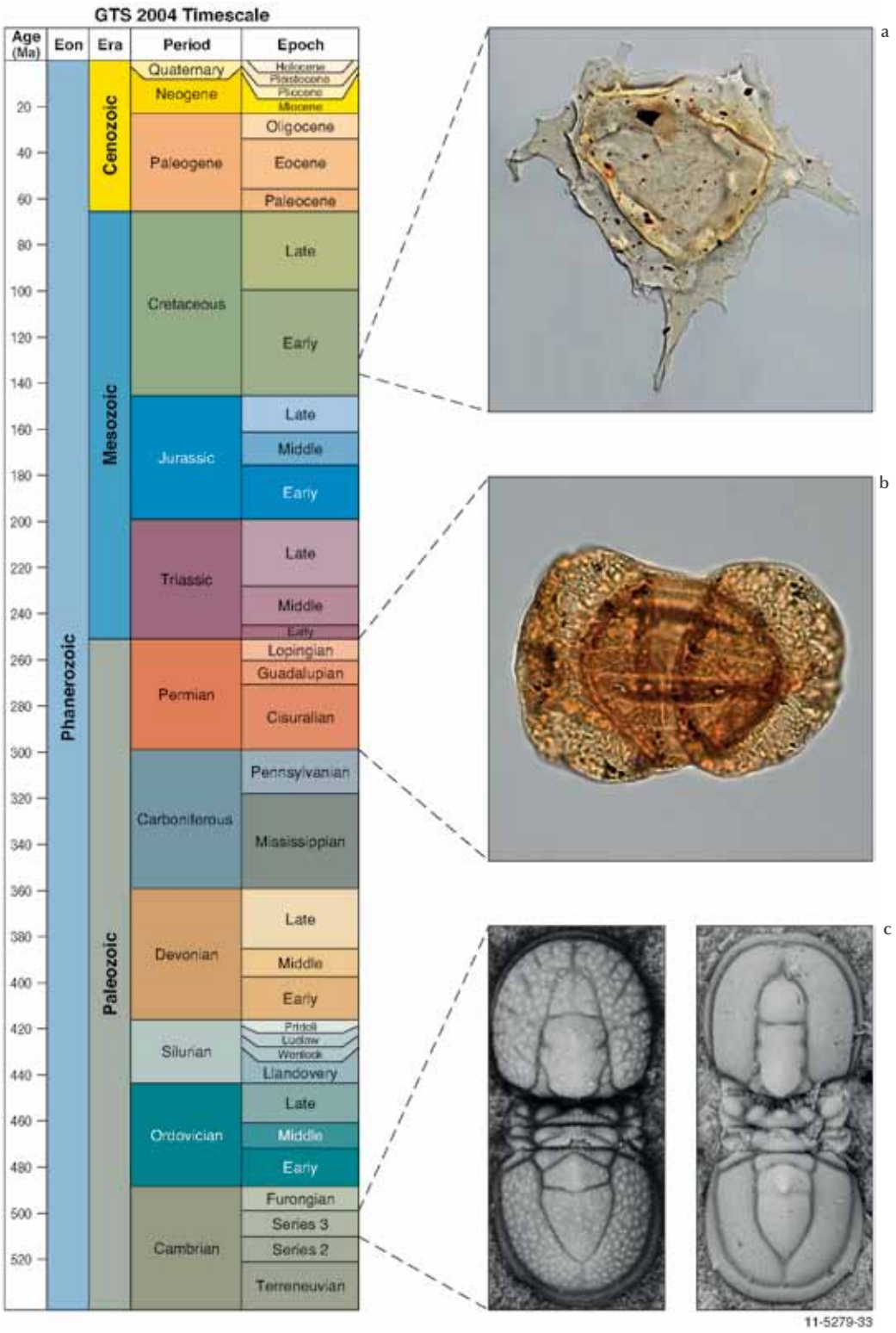

1: Examples of Australian fossil markers: (a) *Phoberocysta necomica;* (b) Permian striate pollen; (c) trilobites tied to the internationally accepted Geologic Time Scale 2004, thus allowing meaningful correlation of rock strata on a regional and global scale.

TIMESCALES PROJECT

Geological timescales provide a global means of understanding the Earth's history. Geoscience Australia has adopted the 2004 Geologic Time Scale, accepted by the International Commission on Stratigraphy as the global standard though its International Stratigraphic Chart. The Timescales Project relates local fossil biozones to the international scales. Plant microfossils, including spores, pollen and marine dinoflagellate algal cysts are widely used by the Australian petroleum industry as zonal markers. Many zones are yet to be formally defined and through a collaborative Virtual Centre for Economic Micropaleontology and Palynology, Geoscience Australia works with the British Geological Survey to formally define these zones. Modern radio-isotopic dating techniques also deliver increasingly accurate numeric ages, which contributes to the ongoing revision of the International Stratigraphic Chart.

Based on these studies, an extensively revised Australian Biozonation Chart (2010) was produced showing the fossil zones against the timescale. Compilations were produced for each of the major petroleum basins showing sedimentary successions and hydrocarbon occurrences. The sedimentary rock packages are related to the timescale, mostly by microfossil occurrences, which allows for precise and consistent correlation at a basinal, regional or global scale. Microfossils remain one of the most important tools used by hydrocarbon exploration companies to correlate within and between basins, and can be used to aid detailed hydrocarbon-reservoir mapping.

ACHIEVEMENTS:

- **Related the Australian biozonation schemes to the Geologic Time Scale 2004—the accepted global standard reference. This allows for meaningful correlation of rock strata on a regional and global scale.**
- **Revised biozonation and lithostratigraphy charts for Australia's major offshore hydrocarbon producing basins. These charts depict the standardised biozones, formation names and hydrocarbon occurrences for each basin against the global standard timescale.**
- **Review of the chronostratigraphic ages of the Triassic-Jurassic palynological zones of the North West Shelf. These fossil zones are a major correlation tool used by the hydrocarbon exploration industry.**

NEW OPPORTUNITIES:

- **The petroleum exploration industry can now produce stratigraphic and timescale charts using a readily available datapack of standardised Australian biostratigraphic and lithostratigraphic data in conjunction with the TimeScale Creator software.**

KEY PRODUCTS:

Australian Datapack for TimeScale Creator Software 2010. www.ga.gov.au/products/servlet/controller?event=GEOCAT_DETAILS&catno=68802

Basin Biozonation and Stratigraphy Charts 2010. www.ga.gov.au/products/servlet/controller?event=GEOCAT_DETAILS&catno=70371

OFFSHORE *Information Management*

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1: Warehousing of data tapes from industry and Geoscience Australia seismic surveys requires labour-intensive retrieval and handling.

2: New Robotic Data Store contains 1.5 Petabytes of readily accessible data to service industry and Geoscience Australia requirements.

ROBOTIC STORAGE AND DELIVERY OF SEISMIC DATA

In support of the Offshore Energy Security Program, Geoscience Australia undertook an extensive program of seismic data concatenation from low density media to high density media (IBM3592 500 Gigabyte tapes). This has improved the efficiency of data storage by reducing the volume of media needed for the collection. Benefits include: improved preservation of the existing collections, faster access to data, and greater ease of copying using industry standard media. In addition, the remastering of seismic data collected by Geoscience Australia in the 1980s and early 1990s on older media and in older formats continued from 2007 to 2010. These surveys are important because they frequently provide a regional framework of key tie lines which link more localised industry seismic surveys.

In conjunction with these initiatives, Geoscience Australia has purchased and installed a Robotics Data Store to house the collections of processed and field seismic data submitted by industry under legislative requirements. Migration of the entire collection of publicly available processed seismic data has been completed and the migration of field seismic and in-confidence data is expected to be complete by the beginning of 2012. The volume of the migrated data is anticipated to be in excess of 1.5 Petabytes (1.5 million Gigabytes).

The benefits of this program include enhanced data preservation, more rapid access to data for clients and improved quality control on data holdings. New data delivery mechanisms have been instituted to provide seismic data on digital hard drives and tape. This has reduced the delivery time for data to clients and seen data borrowings increase from less that 100 Terabytes to more than 300 Terabytes annually over the past three years. Disaster recovery has been improved by the creation of an offsite back-up of this key data collection. The migration process is leading to new quality control mechanisms for submitted seismic data which will improve the overall management of the offshore seismic data collection.

ACHIEVEMENTS:

- **Creation of a near on-line digital data store for seismic data from existing, re-mastered tape collections.**
- **Enhanced preservation and off-site backup of seismic data collections submitted under the *Offshore Petroleum and Greenhouse Gas Storage Act (2006)*.**
- **Improved efficiency of data delivery mechanisms.**

NEW OPPORTUNITIES:

- **Migration of data from tape storage to near on-line digital storage on the robotic system will have future benefits as self-service of data becomes possible and web delivery increases.**

KEY PRODUCTS:

E-mail address (ausgeodata@ga.gov.au) through which data can be requested.

OFFSHORE *Information Management*

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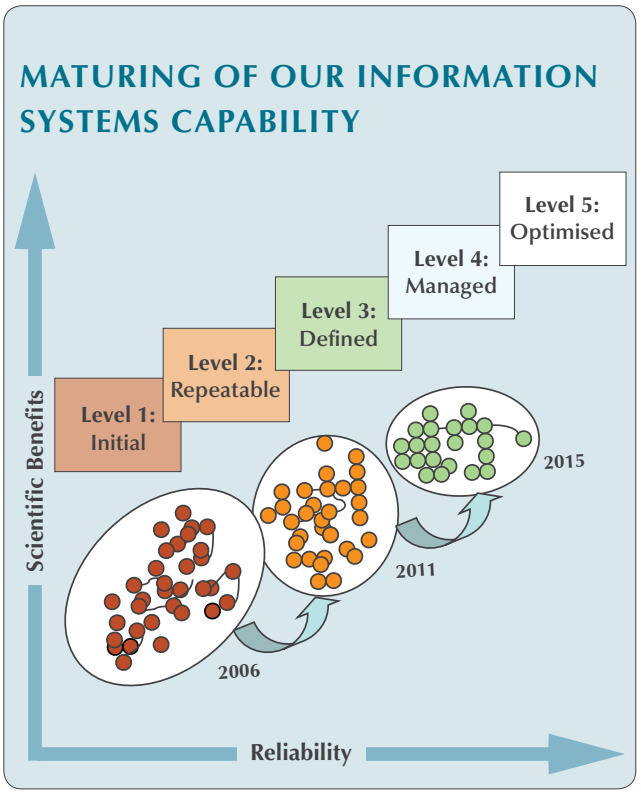


1: The ability to access multiple data sets aids interpretation of complex problems.

2: The new Geoscience Australia Website contains upgraded petroleum data and information about Australia's sedimentary basins.

3: The Virtual Data Room application is designed to facilitate the discovery and delivery of pre-competitive geoscientific data.

4: Maturing of our information systems capability is an ongoing priority to meet ever-increasing demands for data.

PETROLEUM DATABASES AND INFORMATION MANAGEMENT

The Offshore Energy Security Program provided the resources to improve the management of petroleum data and information held by Geoscience Australia. In collaboration with the States and Territories, Geoscience Australia initiated a move to an environment in which the nation's digital assets on petroleum resources are managed within a federated architectural framework with clearer lines of responsibility, custodianship and consistency.

With a better understanding of the data and information being held by Geoscience Australia, it is possible now to rationalise these datasets and move towards achieving a Single Point of Truth framework for petroleum and associated data. This is being achieved by progressively upgrading Geoscience Australia's systems and linking them together in a more modular and integrative architecture.

In 2008, Geoscience Australia set up a number of taskforces to drive improvement in the capability and maturity of the agency's project management and software development practices. This is now an embedded process which will be used for future development strategies.

Development of the Virtual Data Room was undertaken by Geoscience Australia's Petroleum and Marine Division as part of the Energy Security Initiative. This application is aimed at facilitating the discovery and delivery of pre-competitive geoscientific data to assist petroleum exploration within Australia at a national level.

It is envisaged that, in the near future, industry will be able to transfer its operational data seamlessly into Geoscience Australia's data stores as the agency moves towards a service delivery model more in line with Gov 2.0 Taskforce principles. Data and information will become more easily discoverable and accessible and Geoscience Australia will leverage off contemporary technologies and information management practices to free up its scientists and engineers so they can add value to the raw data which has been acquired on Australia's natural resources.

ACHIEVEMENTS:

- **Initiated a move away from a compartmentalised approach to systems development and data management, to a more effective, federated architectural framework.**
- **Development of better integrated petroleum databases with reduced duplication.**

NEW OPPORTUNITIES:

- **Better integrated data management system will allow seamless delivery of high quality petroleum data via a streamlined, web-enabled data discoverability and delivery service.**

KEY PRODUCTS:

Petroleum Information Management System (PIMS). www.ga.gov.au/oracle/npd/

Virtual Data Room (VDR). www.vdr.ga.gov.au

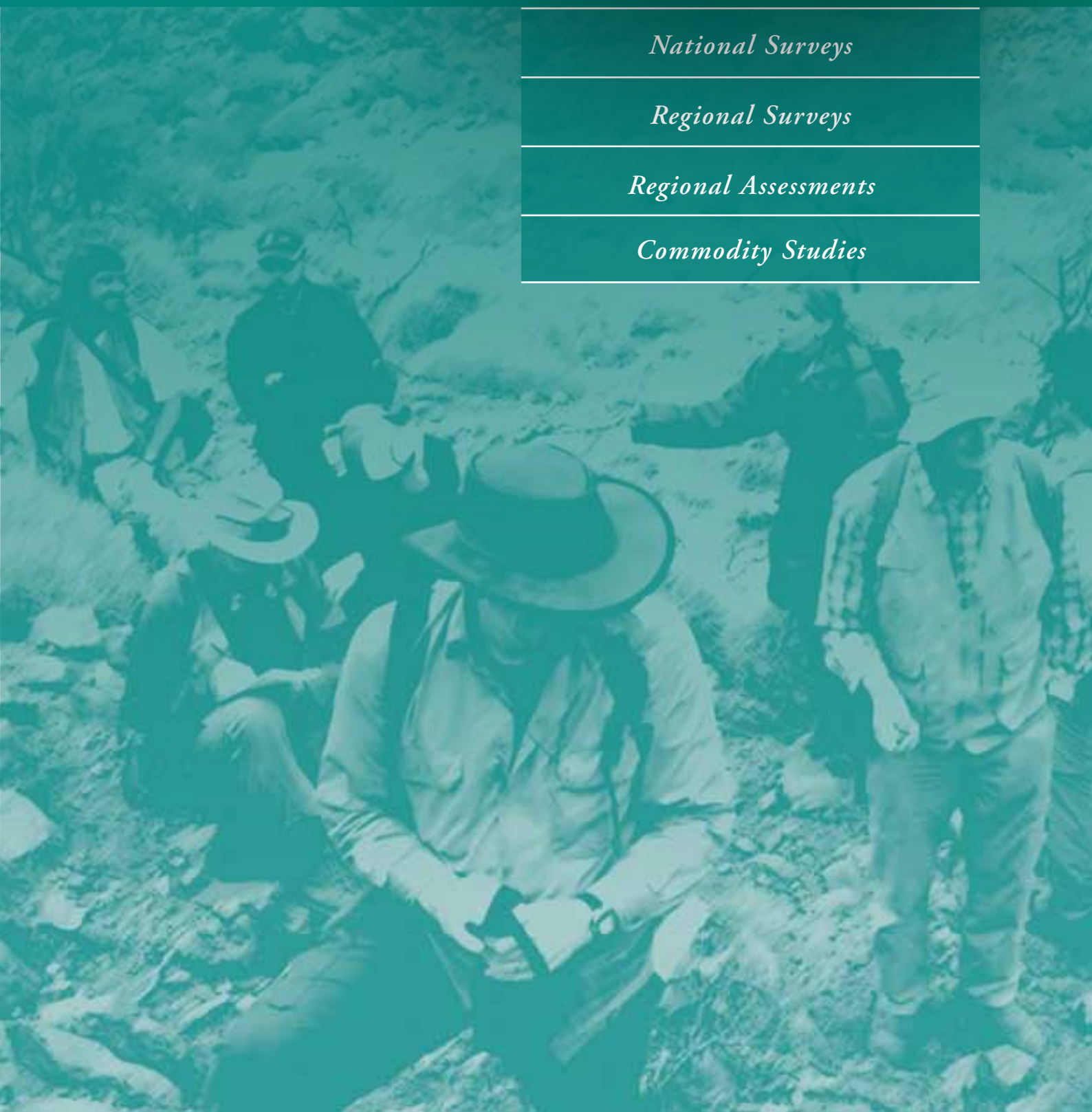
ONSHORE

National Surveys

Regional Surveys

Regional Assessments

Commodity Studies



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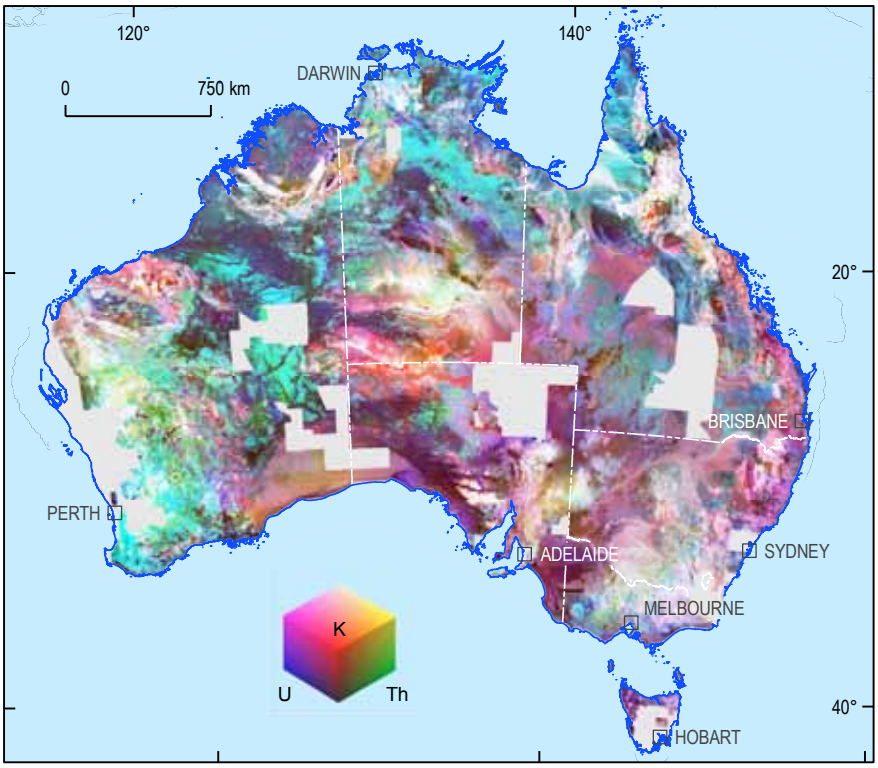

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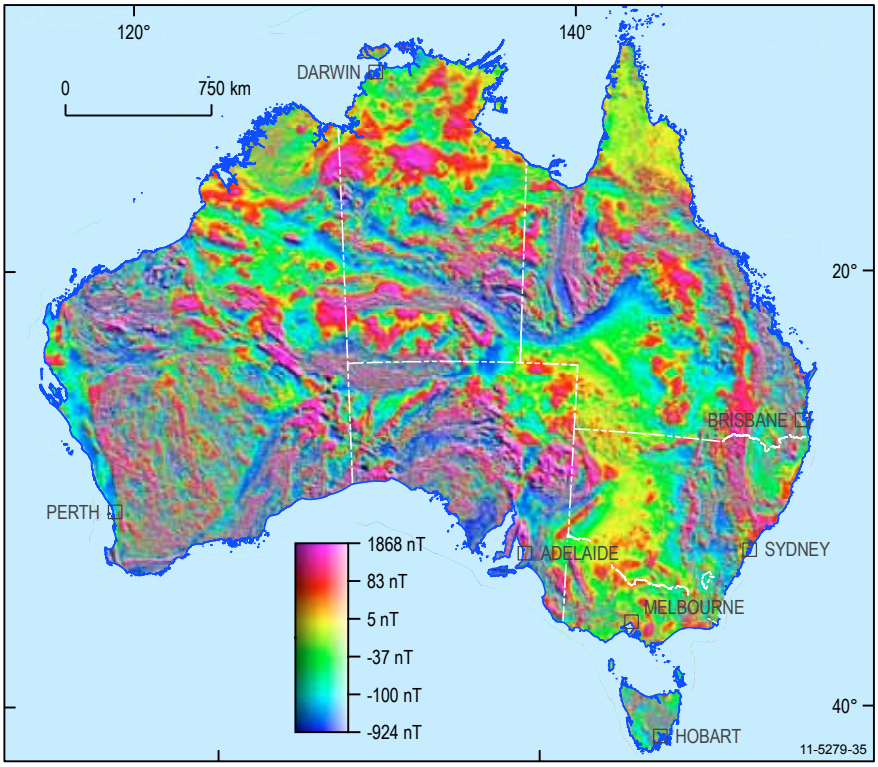

1: Radiometric image of Australia (red—potassium, green—thorium, blue—uranium).

2: Magnetic image of Australia.

RADIOMETRIC AND MAGNETIC MAPS OF AUSTRALIA

The Australia-wide Airborne Geophysical Survey acquired radiometric and magnetic data across the continent and is one of the largest airborne geophysical surveys undertaken anywhere in the world. Flown by Aeroquest (Aust) Pty Ltd in 2007, its purpose was to adjust all available radiometric survey data to a common standard and to improve the quality of continent-scale data within the National Magnetic Database. The survey consisted of north-south flight lines spaced 75 kilometres apart, and east-west tie lines spaced 400 kilometres apart. The data acquired were merged with all existing airborne geophysical surveys to create the first Radiometric Map of Australia and a new edition of the Magnetic Anomaly Map of Australia.

The Radiometric Map of Australia is the first national image of the distribution of airborne measured potassium, uranium and thorium across the continent. The map and associated digital datasets cover more than 80 per cent of the Australian continent at 100 metre resolution and can be used to reliably compare the radiometric signatures of different parts of the continent. This enables the assessment of mineralogical and geochemical properties of bedrock and regolith materials from different geological provinces and regions. The data support a range of different applications including geological mapping, mineral and petroleum exploration, geomorphological studies and environmental mapping.

The Magnetic Anomaly Map of Australia (1:5 million scale) and accompanying composite digital dataset (with cell resolution of 80 metres) is the 5th edition produced by Geoscience Australia and its predecessor organisations. The map enables geologists to view the distribution of rock units below the surface based on their magnetic character. This is important in areas of significant thickness of surface cover (regolith and sedimentary basins) which masks the underlying crystalline basement rocks. The magnetic signatures of the basement can be measured through the cover, and can be used to determine the nature and depth to the basement.

ACHIEVEMENTS:

- Production of the Radiometric Map of Australia, the first for an entire continent.
- Acquisition of radiometric and magnetic data over the entire Australian continent at 75 kilometre flight line spacing.
- Levelling and merging of all public-domain radiometric and magnetic data to a common baseline.

NEW OPPORTUNITIES:

- The Radiometric Map of Australia provides capability to quantitatively compare radiometric responses from all regions of Australia for mineral exploration, surface landform studies and natural radiation hazard assessment.
- The improved quality and resolution of the latest Magnetic Anomaly Map of Australia provides new details on the nature of the crust and depth to basement.

KEY PRODUCTS:

Radiometric Map of Australia (1st Edition) and associated grids.

Magnetic Map of Australia (5th Edition) and associated grid.

ONSHORE *National Surveys*

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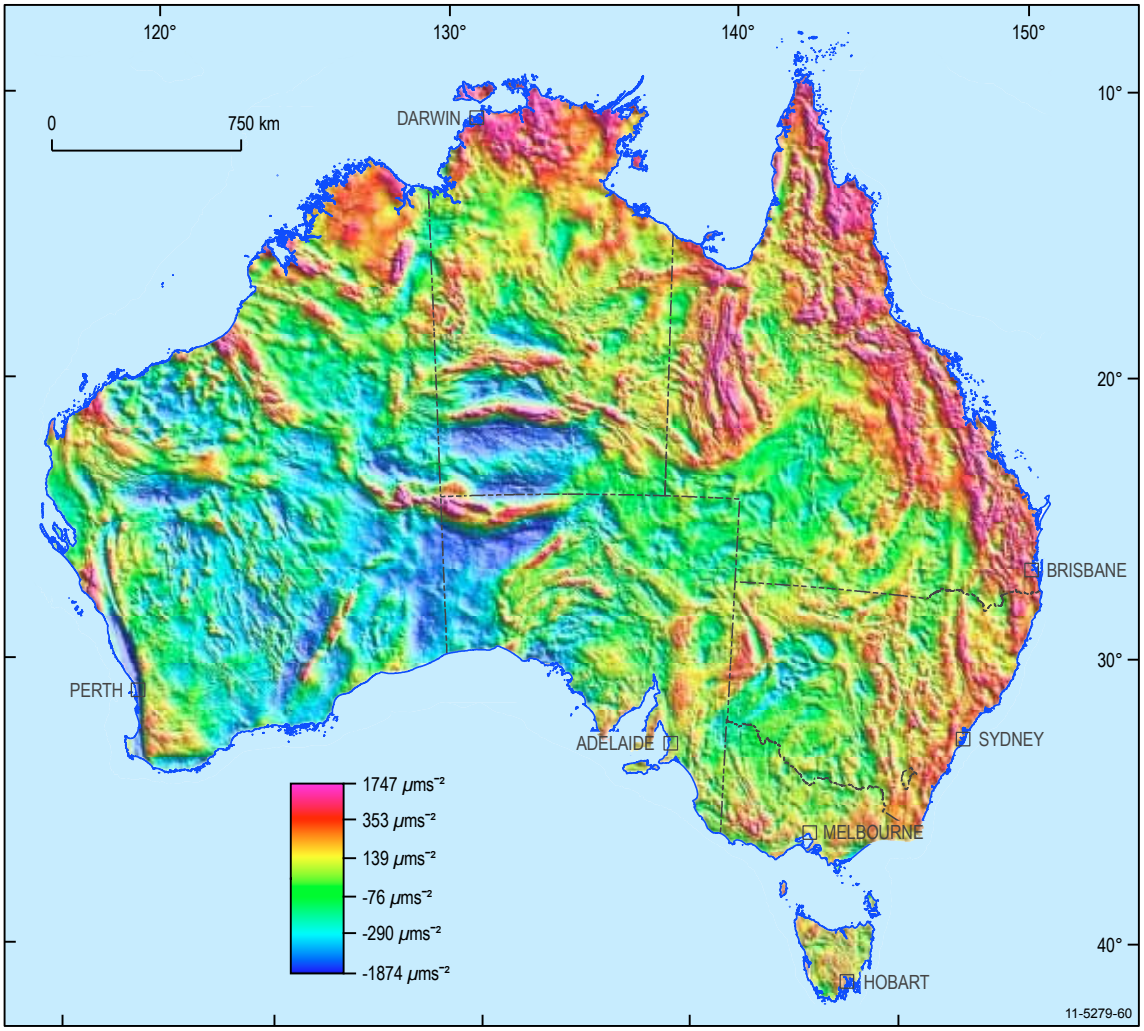

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1: Isostatic Residual Gravity Anomaly image of Australia.

2: Geoscience Australia geophysicist taking a gravity station reading in the field.

3: Field acquisition of gravity data.

GRAVITY MAP OF AUSTRALIA

As part of the Onshore Energy Security Program, Geoscience Australia acquired gravity data over parts of the Cooper Basin in southwest Queensland. Gravity data are used for a range of applications including geological mapping, mineral and petroleum exploration and groundwater prospecting. In the Cooper Basin, the data are assisting with the assessment of hydrocarbon potential in the region as well as with the identification of granites beneath the basin which have the potential for geothermal energy.

This data added to the Gravity Map of Australia (3rd edition) and to the accompanying composite digital dataset (with cell resolution of approximately 800 metres). The map and associated grid display the variation in the strength of gravity at the Earth's surface resulting from changes in sub-surface rock density. Higher gravity values occur over more dense rock types and lower gravity values over less dense rocks.

The national gravity dataset is derived from onshore observations recorded at approximately 1.5 million gravity stations stored in Geoscience Australia's Australian National Gravity Database, and free-air gravity anomaly data derived from published satellite altimetry over marine areas. The onshore data were acquired by the Australian, State and Northern Territory governments, mining and exploration companies, universities and research organisations from the 1950s to the present day.

The Australian continent has a station spacing coverage of 11 kilometres, with South Australia, Tasmania and part of New South Wales covered at a spacing of seven kilometres. Victoria has station coverage of approximately 1.5 kilometres. Geoscience Australia, in collaboration with the states/Northern Territory, has been progressively infilling the gravity network at a grid station spacing of two, 2.5 or four kilometres to provide improved coverage in areas of scientific or economic interest. Other areas of detailed coverage have been surveyed by companies for resource exploration purposes.

Open file gravity data over the onshore region, as held in the Australian National Gravity Database at April 2010 were used in the creation of the gravity grid. Data derived from satellite altimetry were used exclusively over the offshore region.

ACHIEVEMENTS:

- **Interpolation of all public-domain gravity data to a common baseline, which was used to compile the Gravity Map of Australia.**

NEW OPPORTUNITIES:

- **The improved gravity data resolution over mineral and petroleum provinces provides more reliable interpretation of geological structures, particularly those deep within the crust.**

KEY PRODUCTS:

Australian Fundamental Gravity Network Web Application.

Gravity Grid of Australia.

Gravity Map of Australia.

ONSHORE *National Surveys*

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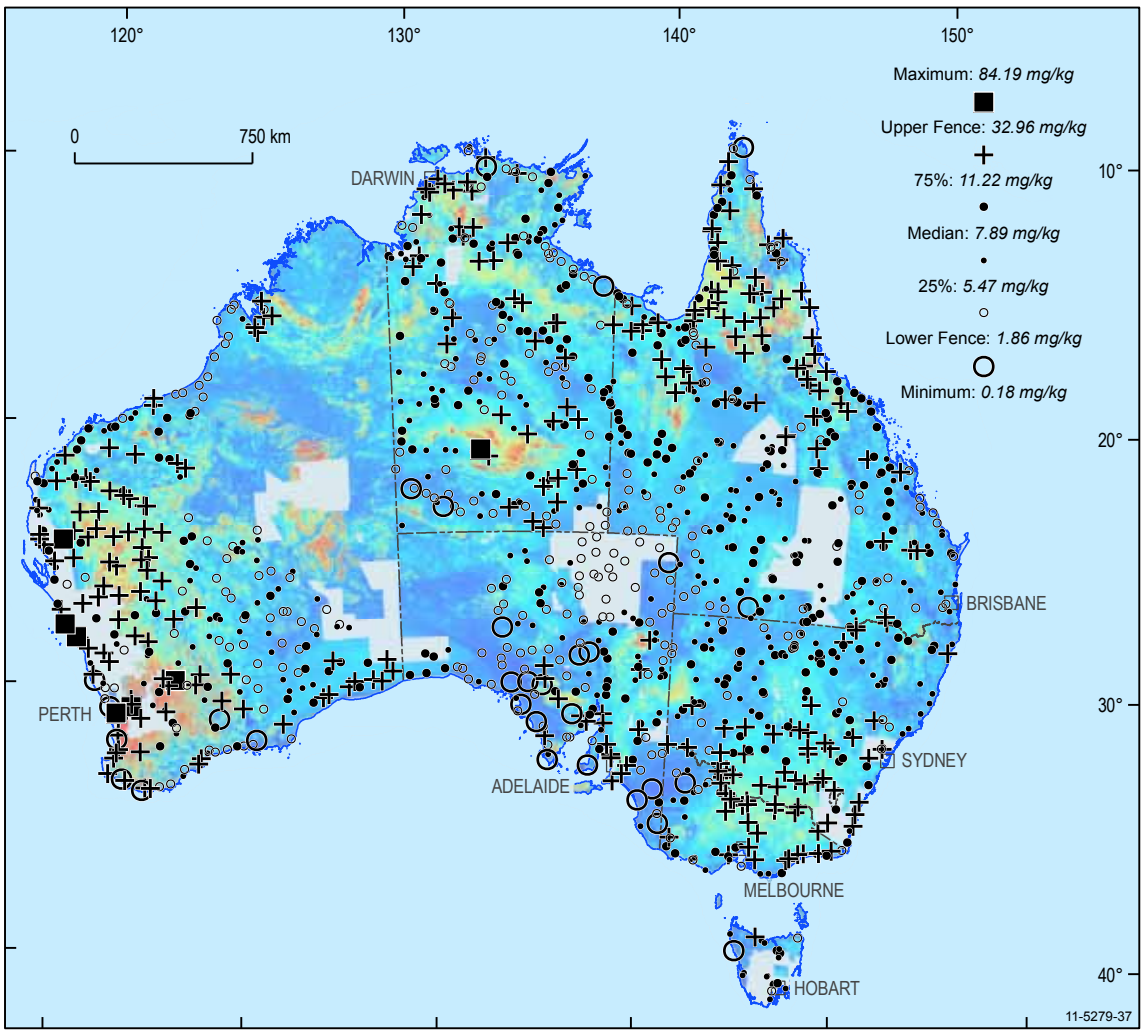

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1: One of the National Geochemical Survey of Australia maps—thorium concentrations in top outlet sediments (less than 2 mm fraction). The symbols are overlain on the airborne radiometric thorium channel data (blue—low thorium, red—high thorium).

2/3: Collection of samples for the National Geochemical Survey of Australia.

NATIONAL GEOCHEMICAL SURVEY OF AUSTRALIA

The National Geochemical Survey of Australia commenced in 2007 and provides the first nation-wide, internally consistent geochemical dataset for calibration and ground-truthing of airborne radiometric surveys. The data have wide application in (i) the exploration for energy (uranium and thorium) and mineral resources, including first-order investigations of the nature of geothermal hot-spots, regional prospectivity analyses and area selection, and (ii) land-use decision making and management of the environment.

Sampling involved close collaboration between Geoscience Australia and State and Northern Territory geoscience agencies. Crucial to the survey's success was the implementation of standardised methods for the collection, preparation and analysis of transported regolith samples. These methods drew on the experience of other international surveys as well as pilot geochemical surveys carried out by Geoscience Australia and collaborators. The surveys identified catchment outlet sediments as an ideal sampling medium present over much of the continent. Sample depth, grain size and analytical methods were selected to maximise the amount of geochemical information yielded by the project.

The survey involved the collection of regolith samples from 1186 catchments across Australia. At each sample site, two samples were collected, one from surface to 10 centimetres depth and a second from around 60 to 80 centimetres depth. All samples were dried, split into less than two millimetre and less than 75 micrometre grain-size fractions and analysed using a range of analytical techniques for more than 60 elements.

The National Geochemical Survey of Australia data improve knowledge about the character of surficial cover. Sample collection and analysis was carried out in accordance with international standards. The data are expected to contribute to the International Union of Geological Sciences/International Association of Geochemistry's Global Geochemical Baselines Programme.

ACHIEVEMENTS:

- **The first nationally consistent geochemical data set, with sediment samples collected from 1315 sites in 1186 catchments.**
- **Compilation of geochemical maps and the national geochemical dataset for use in resource exploration and as environmental baselines.**
- **Release of the preliminary soil pH map of Australia with applications in agriculture and environmental management.**

NEW OPPORTUNITIES:

- **The National Geochemical Survey of Australia provides a unique data set for energy and mineral exploration and landuse decisions.**

KEY PRODUCTS:

Mapping iron oxides and the color of Australian soil using visible–near-infrared reflectance spectra. *Journal of Geophysical Research 115.*

pH of Australian soils: field results from a national survey. *Soil Research 49.*

Field Data from the National Geochemical Survey of Australia. *Geoscience Australia Record 2010/18.*

ONSHORE *Regional Surveys*

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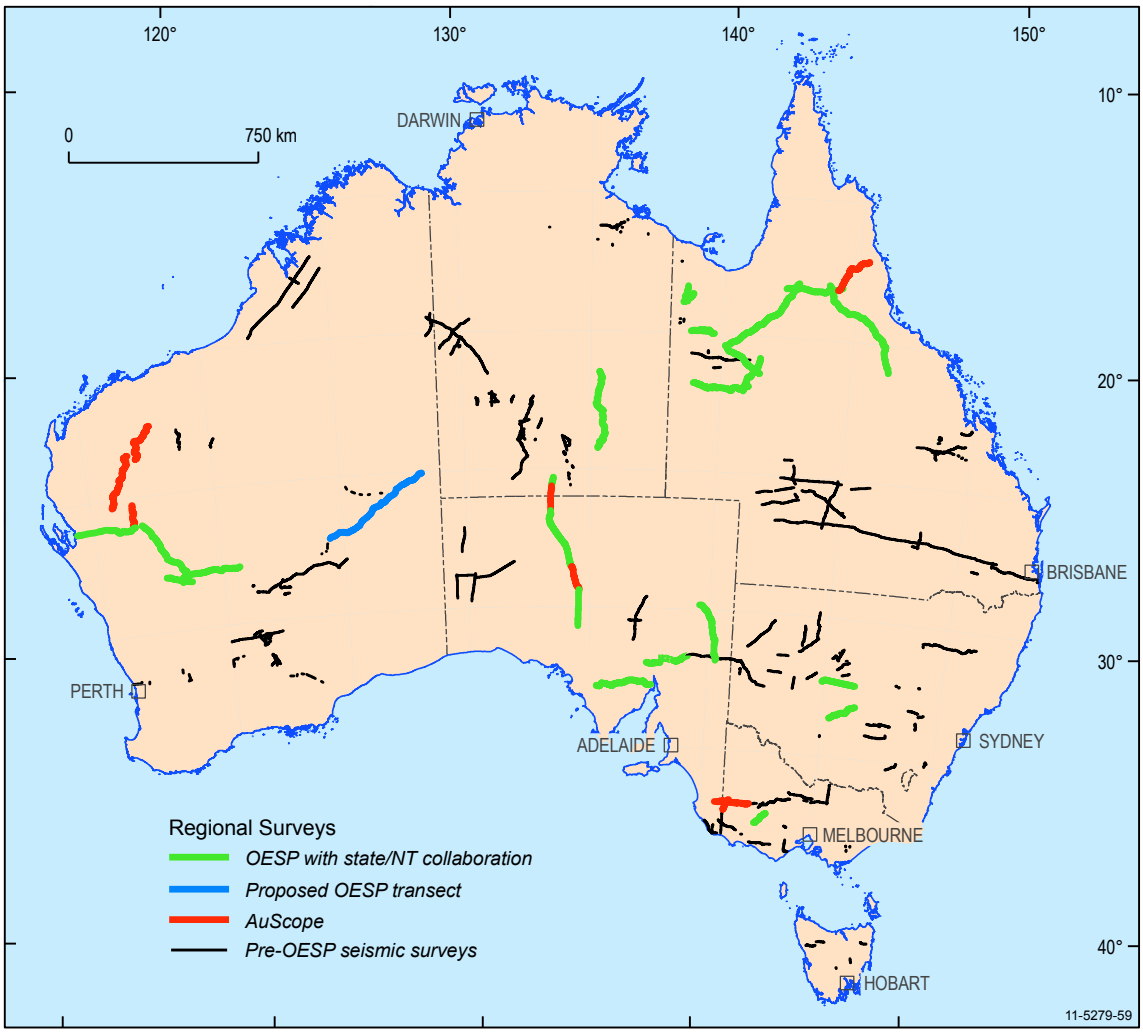

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1: Seismic data acquired during the Onshore Energy Security Program (OESP) in conjunction with collaborators.

2/3: Field acquisition of seismic (left) and magnetotelluric (right) data.

DEEP CRUSTAL SEISMIC AND MAGNETOTELLURICS

Between 2006 and 2011, Geoscience Australia acquired 6500 line kilometres of deep crustal seismic reflection data. The surveys provided an understanding of the crustal architecture of sedimentary basins and their tectonic relationship to older basement terrains. These as well as magnetotelluric surveys were undertaken in collaboration with the State and Northern Territory geological surveys and the Australian National Seismic Imaging Resource (ANSIR) facility, with Terrex Pty Ltd the lead contractor and AuScope acquiring some transects.

Of particular importance to the program was the identification of structural elements in sedimentary basins, which may host or provide information on the generation, movement or entrapment of hydrocarbons. Seismic data also assist with understanding the formation of early crust and subsequent rock-forming processes, including those which lead to the formation of mineral deposits. For this reason, a number of the seismic surveys crossed a variety of geological provinces and their boundaries.

Magnetotelluric survey depth soundings, which measure the electrical conductivity of the Earth's crust, provided complementary information for interpretation of the seismic images along many of the new transects. Gravity data also were acquired along most of the seismic transects and incorporated into Geoscience Australia's Australian National Gravity Database.

The results and interpretations of the seismic and magnetotelluric surveys, including implications for petroleum, geothermal energy and minerals exploration, are presented in the Regional Assessments and Commodity Studies section of this report.

ACHIEVEMENTS:

- **Discovery of the Millungera Basin, a new energy-prospective basin in north Queensland.**
- **Completion of 11 major survey programs in Queensland, New South Wales, South Australia, Northern Territory and Western Australia and collection of almost 700 magnetotelluric soundings at sites along most of the seismic traverses.**

NEW OPPORTUNITIES:

- **Improved understanding of crustal architecture in many hydrocarbon and ore-bearing geological terrains in frontier areas.**

KEY PRODUCTS:

Deep crustal seismic reflection and selected magnetotelluric data sets:

Qld: L180 Mt Isa Survey 2006–2007; L184 Mt Isa–Georgetown Survey 2007; L185 Charters Towers Survey 2007.

NSW: L188 Rankins Springs and Yathong Trough Survey 2008; Rankins Springs Extension Survey, 2009.

SA: L189 Gawler–Curnamona–Arrowie Survey 2008; L191 Curnamona–Gawler Link Survey 2009.

SA and NT: L190 Gawler–Officer–Musgrave–Amadeus Survey 2009.

NT: L192 Georgina–Arunta Survey 2009.

WA: L199 Yilgarn–Officer–Musgrave Survey 2011 and L200 Southern Carnarvon Survey 2011 (data acquisition scheduled for mid-2011).

ONSHORE *Regional Surveys*

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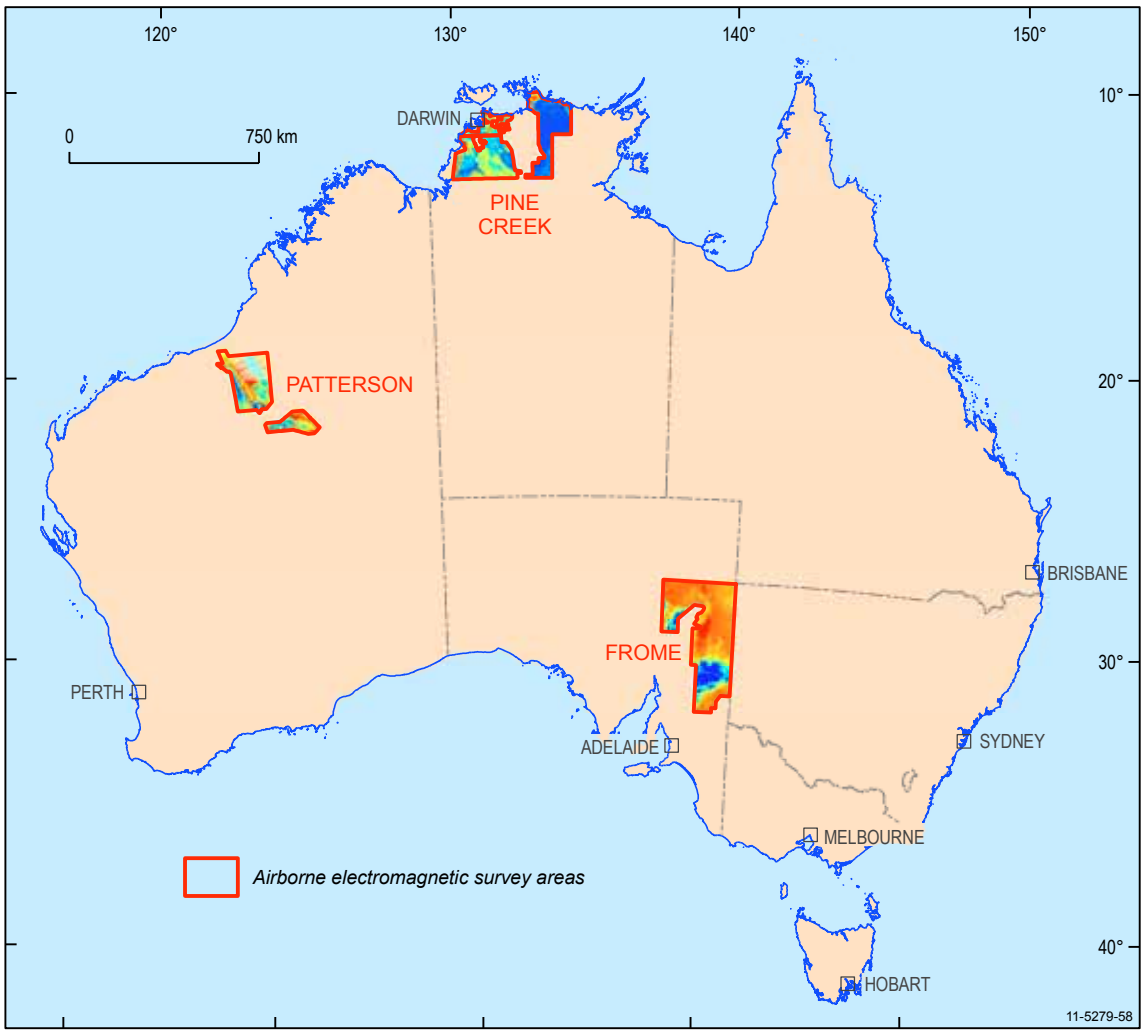

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1: Airborne electromagnetic surveys completed as part of the Onshore Energy Security Program.

2: Airborne electromagnetic acquisition aircraft used in the Frome Embayment–Murray Basin survey.

3: Field logging of drill holes to validate airborne electromagnetic data in Frome Embayment–Murray Basin area.

AIRBORNE ELECTROMAGNETICS

The airborne electromagnetic technique senses variations in the electrical conductivity of near-surface rocks down to a few hundred metres below cover materials. When the cover is thin, or the near surface materials are quite resistive, greater depth penetration is possible. However, because of the cost of data acquisition and the complex nature of the data processing required, airborne electromagnetics has not been used extensively for mineral exploration in Australia, and never at a regional scale prior to the Onshore Energy Security Program.

Between 2007 and 2010, Geoscience Australia evaluated the use of airborne electromagnetics as a possible regional exploration technique. Fugro Airborne Surveys Pty Ltd was contracted to acquire data over extensive areas in the Paterson Province in Western Australia (46 300 square kilometres), part of the Pine Creek region (together with Geotech Airborne) in the Northern Territory (73 700 square kilometres) and the Frome Embayment–Murray Basin area in South Australia (95 400 square kilometres).

In total 91 000 line kilometres of airborne electromagnetic data were acquired. The results of the surveys demonstrated the utility of regional airborne electromagnetic data for mineral exploration and groundwater studies. In the areas flown, it was possible to improve the interpretation of the regional geology and identify anomalous conductors in basement rocks, some of which will be targets for explorers. Of equal importance was demonstrating the ability to see down to two kilometres in areas of highly resistive near-surface materials, which was achieved in the Pine Creek region. It marked the first time globally that an airborne electromagnetic survey had achieved such depth penetration.

As part of the airborne electromagnetic acquisition program, Geoscience Australia developed new processing techniques, including software to invert data to a multi-layered Earth model, whereby it is possible to interpret regional and local scale airborne electromagnetics data in more detail and to a greater depth.

ACHIEVEMENTS:

- Acquisition of airborne electromagnetic data over more than 215 000 square kilometres in Western Australia, Northern Territory and South Australia.

NEW OPPORTUNITIES:

- New areas of mineral prospectivity highlighted in three frontier regions and demonstration of the cost-effective use of airborne electromagnetics as a regional investigation technique for energy and mineral exploration and in groundwater studies.
- Development of airborne electromagnetic data-inversion processing software, which provides greater detail and enhanced penetration for energy and mineral exploration.

KEY PRODUCTS:

Paterson TEMPEST AEM Survey, Western Australia, 2010 Final Inversion Data and Conductivity Models.

Pine Creek TEMPEST AEM Survey, Northern Territory, 2010 Final Inversion Data and Conductivity Models.

Frome Embayment TEMPEST AEM Survey, South Australia, 2010 Final Data (P1231).

ONSHORE *Regional Surveys*

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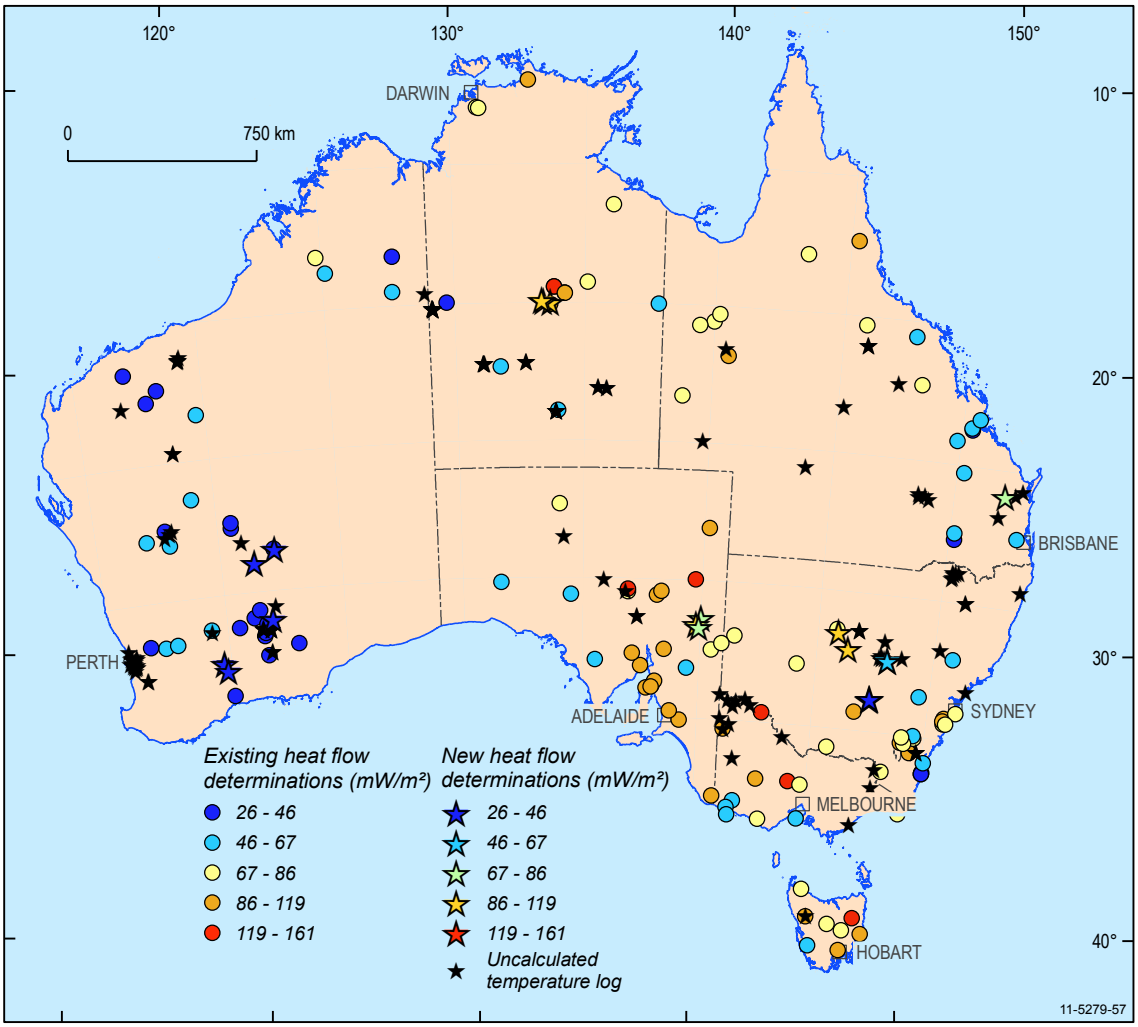

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1: Heat flow determinations across Australia.

2: Logging thermal gradient in drill holes in the field.

3: Thermal conductivity apparatus: clockwise from left—thermal conductivity meter, rock sample discs and vacuum chamber for water saturation.

GEOTHERMAL ENERGY—HEAT FLOW

Geothermal energy is a potential source of renewable base load power without a significant carbon footprint. A key to mapping prospective areas for geothermal energy is an understanding of heat flow. Prior to 2006, there were fewer than 200 published determinations of crustal heat flow across Australia, which was inadequate for effective geothermal exploration. Most regional exploration was crudely guided by temperature data from deep petroleum drill holes, which are sparsely distributed across the continent. These deep hole temperature measurements alone are not an effective tool for planning regional geothermal exploration. Areas of geothermal potential are not restricted to petroleum fields, where most of the deep drilling has been carried out and deep drilling to directly measure reservoir temperature is prohibitively expensive.

To help overcome this Geoscience Australia has developed the capability to collect information for heat flow determinations from holes drilled for purposes other than petroleum exploration, such as mineral exploration, groundwater and other purposes. Heat flow determinations from pre-existing drill holes are made by measuring thermal gradients to depths of around 300 metres and the thermal conductivity of rock samples from the same holes. Working collaboratively with the State and Northern Territory geological surveys, Geoscience Australia has embarked on a major program of heat flow data acquisition. Currently, more than 71 000 metres of wireline thermal logging in 158 drill holes has been completed in all parts of the continent, along with measurements of thermal conductivity.

This information can be combined with other geological data to calculate thermal gradients to greater depths and to conduct assessments of geothermal potential at a regional scale.

ACHIEVEMENTS:

- By the end of 2011, close to 100 new heat flow determinations will be released, a significant increase on the number available to support the growing geothermal energy exploration sector.
- Establishment of a trailer-mounted system to measure thermal gradient in drill holes and commissioning of instrumentation for bench-top measurement of thermal conductivity of drill core.
- Completion of more than 71 000 metres of thermal logging in 158 drill holes in all States and the Northern Territory and measurement of the thermal conductivity of 550 core samples.

NEW OPPORTUNITIES:

- The determination of heat flow from existing drill holes opens up possibilities for more extensive and cost-effective regional exploration for geothermal energy in many areas.

KEY PRODUCTS:

Heat Flow Interpretations for the Australian Continent, Release 1. *Geoscience Australia Record 2010/041.*

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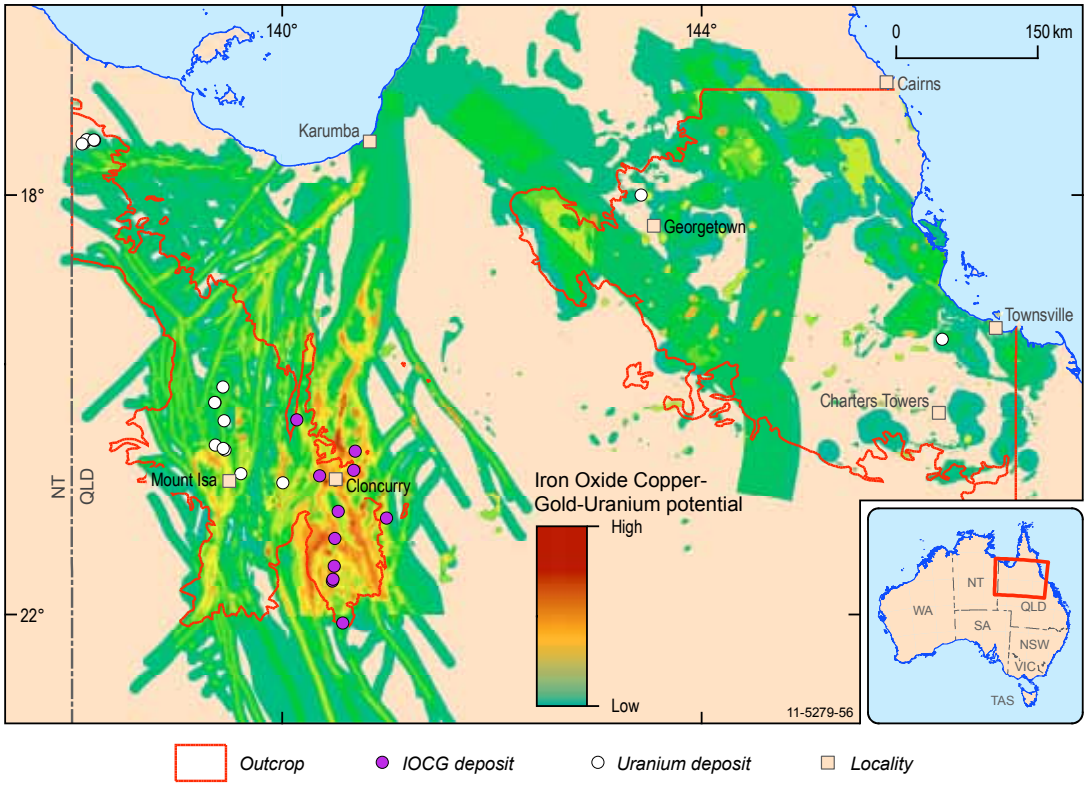

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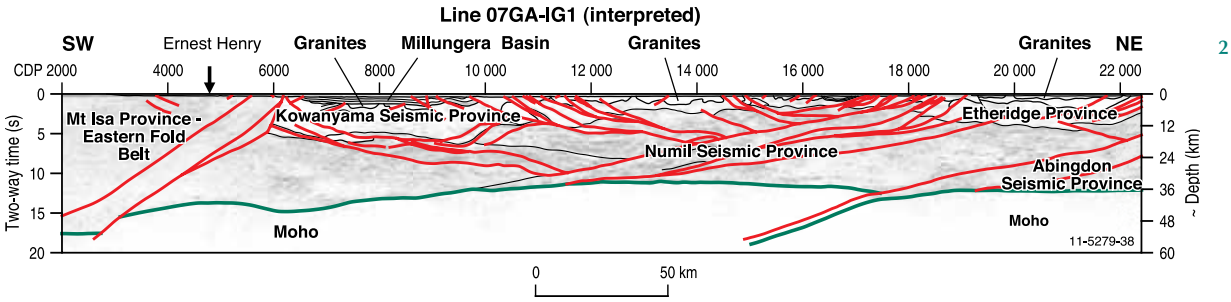

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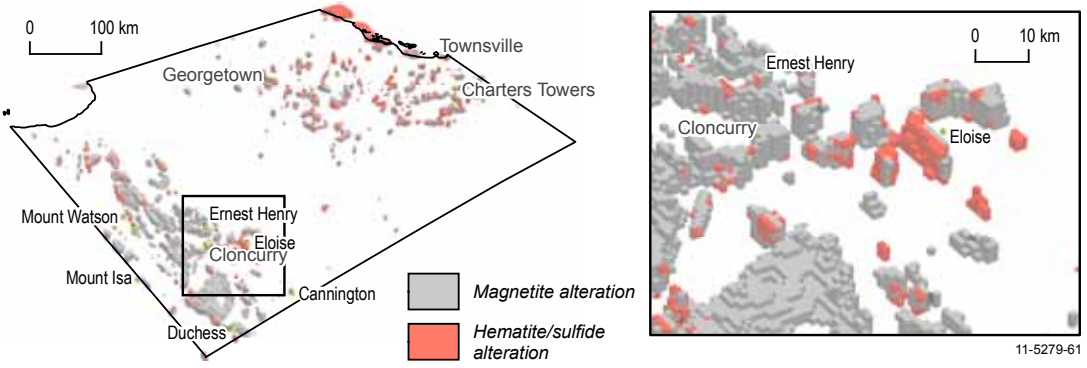

1: Map of assessed iron oxide copper-gold-uranium potential for north Queensland.

2: Interpretation of the seismic traverse 07GA-IG1 showing a west-dipping boundary between the Mount Isa Province to the west and the Numil Seismic Province to the east.

3: Mineral mapping associated with iron-oxide copper-gold deposits, based on geophysical inversion modelling.

MOUNT ISA–GEORGETOWN–CHARTERS TOWERS (QUEENSLAND)

The Mount Isa-Georgetown-Charters Towers assessment centred on the interpretation of deep seismic reflection data in the Mount Isa region (about 900 line kilometres in 2006), Mount Isa–Georgetown–Charters Towers area (about 1387 line kilometres in 2007) and a line from Mount Surprise to Mareeba which was funded by AuScope. Magnetotelluric data were also collected along the Mount Isa–Georgetown–Charters Towers lines.These data were integrated with new geochronology and geochemical information and existing geological and geophysical data to enhance understanding of the geological evolution, mineral systems and energy resources of north Queensland.

The seismic surveys imaged the deep crustal architecture of north Queensland, particularly the relationship between the Georgetown and Mount Isa Provinces, the architectural controls on energy resources and mineral systems and the thickness and extent of Cenozoic basins and cover. The data were used to evaluate the uranium and geothermal potential of this area. This was undertaken in collaboration with the Geological Survey of Queensland, James Cook University and AuScope.

ACHIEVEMENTS:

- Identification of a relationship between the position of known major ore deposits in the Cloncurry district and a crustal scale structure observed in the seismic data. This relationship enhances the potential for mineral resources along the length of this structure.
- Recognition of a fossilised subduction (plate-boundary) zone beneath the Eromanga Basin.
- Modelling of regional iron oxide-copper-gold deposit targets by specialised (inversion) processing of magnetic and gravity data to map magnetite and hematite altered rock in 3D.
- Generation of predictive maps showing the energy prospectivity for uranium and geothermal systems in north Queensland.

NEW OPPORTUNITIES:

- Mapping of the Isa-Numil boundary using seismic, gravity and magnetic data has identified significant areas with iron oxide-copper-gold-uranium potential under cover to the north and south of the Cloncurry region.
- Prospectivity maps for uranium and geothermal energy open new exploration opportunities.

KEY PRODUCTS:

Interpretation of the North Queensland Seismic and MT surveys. *Australian Institute of Geoscientists Bulletin 49.*

Basement Geology of Northern Queensland, Map and GIS Dataset.

Depth to Basement of Northwest Queensland, Map.

3D map and supporting geophysical studies in the North Qld region. *Geoscience Australia (GA) Record 2009/029.*

Geodynamic Synthesis of the North Qld region and implications for Metallogeny. *GA Record 2009/030.*

An assessment of the uranium and geothermal potential of North Queensland. *GA Record 2010/014.*

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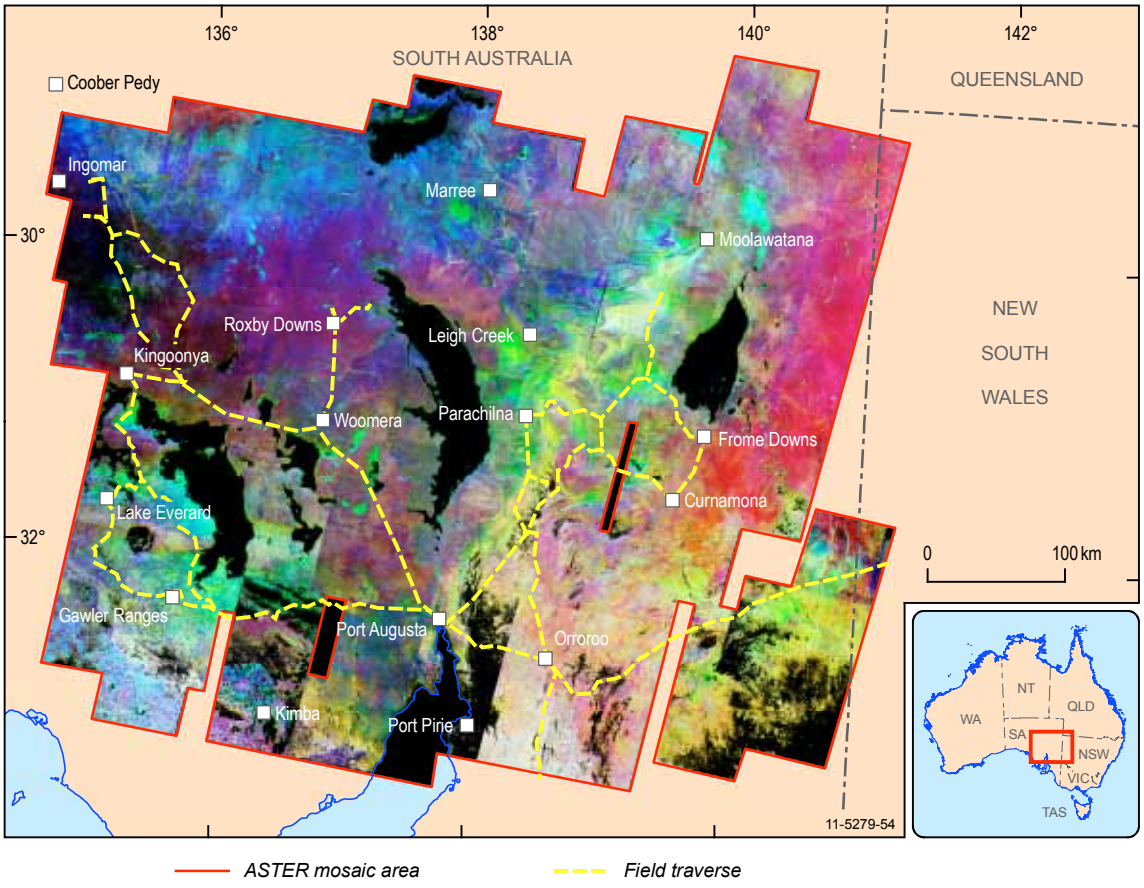

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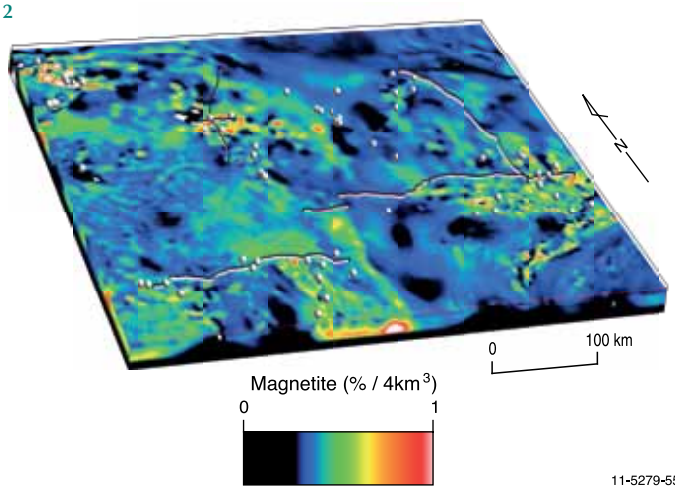

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1: Mineral map of iron oxide abundance created from ASTER data for the Gawler–Curnamona region, South Australia.

2: Mineral mapping using geophysical data in the Gawler–Curnamona region, South Australia.

3: Outcrop of newly identified ~3150 Ma rocks in the Gawler Craton.

GAWLER–CURNAMONA–ARROWIE (SOUTH AUSTRALIA)

The Gawler–Curnamona–Arrowie assessment was centred on the interpretation of approximately 720 line kilometres of deep seismic reflection data acquired during 2008 and 2009 in the southern Gawler Craton, Curnamona Province and Adelaide Rift System in South Australia. Wide-angle seismic reflection data also were acquired in one region and magnetotelluric data along a number of the seismic lines. As part of the study, and to assist with the interpretation of the geological evolution of the area, new geochronological ages were determined from 69 rock samples collected across the region. These datasets were integrated with new and existing geological, geochemical and geophysical information for a regional energy assessment.

The main aim of the seismic surveys was to image the crustal architecture of these areas, to assess the energy prospectivity of the region for a range of uranium and geothermal systems. The work was carried out in collaboration with Primary Industries and Resources SA.

ACHIEVEMENTS:

- Demonstration of the depth and geometry of sedimentary rocks within the Arrowie Basin, highlighting new potential for hydrocarbon accumulations.
- Identification of the oldest rocks in South Australia (around 3150 million years old), extending the known geological history of South Australia by over 500 million years.
- Mapping of regional mineral alteration systems using Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) mosaic images.
- Greater understanding of the architecture, age and evolution of the Gawler Craton and Curnamona Province, which are major mineral provinces of South Australia.

NEW OPPORTUNITIES:

- 3D geophysical modelling techniques have identified regional targets for Olympic Dam type iron oxide-copper-gold deposits, which should generate more exploration activity.
- Correlation of major crustal boundaries, changes in seismic character and variations in surface heat flow provide a guide for geothermal exploration in this area of high heat flow.

KEY PRODUCTS:

South Australia Seismic and MT Workshop 2010. *Geoscience Australia Record 2010/010.*

ASTER GIS dataset from the southern Gawler–Curnamona region, South Australia.

Depth to magnetic basement map and 3D map of the Gawler–Curnamona region, South Australia.

Geodynamic Synthesis of the Gawler Craton and Curnamona Province. *Geoscience Australia Record 2010/027.*

New SHRIMP U-Pb zircon ages from the Gawler Craton and Curnamona Province, South Australia. *Geoscience Australia Record 2010/016.*

ONSHORE *Regional Assessments*

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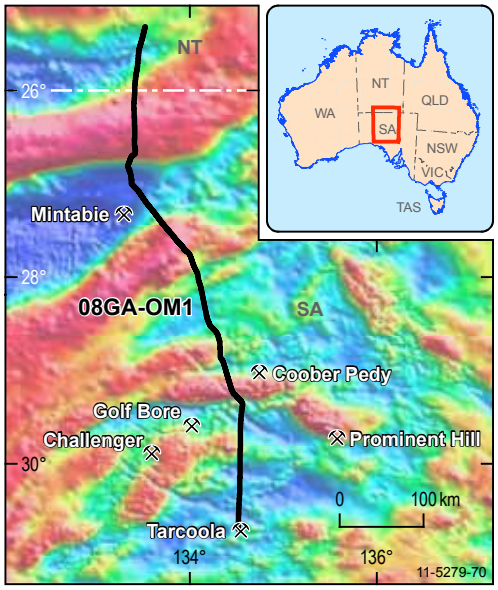

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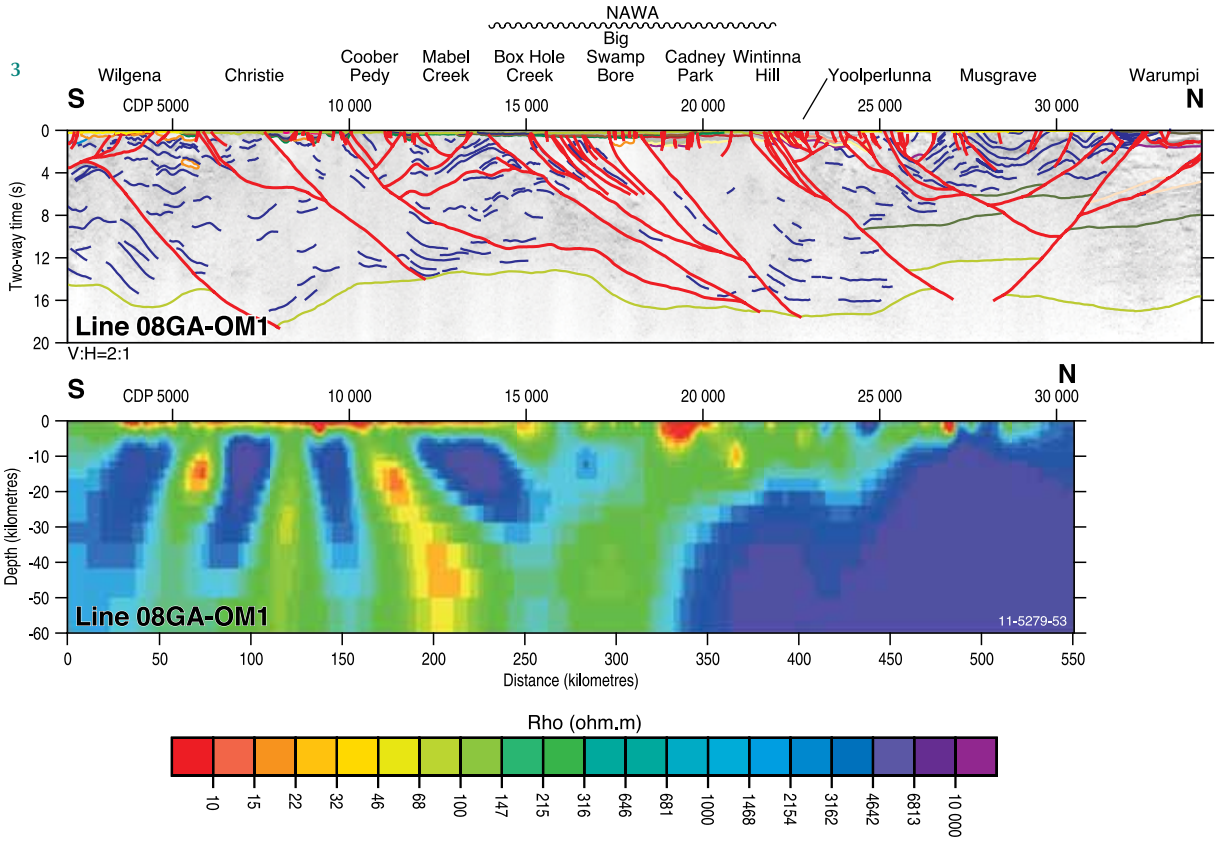

1: Regional gravity image and location of the Gawler–Officer–Musgrave–Amadeus survey.

2: Acquiring seismic data along the Gawler–Officer–Musgrave–Amadeus traverse.

3: New seismic and modelled magnetotelluric data from the Gawler–Officer–Musgrave–Amadeus line.

GAWLER–OFFICER–MUSGRAVE–AMADEUS (SOUTH AUSTRALIA–NORTHERN TERRITORY)

The Gawler–Officer–Musgrave–Amadeus regional assessment focussed on more than 630 line kilometres of deep seismic reflection data acquired during 2008 across the northern Gawler Craton, Officer Basin, Musgrave Province and southern Amadeus Basin of South Australia and the Northern Territory. Gravity measurements were acquired along the seismic line, and magnetotelluric data were collected also along part of this transect. Datasets were integrated with existing geological, geochemical and geochronological data.

This survey was undertaken across a remote area of Australia where most of the rocks which are considered to have potential for either energy or mineral resources are covered by unconsolidated sediments, including desert sands. The area also has very few drill holes which have sampled the underlying rocks.

The seismic and magnetotelluric data provide the first regional-scale images of the deep crust in the area. When combined with geochemical and geochronological data it was possible to delineate major geological features and conduct an initial evaluation of the uranium and geothermal potential of the region. The work was carried out in conjunction with Primary Industries and Resources SA, the Northern Territory Geological Survey, AuScope and university groups.

ACHIEVEMENTS:

- Improved understanding of the architecture of parts of the eastern Officer and Arckaringa basins and characterisation of faults which control their boundaries, highlighting the potential for hydrocarbons.
- Identification and description of the boundaries between the Gawler Craton, Musgrave Province and Warumpi Province which are major geological blocks within the Australian continent. This provides new constraints on the geodynamic evolution of central Australia and better information to help predict the location of undiscovered mineral and energy resources.

NEW OPPORTUNITIES:

- Recognition of deep faults and changes in crustal (electrical) conductivity, which are similar to those observed at the Prominent Hill and Olympic Dam deposits farther to the east, indicating there may be further potential for undiscovered iron oxide-copper-gold deposits in the northern Gawler Craton.
- Mapping of a series of north-dipping, crustal-scale structures, which have a similar crustal geometry to faults in the Eastern Goldfields of the Yilgarn Craton in Western Australia, indicate potential for gold systems throughout this region.
- Determination of the thickness and geometry of the Officer and Arckaringa basins provides new information regarding their prospectivity for a range of conventional and unconventional hydrocarbon systems.

KEY PRODUCTS:

GOMA (Gawler Craton–Officer Basin–Musgrave Province–Amadeus Basin) Seismic and MT Workshop 2010. *Geoscience Australia Record 2010/039.*

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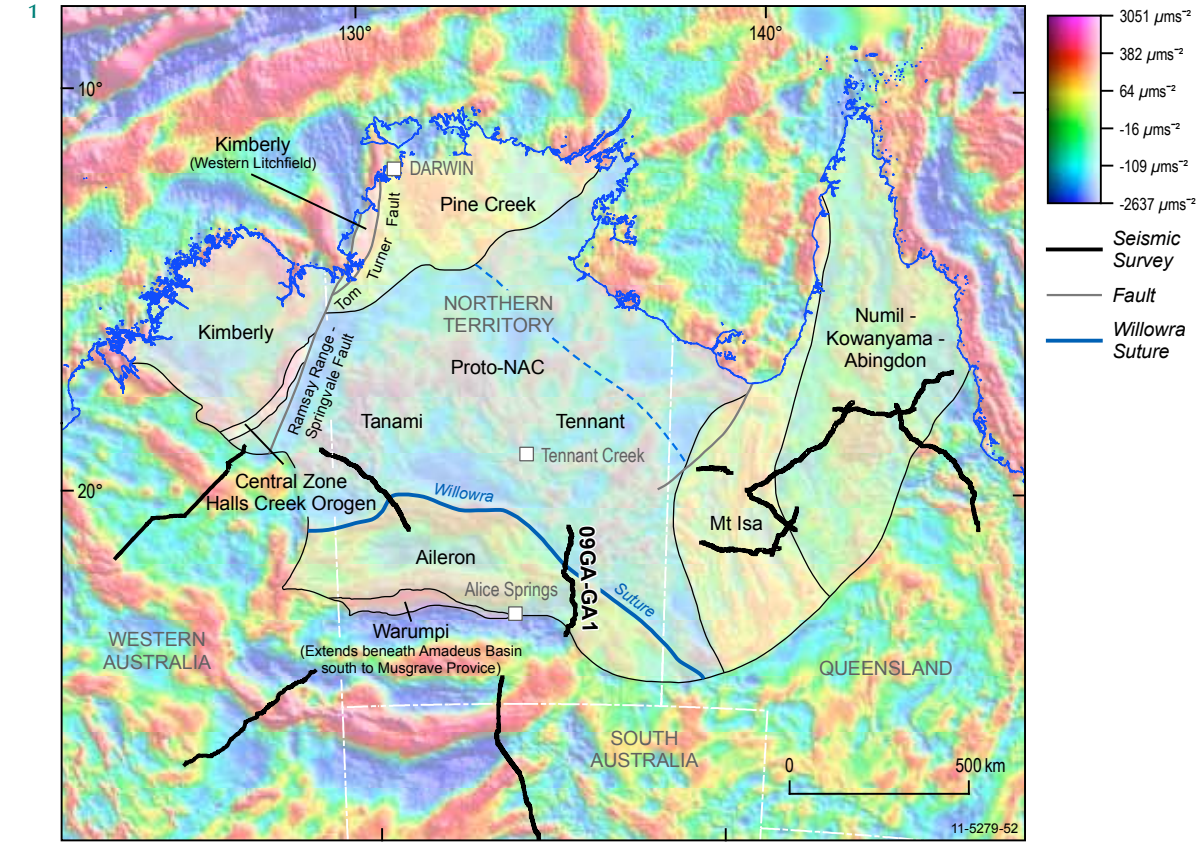

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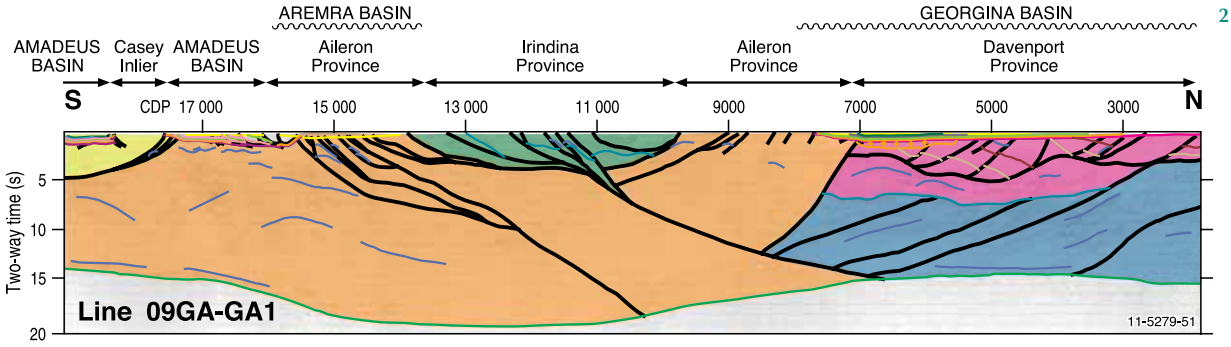

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1: Map showing interpreted provinces of the North Australian Craton superimposed on gravity image, and the location of the Willowra Suture and seismic surveys.

2: Interpretation of the Georgina–Arunta seismic line, from south (left) to north (right).

3: Field work in the Georgina–Arunta region.

GEORGINA–ARUNTA (NORTHERN TERRITORY)

The Georgina-Arunta regional assessment centred on 370 line kilometres of deep seismic reflection data collected during 2009 along a north-south traverse from the Amadeus Basin in the south, across the Aileron Province, Irindina Province and Georgina Basin to the Davenport Province in the north. Magnetotelluric and gravity data also were collected along the seismic transect. The purpose of the survey was to assess the mineral and energy resources prospectivity of this part of central Australia. The data were integrated with new, targeted geochronological and geochemical data and existing geological and geophysical information to enhance understanding of the geological evolution of the region.

The seismic survey was designed to image the architecture of the Georgina and northeastern Amadeus basins as well as the deep crustal architecture of the region to determine whether the Willowra Suture, which was recognised from an earlier seismic study, continued through central Australia into the survey area. The survey also was designed to image the geometry of the Irindina Province and to establish crustal architectural controls on energy resources and mineral systems. The complete data package will be used to evaluate the uranium, geothermal and hydrocarbon potential of the region. This work was conducted in collaboration with the Northern Territory Geological Survey.

ACHIEVEMENTS:

- Improved understanding of the architecture of basins and basement provinces in central Australia and the geological evolution of the region.
- Identification of a crustal structure which may be the south-eastern extension of the Willowra Suture, a major boundary between Proterozoic provinces in central Australia.
- Improved understanding of the architecture of the Irindina Province, the boundaries of which were possibly extensional faults during basin formation and contractional faults during basin inversion.
- Recognition of two mantle-tapping structures, one of which may be a fundamental control on lode gold deposits.

NEW OPPORTUNITIES:

- The Willowra Suture has features similar to major structures associated with the Olympic Dam mineral system in South Australia and those in the Cloncurry region in Queensland, which increases the prospectivity of the region for copper-gold-uranium type deposits.
- Improved potential for basin-related uranium systems in Proterozoic basins of the Davenport and Tomkinson provinces to the north and the Cenozoic Aremra and correlative basins to the south.

KEY PRODUCTS:

Geological interpretations, geodynamic scenarios, and preliminary implications for energy and mineral systems in the Georgina–Arunta region. *Northern Territory Geological Survey Record 2011–002.*

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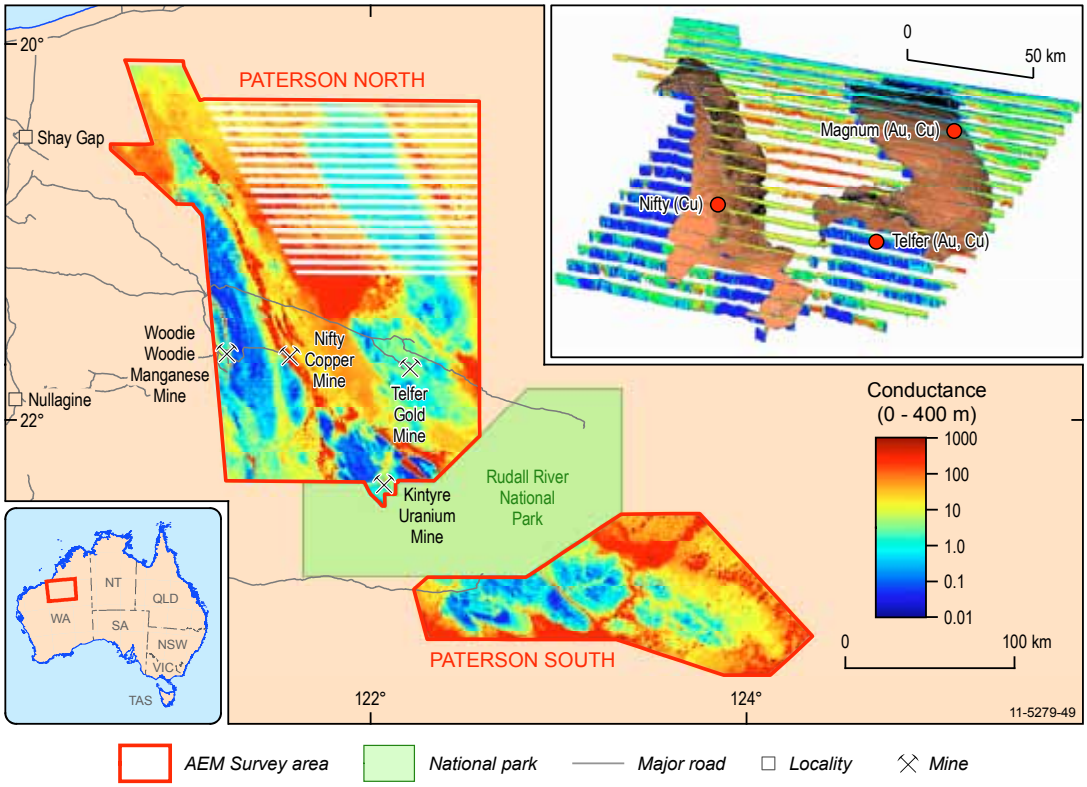

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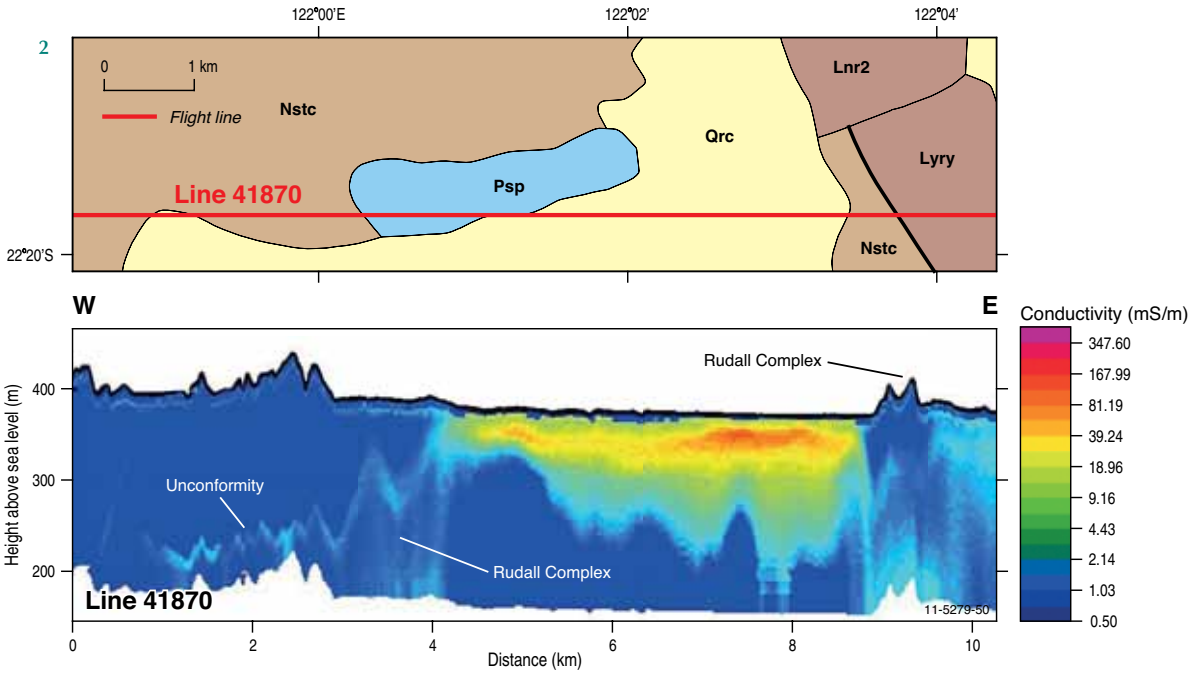

1: Airborne electromagnetic surveys within the Paterson region, Western Australia with perspective view of the Paterson South airborne electromagnetic survey (inset).

2: Plan view of the surface geology and airborne electromagnetic conductivity section from the Paterson region.

PATERSON (WESTERN AUSTRALIA)

The Paterson airborne electromagnetic survey in northern Western Australia covered an area which included the Woodie Woodie (manganese), Nifty (copper) and Telfer (gold-copper) mines. The results of the survey, the first of its type in Australia, demonstrated the potential of airborne electromagnetics as a cover-penetrating system for regional exploration, seeing through solid material to depths of up to 400 metres.

After specialised processing and integration of drill hole conductivity logs, interpretation of the airborne electromagnetic data yielded information on uranium prospectivity in sandstones associated with a break in the geologic record, (unconformity-related sandstones). The data imaged a major unconformity associated with the Kintyre uranium deposit and revealed where this and similar structures, which may have potential for uranium mineralisation, occur elsewhere in the region.

The airborne electromagnetic data have greatly improved understanding of the basement-cover relationships in the Paterson Province, particularly between Proterozoic rocks of the Yeneena Basin and Rudall Complex and the overlying Paleozoic-Mesozoic rocks of the Canning Basin. The data, combined with drilling information, facilitated interpretation of the Canning Basin stratigraphy in 3D over a broad area, revealing a number of previously unknown, large-scale sedimentary structures. The survey was influential in encouraging further mineral exploration in the region which led to company drilling that intersected copper mineralisation.

The survey also revealed detailed structure of large paleodrainage systems in the Canning, Disappointment and Wallal paleorivers, and showed conductivity anomalies associated with groundwater salinity within each system. It also indicated that a number of these paleodrainage systems have potential for fresh to brackish groundwater resources.

ACHIEVEMENTS:

- Influenced industry interest in new exploration projects in the region, with results cited in company reporting of the discovery of copper mineralisation.
- Demonstrated the ability to map unconformity and paleovalley-related uranium systems.
- Regional mapping of a major unconformity related to the Kintyre uranium deposit.
- Recognition and delineation of Proterozoic units with high potential for uranium-copper-gold mineralisation under surface cover.

NEW OPPORTUNITIES:

- Identification of airborne electromagnetic anomalies in this survey which indicate potential targets for base metal and copper-gold mineralisation.
- Airborne electromagnetics allows other geophysical techniques to more effectively target groundwater resources for habitation, mining and exploration in the region.

KEY PRODUCTS:

Geological and energy implications of the Paterson Province airborne electromagnetic (AEM) survey, Western Australia. *Geoscience Australia Record 2010/012.*

Drill hole database for the Paterson airborne electromagnetic (AEM) survey, Western Australia. *Geoscience Australia Record 2009/031.*

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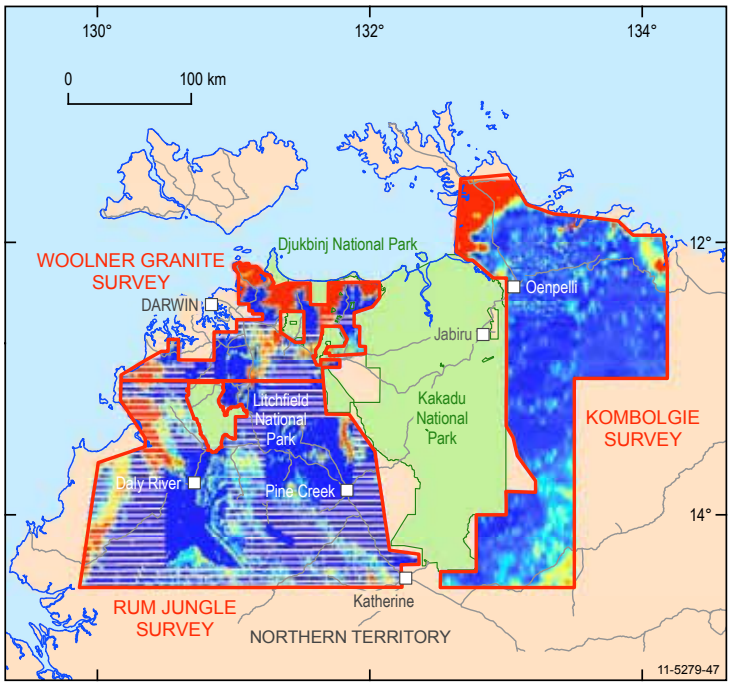

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AEM Survey area *National park* *Major road* *Locality*

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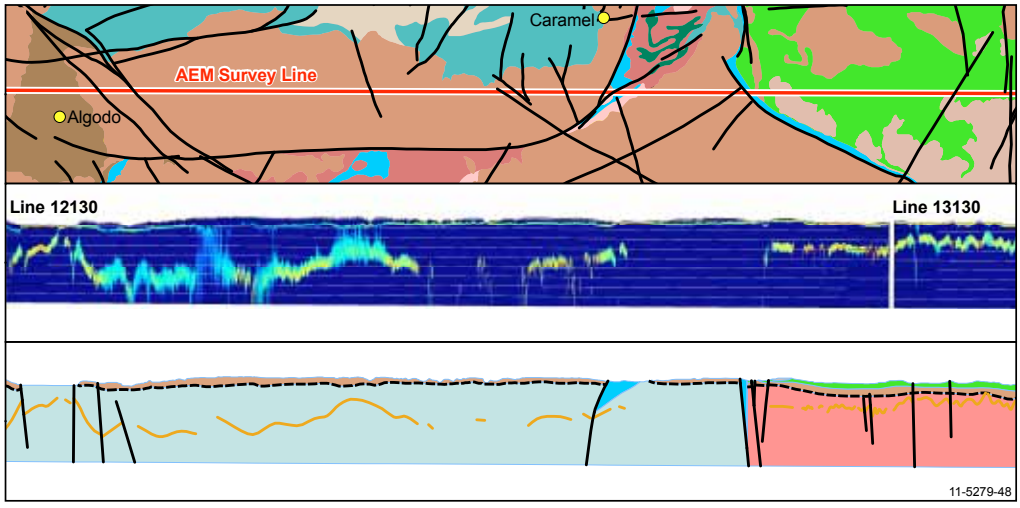

0 10 km

Mesoproterozoic to Archean

- *Granite*
- *Oenpelli Dolerite*
- *Amphibolite*
- *Gumarrirnbang Sandstone*
- *Nungbalgarri Volcanics*
- *Mamadawerre Sandstone*
- *Nourlangie Schist*
- *Cahill Formation*
- *Kudjumarndi Quartzite*
- *Nimbuwah Complex*
- *Pre-Kombolgie basement, and/or intrusive, undivided, including Archean*
- *Archean*
- *Fault*
- *Unconformity*
- *Conductors in pre-Kombolgie basement*
- *Mineral location*

1: Airborne electromagnetic surveys within the Pine Creek region, Northern Territory.

2: Acquisition of airborne electromagnetic data with a transmitter loop and receiver coil deployed beneath helicopter.

3: Plan view of the surface geology, airborne electromagnetic conductivity section and interpreted cross section of geology in the Pine Creek region, Northern Territory.

PINE CREEK (NORTHERN TERRITORY)

The Pine Creek airborne electromagnetic survey in the Northern Territory was designed to support regional exploration for uranium and other mineral commodities. The area contains several uranium deposits, including Rum Jungle, Nabarlek and the Ranger uranium mine. The region is prospective for copper, lead, zinc, gold, tin, rare earth elements, tantalum, tungsten, molybdenum, nickel and other commodities. In processing and interpreting the airborne electromagnetic data, it was possible to recognise geological features, including prospective contacts and faults, to a depth of two kilometres. The survey marked the first time an airborne electromagnetic survey has penetrated to such a depth in the crust.

The survey mapped a number of geological features, including prospective unconformities and the depth of fertile sedimentary rocks above them; critical conductive layers that are essential for uranium mineralisation; geological structures (faults and folds) critical for the understanding of ore formation; depth of regolith cover; and, sea water incursion into coastal aquifers.

The airborne electromagnetic data were used to construct a 3D model of the northeast margin of the Daly Basin where electromagnetic models indicate the prospective unconformity below the Tolmer Group sediments, which are beneath younger rocks of the Daly Basin.

In the Nabarlek area the airborne electromagnetic data allowed mapping of several geological units of the Kombolgie Subgroup sediments fertile for uranium mineralisation. A new basement solid geology map shows extent of the Cahill Formation which contains conductive materials critical for uranium mineralisation.

ACHIEVEMENTS:

- Demonstration of the utility of modern airborne electromagnetic systems for regional mineral exploration in a wide range of geological settings, notably the capability to see deeper through a variety of near-surface material.
- Identification of the prospective unconformity in the Pine Creek area and folds and faults at depth, which have potential for uranium exploration.
- New maps of basement solid geology in areas highly prospective for uranium.

NEW OPPORTUNITIES:

- Anomalies identified in the airborne electromagnetic survey data are potential targets for uranium, copper and gold mineralisation in the Pine Creek region.

KEY PRODUCTS:

Geological and energy implications of the Pine Creek region airborne electromagnetic (AEM) survey, Northern Territory. *Geoscience Australia Record.*

Point-located airborne electromagnetic digital dataset, Pine Creek region.

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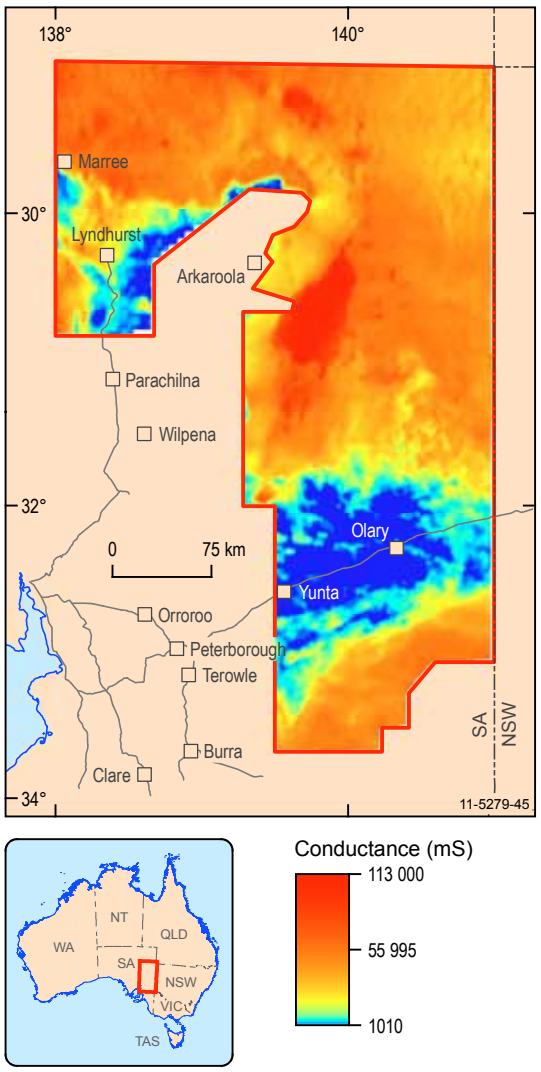

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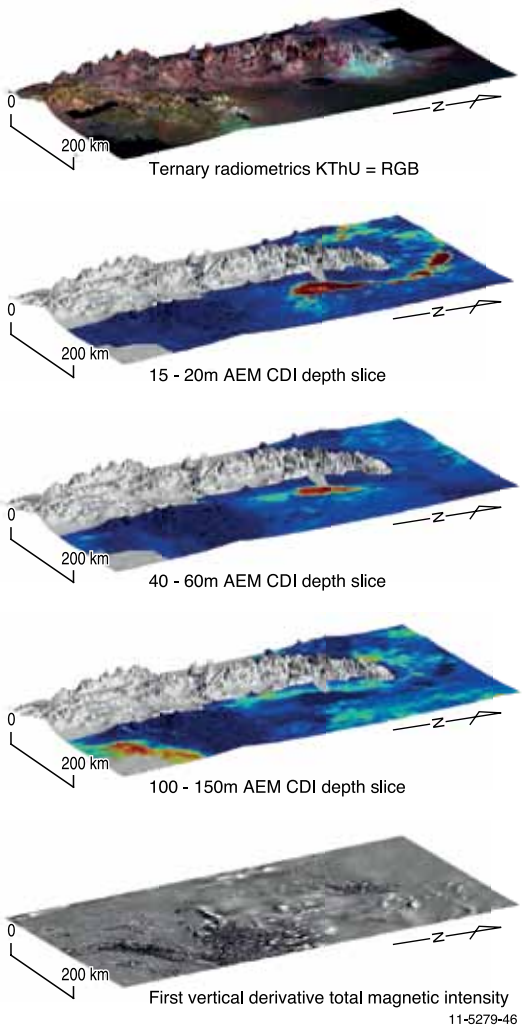

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4

1: Frome airborne electromagnetic survey showing the zero-200 metre conductance image.

2: Perspective view of the Frome radiometrics (top), airborne electromagnetic conductivity slices at 15–20 m, 40–60 m and 100–150 m below surface and magnetics (bottom).

3: Frome airborne electromagnetic survey aircraft on station in South Australia.

4: Drill hole logging to validate data collected during the Frome airborne electromagnetic survey.

FROME (SOUTH AUSTRALIA)

The Frome airborne electromagnetic survey in South Australia was undertaken to encourage exploration for uranium and other mineral commodities. The survey area included the Frome Embayment, northwest Murray Basin and portions of the Strzelecki Desert. It encompassed the Beverley and Honeymoon uranium mines and the Oban project. The area includes sandstone-style and breccia complex-style uranium deposits or prospects at Four Mile East and Four Mile West, Pepegoona, Yadglin, Pannikin, Crocker Well, Goulds Dam, East Kalkaroo, Junction Dam, Glencoe and Radium Hill. The region is prospective also for metals such as copper, lead, zinc, gold, silver, magnesium, manganese, cobalt, tin, rare earth elements, molybdenum and iron as well as for coal.

The survey helped to delineate geological features and groundwater within the Frome Embayment and Murray Basin. In the Frome Embayment, it revealed the sub-surface extent and conductive nature of rocks of the Benagerie Ridge which is part of the Curnamona Province, and is prospective for copper, gold and Broken Hill-style lead-zinc-silver deposits. It also uncovered extensions to paleovalley systems, which host sandstone uranium deposits at Goulds Dam, Honeymoon, Oban and Glencoe. Large fault structures associated with the Beverley uranium deposit also were delineated along with the Cenozoic stratigraphy of the Callabonna Sub-basin and broader Lake Eyre Basin.

In the Murray Basin, portions of the Delamerian Orogen, which is highly prospective for copper-gold mineralisation, were recognised under approximately 100 metres of cover rock. The survey also revealed structures within the Adelaide Rift System, including folded and faulted potentially mineralised zones, greatly improving knowledge of the area's structural geology.

New 3D models of the Benagerie Ridge and Delamerian Orogen have been prepared from the data, to provide greatly improved depth of cover information for these prospective areas.

ACHIEVEMENTS:

- Identification of extensions to uranium-bearing paleovalley systems and probable new paleovalley systems in the Frome Embayment.
- Improved understanding of the prospective Benagerie Ridge, including the location of conductive, or potentially chemically reactive rocks in the Curnamona Province.

NEW OPPORTUNITIES:

- Increased understanding of the 3D structure of paleovalley networks, which will reduce the risk for uranium exploration and may aid in groundwater investigations.
- Interpretation of airborne electromagnetic data in areas of shallow to moderate cover will assist with the determination of the thickness and nature of sediments in regions under cover.

KEY PRODUCTS:

The Frome airborne electromagnetic survey, South Australia: implications for energy, minerals and regional geology. *Geoscience Australia Record.*

Point-located digital dataset, Frome region.

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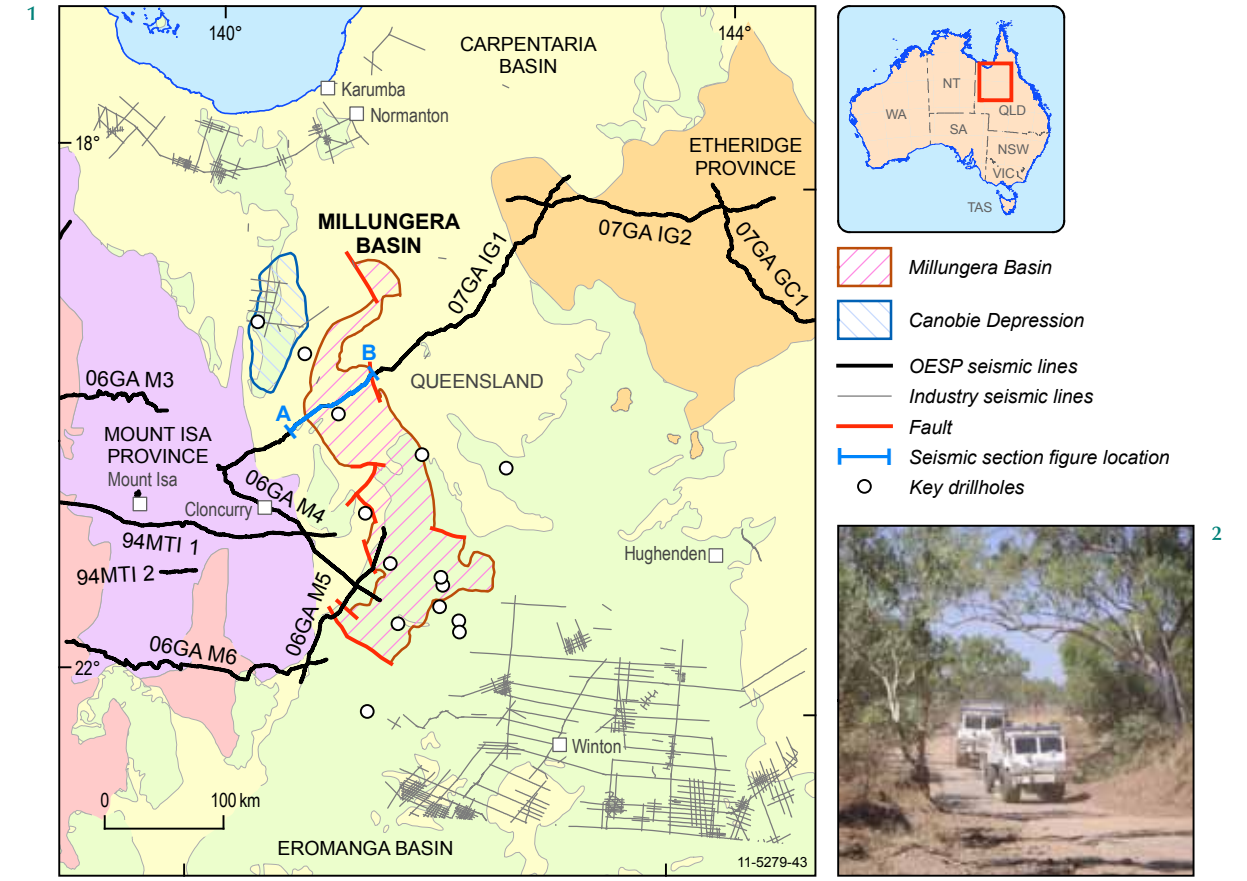

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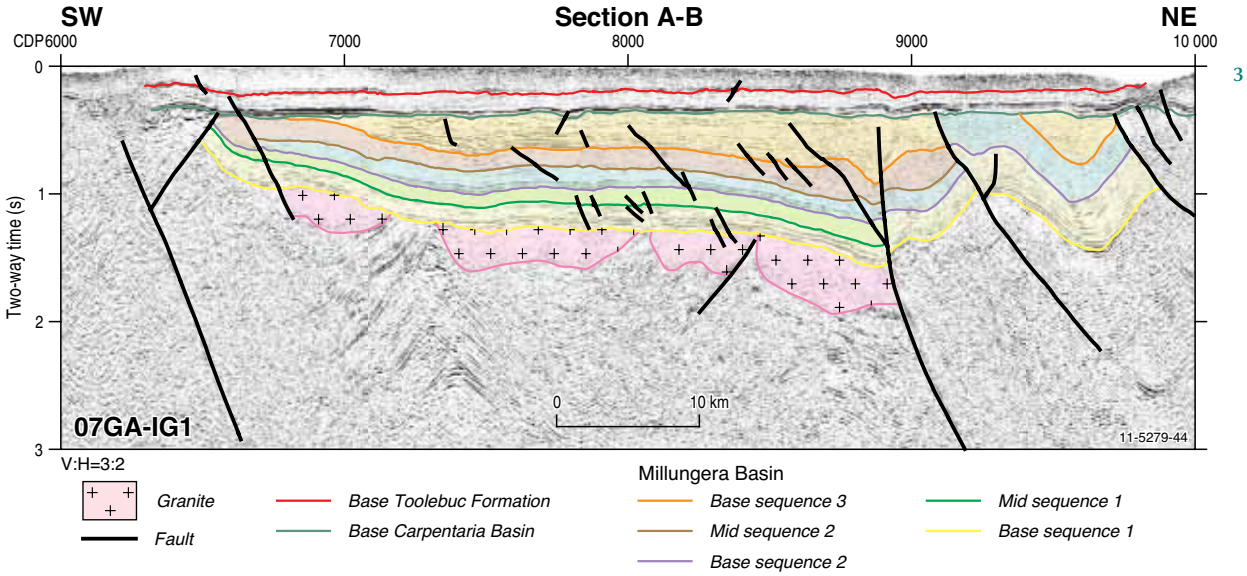

1: The recently discovered Millungera Basin, north Queensland.

2: Seismic data acquisition vehicles.

3: Seismic section of the Millungera Basin (highlighted in 1), with interpreted stratigraphic units and fault architecture.

ONSHORE PETROLEUM

Onshore petroleum studies focused on a review of the Central Basins region and interpretation of seismic reflection data in frontier basins to stimulate exploration in under-explored areas of Australia. As the Central Basins region straddles South Australia, Queensland and Northern Territory borders, integrated regional appraisals of basement structure and basin architecture in these areas had not been previously undertaken. New data and geological interpretations provide better understanding of the structure and depositional histories in the Georgina, Millungera, Darling, Arrowie, Arckaringa, Officer and Amadeus basins. The data, which were acquired in collaboration with State and Northern Territory geological surveys and Auscope, will enable a more rigorous assessment of petroleum prospectivity in these basins.

The seismic interpretations provide information on the thickness and internal structure of the basins as well as sedimentary fill, including hydrocarbon-bearing source rocks, and faults which control the basin boundaries. Petroleum systems modelling undertaken using data obtained in several basins provides further information and insights into their prospectivity.

In the Millungera Basin, which was discovered as a result of Onshore Energy Security Program data acquisition, two petroleum modelling scenarios indicate potential source rock possibilities. In one scenario based on analogy with the Georgina Basin, potential source rocks could be mature over most of the Millungera Basin, with significant expulsion of hydrocarbons occurring in two phases in response to sediment loading. In a second scenario based on analogy with the Galilee Basin, potential source rocks are likely to be oil-mature in the central Millungera Basin, but immature on the basin margins with significant oil generation and expulsion probably occurring in response to sediment loading. The data are expected to inform new exploration aimed at more clearly identifying the possible hydrocarbon potential in the Millungera Basin and other onshore frontier regions.

ACHIEVEMENTS:

- Improved understanding of basin architecture and stratigraphy of the under-explored Georgina, Millungera, Darling, Arrowie, Arckaringa, Officer and Amadeus basins.
- Discovery of the Millungera Basin and petroleum systems modelling and assessment of its hydrocarbon potential.

NEW OPPORTUNITIES:

- Modelling of the Millungera Basin indicates that potential hydrocarbon-bearing sources rocks will be mature over large parts of the basin.
- Enhanced hydrocarbon prospectivity in frontier sedimentary basins in Queensland, Northern Territory and South Australia.

KEY PRODUCTS:

Energy Potential of the Millungera Basin: A newly discovered basin in north Queensland. *APPEA Journal 51.*

Hydrocarbon and geothermal prospectivity of sedimentary basins in Central Australia: Warburton, Cooper, Pedirka, Galilee, Simpson and Eromanga Basins. *Geoscience Australia Record 2009/025.*

Gas shale potential of the Amadeus and Georgina Basins. *Geoscience Australia Record 2011/010.*

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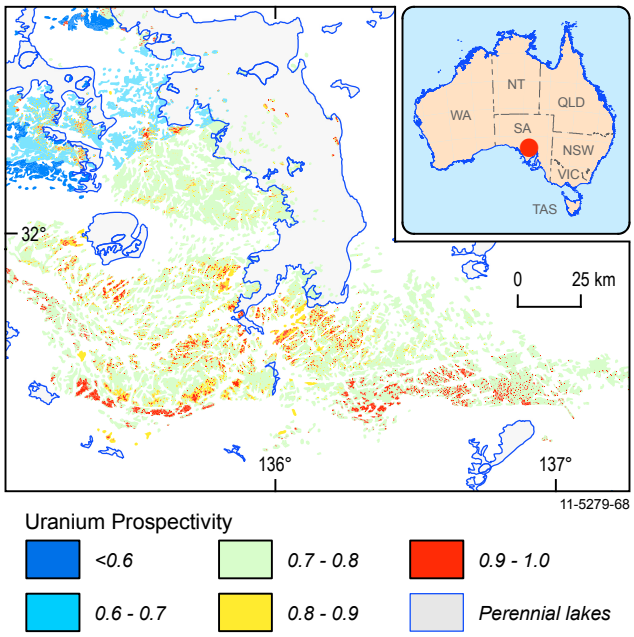

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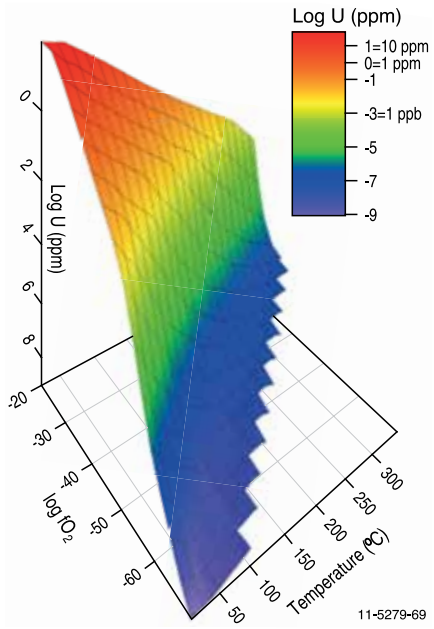

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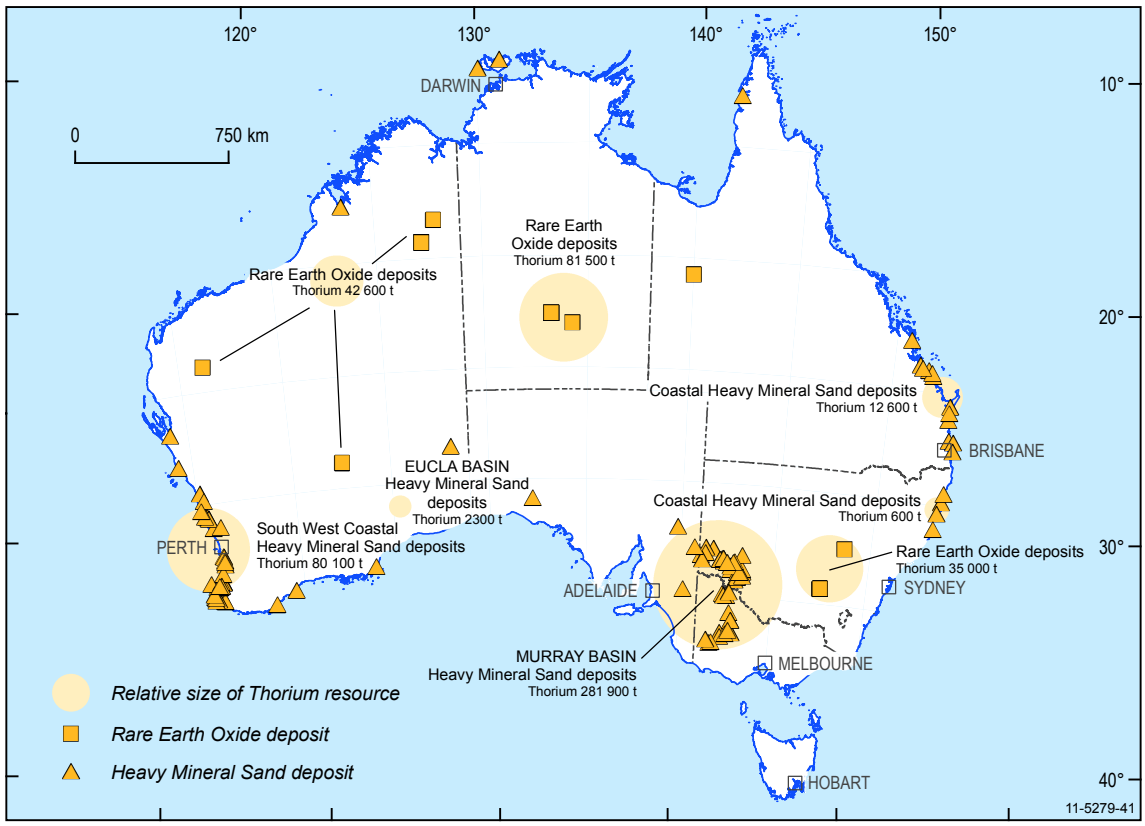

1: Excerpt from national map of potential for magmatic-related uranium mineralisation.

2: Modelled concentration of uranium in geological fluids relevant to ore formation.

3: Australia's thorium resources.

URANIUM AND THORIUM

Assessments of uranium prospectivity were carried out in regions where seismic and airborne electromagnetic data were acquired. From a major reappraisal of mineral systems, examining the key processes controlling 'where' and 'how' uranium mineralisation occurs, a new conceptual framework was developed to provide a better predictive basis for uranium mineral exploration.

A continent-wide study examining the relationship of uranium mineralisation to igneous rocks demonstrated potential for magmatic-related uranium deposits in parts of central Australia, north Queensland and northern Western Australia. Regional studies into uranium ore-forming systems were undertaken in the Lake Frome region of South Australia, Eromanga Basin of eastern Australia and around the Ranger uranium deposit in the Northern Territory. New rock samples were obtained for geochronological analysis to determine the age of known uranium mineral systems and provide a temporal framework for understanding key periods of uranium mineralisation.

Thorium is a naturally occurring radioactive element which is attracting increasing interest as a possible alternative nuclear fuel for electricity generation. A continent-wide review of thorium resources found that about 70 per cent of the known thorium resources are in the monazite component of heavy mineral sand deposits. Most of the known resources of monazite in mineral sands are in Victoria and Western Australia. The monazite in Australian heavy mineral sands averages about six per cent thorium and 60 per cent rare earths. Together with other types of deposits, Australia has an estimated 485 000 tonnes of recoverable thorium resource, giving it the world's largest total identified resource of this commodity.

ACHIEVEMENTS:

- Development of a new conceptual framework for uranium mineral exploration and identification of greenfields uranium provinces.
- Completion of the first national review of thorium resources and enhanced awareness of their status, distribution and potential.

NEW OPPORTUNITIES:

- North Queensland and South Australia are prospective for basin-hosted uranium, uranium-bearing iron oxide-copper-gold and unconformity-related uranium deposits. Central Australia, northern Western Australia and north Queensland have a high potential for magmatic-related uranium deposits.
- Australia is well placed to take advantage of future demand for thorium as an alternative nuclear fuel for electricity generation.

KEY PRODUCTS:

Potential for magmatic-related uranium mineral systems in Australia. *Geoscience Australia (GA) Record 2010/020.*

Uranium mineral systems: Processes, exploration criteria and a new deposit framework. *GA Record 2009/020.*

A review of the geochemical processes controlling the distribution of thorium in the earth's crust and Australia's thorium resources. *Geoscience Australia Record 2008/05.*

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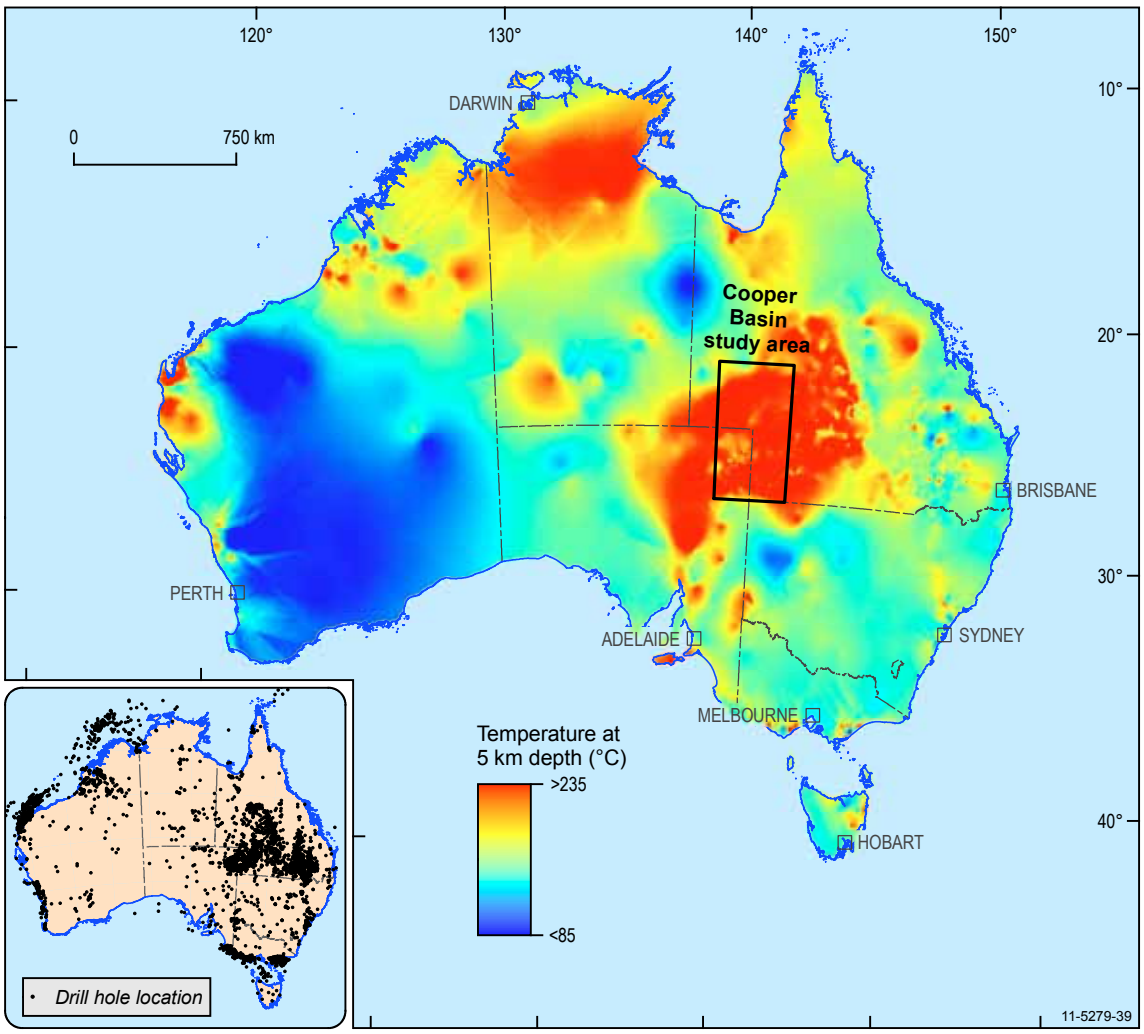

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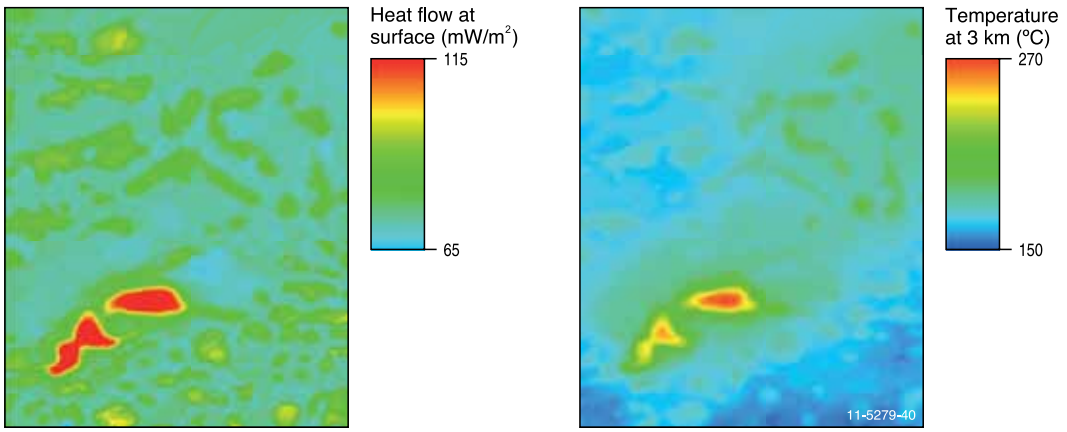

1: Updated OzTemp map of predicted temperature at five kilometres depth for Australia.

2: Outputs of Cooper Basin thermal model shown in study area (see 1); heat flow (left) and temperature at three kilometres (right).

GEOTHERMAL

National-scale studies of geothermal energy addressed the nature and location of geothermal resources in Australia. In order to better define and locate geothermal resources, temperature information derived from petroleum and mineral exploration drill holes and water bores was used to update the map of interpreted temperature at five kilometres depth across the continent. The map data are the basis of Geoscience Australia's estimate of the amount of thermal energy (190 million petajoules) contained in the crust, where temperatures are above 150°C at depths shallower than five kilometres. If just one percent of this energy were extractable, the total contained heat in this part of the crust would be equivalent to approximately 26 000 times Australia's total current annual energy consumption.

There is little geothermal-specific data available for regional exploration. Existing geological data needs to be utilised in a systems-based approach to infer geothermal prospectivity. Geoscience Australia has developed 2D and 3D methods to predict geothermal potential in areas with little temperature data.

The Cooper Basin area was selected to test the 3D thermal modelling method, with geological and thermal data in the region allowing construction of a comparatively well-constrained model. The model indicates there is geothermal potential in areas outside the current exploration focus in the Cooper Basin. Development of the Cooper Basin model is ongoing and the methodology developed during its construction has been applied to other regions, including the recently discovered Millungera Basin in Queensland.

ACHIEVEMENTS:

- Estimation of the amount of energy stored as heat in the upper part of the Australian crust, found to be the equivalent of 26 000 years of energy supply.
- A revision of the OzTemp map showing modelled (predicted) temperature at five kilometre depth.

NEW OPPORTUNITIES:

- Updated datasets and a new approach to the compilation of OzTemp data provides a framework for future geothermal potential studies at national and regional scale.
- Integration of seismic interpretations, geophysical images and thermal modelling of the Millungera Basin indicates that the basin may be prospective for geothermal energy.
- 3D thermal modelling methodology developed during the Cooper Basin study, using high performance computing, will be applicable to other regions.

KEY PRODUCTS:

OzTemp database of temperature measurements in drill holes.

OzTemp Map of Predicted Temperature at 5 km Depth.

Australian radiogenic granite and sedimentary basin geothermal potential map.

The Cooper Basin Region 3D Map Version 1: A Search for Hot Buried Granites.

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Image Analysis and Mapping Pty Ltd
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Terrex Pty Ltd
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Velseis Processing Pty Ltd
Veritas DGC Australia Pty Ltd

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University of Alberta (Canada)

University of Melbourne

University of the Sea

University of Sydney

STATE AND NORTHERN TERRITORY GOVERNMENTS

(National Geoscience Agreements)

New South Wales through Department of Industry & Investment and through Geological Survey of New South Wales

Northern Territory through Department of Regional Development, Primary Industry, Fisheries and Mines and through the Northern Territory Geological Survey

Queensland through Department of Employment, Economic Development and Innovation and through the Geological Survey of Queensland

South Australia through Department of Primary Industries and Resources, South Australia

Tasmania through Department of Mineral Resources Tasmania

Victoria through GeoScience Victoria

Western Australia through the Geological Survey of Western Australia

ONSHORE SEISMIC AND MAGNETOTELLURIC WORKSHOPS

Deep crustal seismic data, acquired as part of the Onshore Energy Security Program, were released to the public in a series of workshops located in centres near the area where the seismic data were collected. A total of five workshops were held.

2006 Mount Isa Deep Crustal Seismic survey

The seismic data acquired in 2006 by Geoscience Australia, Geological Survey of Queensland, Predictive Mineral Discovery Cooperative Research Centre and Zinifex were released in a full day workshop in Mount Isa on 24 June 2008. The workshop provided interpretations of the seismic traverses and re-interpretation of seismic data collected previously as well as 3D models of the Mount Isa region.

2007 Isa-Georgetown-Charters Towers Seismic and Magnetotelluric survey

The seismic data acquired by Geoscience Australia, Geological Survey of Queensland and AuScope were released in a full day workshop in Townsville on 5 June 2009. The workshop provided interpretations of the seismic traverses and presented a 3D model of north Queensland and a geodynamic model for the region's evolution. There was a discussion also on the implications of the results for energy and mineral systems.

2008–2009 South Australian Seismic and Magnetotelluric survey

These surveys were acquired jointly by Geoscience Australia and Primary Industries and Resources SA and the results were released at a public workshop in Adelaide on 6 May 2010. The workshop discussed the data acquisition, processing and interpretation, as well as the geology in the vicinity of the seismic lines and initial results of 3D geophysical modelling and alteration mapping of the study area as well as geodynamic implications of a transect from the western Gawler Craton to the Darling Basin. The workshop also discussed the implications of the results for regional energy systems.

2009 Gawler–Officer-Musgrave–Amadeus Seismic and Magnetotelluric survey

On 25 November 2010, a public workshop was held in Adelaide to present the results from a single traverse carried out along the Port Augusta to Alice Springs rail corridor by Geoscience Australia, Primary Industries and Resources SA, AuScope and the Northern Territory Geological Survey. The workshop discussed the acquisition and processing of the seismic and magnetotelluric data, the geology in the vicinity of the seismic line and interpretations of the sedimentary basins and basement components of the seismic line as well as a geodynamic model for the evolution central Australia and the implications of the results for regional energy and mineral systems.

2009 Georgina–Arunta Seismic and Magnetotelluric survey

The results of seismic data acquired by Geoscience Australia and the Northern Territory Geological Survey were released in a half-day workshop in Alice Springs on 23 March 2011. The workshop provided an overview of the geological history of the Arunta region and surrounding basins, interpretations of the seismic traverse, initial results of 3D and forward geophysical modelling of the study area and discussed the implications of the results for energy and mineral systems.

ONSHORE AIRBORNE ELECTROMAGNETIC WORKSHOPS

Airborne electromagnetic data, acquired as part of the Onshore Energy Security Program, were released to the public via Geoscience Australia's web site and at three public workshops.

2010 Paterson Airborne Electromagnetic survey

The survey data were acquired between 10 September 2007 and 28 October 2009 as a joint public-private venture between Geoscience Australia and five minerals industry subscribers. The contractor-delivered data were made available publicly on 4 March 2009 for the Paterson North survey and 17 April 2009 for the Paterson South survey, while value-added Geoscience Australia layered earth inversion data were made publicly available on 30 April 2010. The release was followed by a one day workshop held at the Geological Survey of Western Australia in Perth on 4 May 2010 which covered the collection, processing, quality assurance and quality control, value-added data inversion and interpretation as well as implications for the minerals industry for locating uranium and other minerals and groundwater resources.

2011 Pine Creek Airborne Electromagnetic survey

The survey data was acquired as a joint public-private venture between Geoscience Australia and nine minerals industry or government subscribers between 7 October 2008 and 24 May 2009 using the aircraft-mounted TEMPEST™ system and the helicopter-mounted VTEM™ system. Because of the complexity of the survey data were made available publicly over a range of dates from 30 September 2009 to December 2010 The data release was followed by two workshops, the first in Alice Springs on 24 March 2011 and the second in Perth on 7 June 2011, both of which included presentations on the collection, processing, quality assurance and quality control, value-added data inversion and interpretation and implications for the minerals industry for locating uranium and other minerals.

2011 Frome Airborne Electromagnetic survey

The survey data was acquired in a joint public-private venture between Geoscience Australia, Primary Industries and Resources SA and a minerals industry company between 22 May 2010 and 2 November 2010. Contractor-delivered data from the survey were released to the public on 31 March 2011 and were demonstrated to industry and government on 4 May 2011. A series of public workshops are scheduled to be held during 2011/12 to describe the data, interpretation products and implications for locating new uranium and other mineral resources.