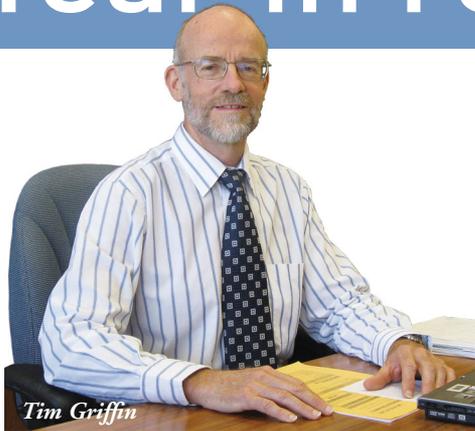


2009-10

Year in review



During the first half of 2010 there was more optimism that Australia's economy was recovering, although there is still doubt about the robustness of the world's economy. Commodity prices have climbed strongly from their lows in early 2009, but the number of mineral-related initial public offerings in the first half of 2010 remains subdued. In May 2010 the Australian Government's announcement of a resources rent tax that would apply to the mineral industry from 2012 had a dampening effect on resource investment sentiment. Such conflicting messages meant that total mineral and petroleum exploration expenditure (including in the offshore Commonwealth jurisdiction) in Western Australia declined marginally in 2009. However, this hid a significant decline in mineral exploration expenditure in 2009, although there are good signs of recovery in the first half of 2010.

At the end of 2009–10 all elements of the Exploration Incentive Scheme (EIS) had commenced. This includes the appointment of the first embedded researchers under the Western Australia Regional Researcher Initiative, and the signing of all agreements for exploration-related research undertaken in collaboration with WA:ERA, the Centre for Exploration Targeting, The University of Western Australia, Curtin University, and CSIRO. Particularly pleasing was the completion of a significant program of airborne geophysical surveys and deep seismic reflection surveys by the end of 2009–10. The first round of the Co-funded Industry–Government Drilling Program was a success, with several new discoveries being made. The second-round subsidy winners were announced at the end of June 2010.

For GSWA, the execution of such a large additional geoscience program under EIS, on top of the recurrent program, is placing some strain on our systems and staff. The quality of our staff, and of the considerable investment that has been made in the development of our systems over the last few years, is shown by our ability to rise to the challenge of doubling our output with only eight additional Public Service employees.

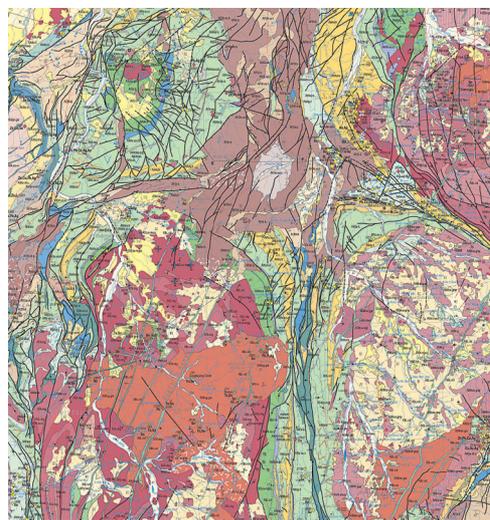
GSWA publications

During 2009–10 GSWA published:

- 24 geoscience maps including 12 Geological Series maps at 1:100 000 and one at 1:250 000 scale
- 36 records, reports and other publications
- 22 digital information packages.

GSWA met or exceeded its 2009–10 planned achievements for the recurrent budget-funded program despite the fact that some managers were also involved in implementing major EIS projects. Series map production continued at a high level for the second year in a row, which reflects the mature stage several mapping projects have reached.

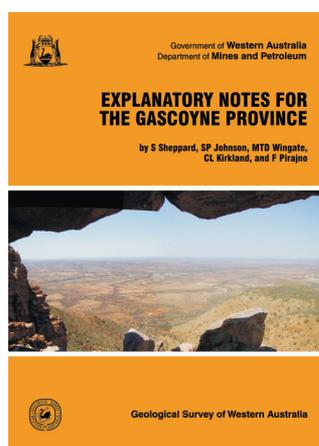
For the Pilbara mapping project, the Marble Bar 1:250 000 Geological Series map (third edition) is its final release. This map was compiled very differently from all previous 1:250 000 geological maps from the Pilbara. The new 1:250 000 geology was derived by a two-stage process involving simplification by ‘rolling-up’ up the 1:100 000-scale geology layers in the digital Pilbara Geological Information Series (GIS) package covering the area of the 1:250 000 sheet, followed by recompilation to further simplify areas still too complex for a 1:250 000-scale publication. This process achieved a much-improved consistency between the 1:100 000-scale GIS database and the geology of the 1:250 000 map sheet.



Part of the Marble Bar 1:250 000 Geological Series map

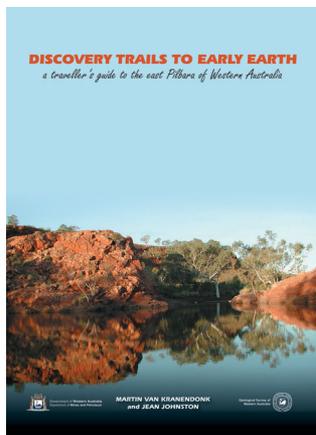
Seven 1:100 000 Geological Series maps were released for the Northeast Yilgarn mapping program. These, together with ‘digital only’ versions of three other 1:100 000-scale map sheet areas, are included in the latest release of the East Yilgarn GIS digital package, and complete the coverage of the Archean granite–greenstones up to the edge of the Gunbarrel Basin. Updated GIS packages were also released for the Murchison, west Musgrave, and western Capricorn Orogen, together with an updated Geological Exploration package for the west Arunta.

A number of Records and Reports were released detailing our understanding of the Proterozoic events in both the Capricorn Orogen and the Musgrave Province. This has involved the synthesis of extensive sets of geochronology, whole rock geochemistry, and isotope data, combined with a mature understanding of the regional geology. In the Capricorn Orogen, publications covered the 2005–1950 Ma Glenburgh Orogeny and the 1820–1770 Ma Capricorn Orogeny, as well as the geochronology of the Abra polymetallic deposit. In the Musgrave Province, publications detailed the age and geochemistry of the both the mafic and the felsic rocks. A Record on the Alcurra Suite discusses its relationship to the c. 1068 Ma Nebo–Babel intrusion, which is host to significant Cu–Ni–PGE mineralization, and the implications for further exploration. GSWA released a series of BSc Honours theses carried out as collaborative projects with Adelaide University, with GSWA providing field supervision and logistic support.



Explanatory notes for the Gascoyne Province were released in a new format representing a break from GSWA’s tradition of publishing explanatory notes for individual map sheets. The new format notes are made up of two parts: a front-end containing a synthesis of the geological evolution of the Gascoyne Province, and a back-end consisting of detailed descriptions of each lithostratigraphic unit and tectonic event.

Year in review



GSWA also released a self-drive guide book that showcases to the general public some of Earth's ancient wonders to be seen in the rocks in the Pilbara region, and allows the reader to appreciate the formation of its landscape. Written by Martin Van Kranendonk and Jean Johnston, *Discovery Trails to early Earth — a traveller's guide to the east Pilbara of Western Australia* provides directions for five different trails all beginning from Marble Bar.

The delivery of GSWA information through GeoVIEW.WA continued to expand, with 75 valuable State-wide geoscientific and related datasets available that are updated on a regular basis. A new 'Base Imagery' category was added containing State-wide raster datasets and associated metadata, including radiometrics, magnetics, gravity, 1:250 000 geology mosaic, 1:100 000 geology mosaic, and 1:250 000 topography.

Geological mapping programs

During 2009–10 mapping programs continued in the Yilgarn Craton, with field mapping completed on the Windimurra and Narndee Igneous Complexes in the Murchison Domain of the Youanmi Terrane. New SHRIMP geochronology has confirmed an age of c. 2800 Ma for the Narndee Igneous Complex, part of the Boodanoo Suite, and a c. 2810 Ma date for the Meeline Suite, a part of which is the Windimurra Igneous Complex. The extensive layered mafic–ultramafic intrusions, which host significant vanadium mineralization, collectively make up 40% by volume of the greenstones in the Murchison Domain, and also include the c. 2792 Ma Little Gap Suite, the



The Windimurra vanadium mine

c. 2750 Ma Gnanagooragoo Igneous Complex, and the 2735–2710 Ma Yalgowra Suite of layered gabbroic sills. All suites are demonstrably contemporaneous with packages of high-Mg tholeiitic lavas and/or felsic volcanic rocks and are consistent with genesis over a 100 million-year period in a mantle plume setting.

In the Eastern Goldfields, work has commenced on the implementation of a regional stratigraphy, regularizing existing stratigraphic nomenclature, and extending a consistent stratigraphic system across the whole of the Eastern Goldfields Superterrane. Mapping has been completed in the northeastern Yilgarn Craton leading to new interpretations with implications for the extent to which this stratigraphy can be applied, for crustal architecture and geodynamic evolution, and for prospectivity. Results suggest that the Burtville Terrane has affinities with the Youanmi Terrane to the west of the Kalgoorlie Terrane, and is a fragment that rifted off and was 'reaccreted' onto the proto-Yilgarn Craton. The inboard Kalgoorlie Terrane and the outboard Yamarna Terrane developed as adjacent rift basins that were closed during the reaccrusion event.

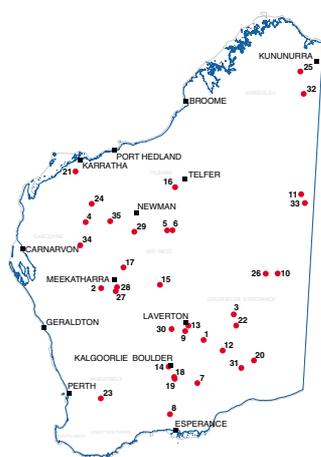
In the Gascoyne Province the east-southeasterly trending Chalba Shear Zone has been shown to control much of the intracontinental reworking recognized in the province. North of the shear zone new SHRIMP

titanate geochronology suggests that the province was pervasively reworked at medium metamorphic grade at c. 1280 Ma, during the Mesoproterozoic. South of the shear zone apparently similar reworking is 500 million years older, and took place during the 1815–1770 Ma Capricorn Orogeny.

In the basement to the Edmund Group in the Egerton Inlier, gold-bearing quartz veins are hosted by low-grade pelitic and psammitic schist, and minor metadolerite, mafic schist, psephite, and metadolostone. Mineralization is centred on the contact between metasedimentary rocks and a strongly foliated to mylonitic metadolerite. The basement rocks may correlate with the Padbury Group, or with the Bryah Group, which hosts recently discovered gold and copper mineralization at DeGrussa.

It has been recognized that the Albany–Fraser Orogen and the Musgrave Province in central Australia have been affected by similar tectonothermal events within the period between c. 1350 Ma and c. 1120 Ma. GSWA's ongoing work in both regions has enhanced our understanding of these events and is being used to test the possibility of a common tectonic link. The c. 1300 Ma Fraser Zone in the Albany–Fraser Orogen is dominated by metamorphosed gabbro and interlayered metamorphosed sedimentary rocks and granite. Its chronological counterpart in the Musgrave Province is the 1345–1293 Ma Wankanki Supersuite, a voluminous sequence of Andean-style continental arc granites and volcanic rocks. The Fraser Zone is interpreted as a lower crustal region of high-temperature metamorphism that was extensively intruded by sheets of gabbro while undergoing partial melting producing a wide spectrum of hybrid mafic to felsic magmas. This scenario is typical of lower crustal 'hot zones' thought to form the roots of active convergent margins, an environment also thought to have existed beneath the Musgrave Province during the formation of the Wankanki Supersuite.

Exploration Incentive Scheme



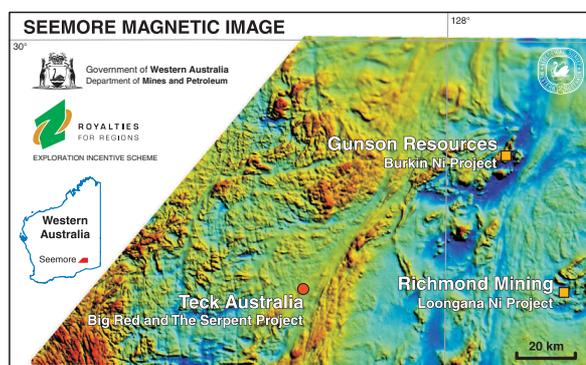
EIS Co-Funded drilling projects 2009–10

The first round of the EIS Co-funded Exploration Drilling scheme allocated \$3.19 million for 35 projects across the State, of which 30 will be completed. Successes include Beadell Resources' West Musgrave gold discovery (60 m @ 0.9g/t from 13 m depth, including 5 m @ 4.7 g/t gold), which is project 10 on the adjacent map. Drillcore will also provide new insights into the geology of remote areas, including the basement to the Eucla Basin. An amount of \$5.5 million is available for co-funded drilling in 2010–11. Following preliminary advertising in November 2009, applications opened in mid-February 2010 (for one month) and 62 successful applicants were announced in June 2010. Gold was the most sought-after commodity, followed by copper, uranium, and nickel.

As part of the Exploration Incentive Scheme (EIS), GSWA released nine regional airborne magnetic and radiometric surveys during 2009–10 totalling 907 000 line-km. The surveys were aimed at some of the most remote parts of Western Australia, covering the central and northern Canning Basin and the western Eucla Basin. The western Eucla Basin was flown at 200 m line spacing — half the usual spacing of GSWA's regional surveys. The images give a remarkably detailed picture of Proterozoic basement rocks buried beneath sand and relatively thin Cenozoic limestone. Ground gravity surveys were completed over the southern central Yilgarn, the eastern Albany–Fraser Orogen, and the northern Capricorn Orogen.

Year in review

EIS funding, in collaboration with AuScope (National Earth Science Infrastructure Program), ANSIR (National Research Facility for Earth Sounding) and Geoscience Australia, was used to acquire the Capricorn and Youanmi deep seismic lines for a total length of 1276 km across the Capricorn Orogen, and across the northwestern and central Yilgarn Craton. Acquisition started near Tom Price and ended at Leinster, providing an unparalleled view into the crustal architecture of the West Australian Craton. Magnetotelluric (MT) surveys were carried out in conjunction with the seismic surveys. Further MT surveys funded through EIS were carried out across the Southern Cross Domain of the Yilgarn Craton from Hyden to Norseman, and across the Musgrave Province.

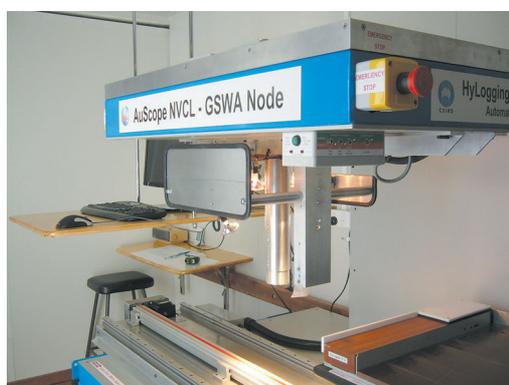


The East Wongatha regolith mapping and regional geochemical survey was carried out in the East Yilgarn and adjacent Albany–Fraser Orogen under EIS. Regolith mapping was also undertaken in the Gascoyne Province. Following on from the purchase and release of the Terra Search surface and downhole geochemical database, the mineral drillhole database to store company data has been developed under EIS and is being tested. It is estimated that there are 7000 historical datasets to be entered plus 1000 new datasets per year. Improvement of GSWA mapping databases continued, with the emphasis on the Explanatory Notes database.

A new initiative under EIS with both the Centre for Exploration Targeting at UWA and CSIRO's Minerals Down Under Flagship is developing exploration targeting products for under-explored areas of the State, starting with the West Arunta and the eastern Albany–Fraser Orogen. A program in collaboration with GEMOC at Macquarie University is well under way to obtain Lu–Hf data from dated zircons, together with a program of obtaining whole-rock Nd isotope data from dated samples. Phosphate dating using SHRIMP is being expanded.

National Virtual Core Library

GSWA is a participant in the National Virtual Core Library (NVCL) as part of AuScope, which aims to deliver high-resolution images and mineral composition information for drillcore throughout Australia. Information will be generated using the HyLogging system, a new and innovative spectral scanning system developed by CSIRO. GSWA's HyLogger has been commissioned at the Perth Core Library and is housed in a custom-built container that ensures a dust-free and temperature-controlled environment. Two spectrometers covering the visible-near-infrared (VNIR) wavelengths and the shortwave-infrared (SWIR) wavelengths are used to scan the core and determine its mineralogy. A Thermal Infrared scanner is still to be delivered.



AuScope's NVCL HyLogging system at GSWA's core library

Current target minerals include the Fe oxide group, the Al(OH) group, the Mg(OH) group, the carbonate group, sulfates, some OH-bearing silicates, the Si(OH) group, and the ammonium-bearing group. More than 15 000 m of core has been scanned. The HyLogging system will provide new insights into alteration-mineral assemblages, vectors to mineralization, objective determination of lithostratigraphic units and their boundaries, and refined inputs to resource block-modelling and mineral-processing characteristics.

Geochemistry and regolith

In 2009–10 more than 700 multi-element geochemical analyses of rocks were carried out in support of GSWA mapping and mineralization studies. Although commercial laboratories can accurately and precisely determine the concentrations of most elements, particularly precious metal analytical data, Geoscience Australia's laboratory provides the best-quality data for some REE and high field strength elements at low-level concentrations.

No progress has been made with the collection of samples in the central and western desert regions and in the Kimberley for the National Geochemical Survey of Australia due to delays in obtaining Aboriginal Heritage clearances.

GSWA has reviewed its approach to regolith mapping to provide a standardized approach to the understanding and classification of regolith, and to the use of remotely sensed data in the production of regolith maps. During the year, GSWA contributed to a meeting held in Kalgoorlie on the Paleovalley Groundwater Project.

Geochronology and isotope geology

Some 90 samples were dated in 2009–10 as part of GSWA's ongoing programs, including samples from the Pilbara Craton, the Youanmi and Burtville Terranes of the Yilgarn Craton, the Gascoyne and west Musgrave Provinces, the Albany–Fraser Orogen, and the Edmund and Collier Basins. In addition to GSWA's ongoing zircon geochronology program, a program of phosphate dating continued in collaboration with Curtin University as part of an ARC Linkage grant.

Integration of results from whole-rock Sm–Nd and zircon Lu–Hf analyses, which are being obtained in part under EIS, provide a valuable complement to U–Pb geochronology by revealing the timing of mantle input into the crust, which may correspond to regional mineralization events.



Sampling granite in the Albany–Fraser Orogen for Hf analysis

The Geochronology Record Series is now published directly to the GSWA website, with the latest results accessible using GeoVIEW. WA or via Digital Paper. GeoVIEW. WA opens with a geochronology theme preloaded, and redesigned tables are now more intuitive, allowing U–Pb and isotope files to be downloaded as text files. GSWA's geochronology and isotope data are downloadable as a KMZ file for use in Google Earth.

Year in review

Petroleum geology

Studies in the Canning Basin have shown that it is 'cooler' than first evaluated. A study to determine potential for geothermal energy has begun in the Carnarvon Basin, incorporating legacy data related to temperature at basement, depth to basement, and thermal conductivity analysis.

Difficult access, extensive sand cover, and a perception of low prospectivity — despite producing oil and gas fields in the NT — make the western Amadeus Basin one of the least-known geological regions in Australia. A field-based reassessment of the thick Neoproterozoic section in Western Australia has commenced with early progress made in correcting some long-standing miscorrelations. Two Neoproterozoic glacial units are present, allowing correlation with mid-Neoproterozoic successions elsewhere in Australia and world-wide. Numerous stromatolite horizons are present and preliminary identifications fit well with lithostratigraphic and sequence stratigraphic correlations. Most of the stratigraphic units in the Northern Territory that have demonstrated or suspected source rock potential are now recognized in Western Australia. If not reservoirs in the Amadeus Basin, they may have provided hydrocarbon charge to the Canning Basin, which onlaps to the west.

Mineral occurrence mapping, commodity analysis, and mineral exploration information

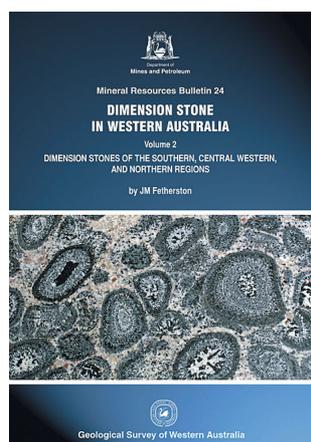
A DVD covering mineral occurrences and exploration activities of the Peak Hill area was released by the Mineral Occurrence Mapping and Commodity Analysis Group. Mineral Resources Bulletin 24 entitled *Dimension stone in Western Australia: volume 2 — dimension stones of the southern, central western, and northern regions*, by JM Fetherston was released.

More than 3376 reports were added to the WAMEX database, with 7686 released to open-file. These included 3176 from the sunset clause release and 4490 covering expired tenements. Another 4336 reports (previously only available on microfiche) were scanned and are available online. During the year there were 21 120 visits to the WAMEX webpage, 86% from outside the department, and by 30 June 2010 55 890 reports were on open-file

The WAMEX3 database is being continually improved. Focus has been on better data management of individual components, such as drilling data, surface geochemistry, geophysics spectral data, and GIS datasets, including reorganizing pre-WAMEX3 data for the website.

Land use geoscience

For Land Use Geoscience, prospectivity studies of proposed conservation areas continued, including for the Great Western Woodlands. Geological advice was given to other government departments on land rezoning and subdivisions, reserve creation, and under Section 16(3) of the Mining Act. Strategic resource studies focused on construction materials for the rapidly growing South West region and on titanium–zircon mineralization.





The rocky limestone coast at Cape Peron

The coast is a dynamic environment responding to changes in sea level, sediment supply and transport, and wave and swell patterns. Shorelines in southwest Western Australia are wave-dominated and can be broadly categorized into rocky and sandy coasts. Of major concern in managing coastal environments is determining the response to predicted rises in sea level. Without good long-term planning, coastal communities and infrastructure are at risk of erosion and flooding. Mapping of the coastline in southwest Western Australia by GSWA, can be used to understand the present stability of coastal landforms and their susceptibility to erosion.

The future

The Exploration Incentive Scheme (EIS) has been running for 15 months and is producing a step change in the amount of quality precompetitive geoscience information available. It is an effective demonstration that WA is committed to attracting more exploration investment by reducing risk. The focus is on areas that are poorly understood geologically; both in under-explored regions, and deep in terranes already known to be mineralized.

Integration of the ongoing mapping programs with the EIS programs should be aimed at developing a mineral-systems approach that will be effective in generating new exploration targets, particularly under the soil and the thin sedimentary basins that cover much of WA's under-explored regions. GSWA is also expanding cooperative projects with Geoscience Australia and CSIRO, and with university earth science research centres.

The challenge for GSWA, together with its government and university research partners, is to assist explorers to make full use of the modernized and expanded products and datasets. The development of new concepts, skills, and technologies is aimed at creating a new generation of exploration targets, which can be tested either under the Government co-funded drilling scheme, or by attracting new investment.

This will be my last review of GSWA operations as I will shortly take up a new position elsewhere in the Department of Mines and Petroleum. My time with GSWA, beginning in 1980 at Kalgoorlie, has been professionally rewarding and very enjoyable. I thank all the GSWA staff who have assisted me over the last thirty years and who have contributed in a collaborative way to making the Geological Survey one of the world's leading geological surveys.

Tim Griffin
Executive Director