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More than bumps: ASEG-PESA 2015 post conference workshop summary

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As part of ASEG-PESA's 24th International Geophysical Conference and Exhibition, a workshop on the geophysical signatures of mineral systems was organised for 19 February, the day immediately following the main convention. The title of the session was 'Geophysical signatures of mineral systems; more than bumps'. The purpose of the 'Bumps' workshop was to examine how prepared the industry is for the transition from searching for deposits generally outcropping or under shallow cover, to environments where the cover is more extensive and geologically complex. Traditionally, geophysics has been primarily used to define singular targets (aka bumps), which were thought to represent potential deposits. Such targets were often shallow, so drill testing was simple and inexpensive and, in addition, such targets could often be further qualified with either geological mapping or basic geochemical approaches. Going forward, recognisable responses directly associated with deposits are deemed far less likely and the expectation is that geophysics will be called upon to map some aspect of a deposit's overall mineral system and, once established, a variety of approaches will be required to then 'vector in' to the economic part of the deposit. The overall economic success of the effort will be much more dependent on how well integrated geophysical technology is with other technologies as well as the financial, commercial and even societal aspects of exploration process.

Back story: the mineral system

Once the theory of continental drift was in place mid-last century, economic geologists could begin to model the earth's crust over time and understand that, in many settings, ore deposits were continually being formed and consumed. This also allowed them to predict where the geological column was more likely to host deposits at depth and quite possibly show little or no surficial expression due to the thickness or nature of the cover material. To be able to search for deposits in such environments required new approaches and the concept of a mineral systems approach, first suggested 20 years ago by Wyborn et al. (1994), has emerged as a powerful means to build strategies and define the required capabilities going forward. Wyborn et al. (1994), after having examined targeting strategies for oil and gas, developed what could be considered a minerals analogue. Central to this approach in the search for oil and gas is the fairway; a pathway or corridor where there is a greater likelihood of accumulations of hydrocarbons. The following definition of a fairway is adapted from Schlumberger's website:

The trend along which a particular geological feature is likely, such as a sand fairway or a hydrocarbon fairway. Prediction of conceptual fairways helps explorationists develop prospects.

The idea of a conceptual fairway is a powerful one as it allows us to envisage the pathway down which mineralised fluids passed prior to potentially being trapped at a depo-site. This pathway has been altered physically and chemically, sometimes for distances of 10 kms or more and therefore can offer a far larger and widespread path to locate and follow towards a potential deposit (the presence of a fairway does not mean, however, a deposit has necessarily formed or been preserved). Not all deposit styles, of course, lend themselves to being scrutinised by a minerals system approach but many do, and this could mean industry preferentially seeks such deposits as compared to more enigmatic ones. An introduction to these ideas and an assessment of the 'state-of-play' from a geophysical perspective is provided in Witherly (2014).

Bumps workshop

The Bumps workshop examined the present state of understanding of geophysical signatures of mineral systems; current examples and the role some of the important supporting technologies such as geochemistry will play. Also, the economic framework in which this new style of work will be carried out was considered, since a much greater degree of 'skin-in-the-game' will be required for all parties involved. Below are summaries of the eleven speakers in the workshop. Note, co-authors have contributed in many cases to these presentations and they are acknowledged on the title pages of the speakers' presentations.

Allan Trench (Curtin University/CET): 'An economic perspective on deep and under cover exploration: what are we looking for and how do we get there?'

Trench and his co-authors showed that there is much still to be understood about the economics of deep deposits that need to be mined underground as compared to those deposits that can be mined by open pit. Issues that include grade, deposit shape and metallurgy are important but are well understood, and they can change over the life of a mine. They examined issues related to a number of common Australian deposit styles including orogenic gold and IOCG and compared these with similar deposits in other parts of the world. The analysis did not factor in either the relative cost or time to find mineable deposits, factors that would have to be considered by a company planning to be in the mining business.

Mike Dentith (University of Western Australia/CET): 'The implications of the mineral systems concept for geophysical exploration: a perspective'

Dentith started by defining the basic concepts of mineral systems and related this to what can be measured with geophysical techniques (Figure 1). He introduced the major geophysical techniques; gravity and magnetics, active and passive seismics and magnetotellurics. The loss of resolution at depth was cited; multiple techniques can possibly help to overcome this. Better understanding of the petrophysics of rocks at depth is important but this has been a particularly difficult challenge to advance for a number of reasons.

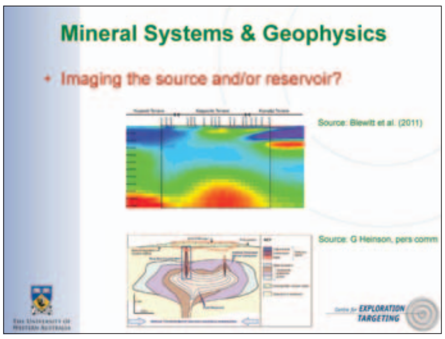

Figure 1. *Dentith PPT Slide: AMT section and hypothetical cross section of deposit forming magma chamber.*

Steve Beresford (First Quantum Minerals): 'Undercover exploration in 2030: an UNCOVER vision'

Beresford is Chair of Geoscience for the national UNCOVER initiative. He started the presentation looking at how most undercover exploration is carried out today, what the UNCOVER program was hoping to then achieve and laid out a vision for how exploration would look in 15-30 years. He then examined the changing role for geophysics in this vision; ie beyond bump finding. Steve emphasised that a new level of collaboration would be required, which is considered one of the major challenges as mining historically limits collaborative work to what is considered pre-competitive R&D (Figure 2). Other groups with similar 'big challenges' such as found in medical are cited as the style of collaborative work model required.

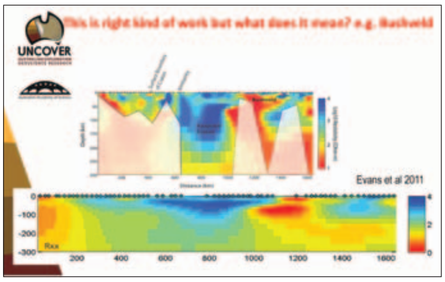

Figure 2. *Beresford PPT Slide: Geophysical imaging of Bushveld; some answers and some questions.*

Eric Anderson (USGS): 'Mineral systems approach to porphyry copper exploration – a magnetic perspective in southwest Alaska'

Anderson provided the first case history of the session and examined regional and detailed aeromagnetic data around the Pebble Cu-Au deposit Alaska. Pebble is one of the largest underdeveloped copper and gold deposits in the world and was the subject of an extensive geological, geochemical and geophysical assessment by the USGS (Kelley et al. 2013). Pebble itself lacks a strong direct magnetic signature but modelling shows that there is a very large magnetic high underlying the deposit area. As well, there are a number of other distinctive magnetic features in the vicinity of Pebble that collectively define a very anomalous terrain. When taken in a regional context Pebble appears to be part of a potential porphyry copper belt over 700 km in strike length that extends eastward into the Yukon (Figure 3).

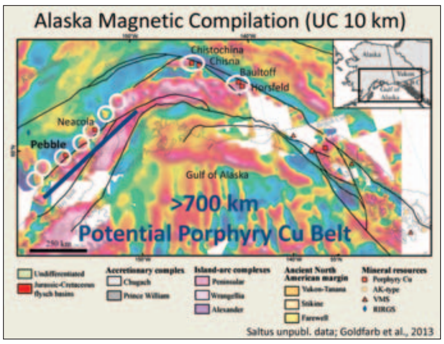

Figure 3. *Anderson PPT Slide: Image of upward continued aeromagnetic cover over southern Alaska-Yukon showing known or suspected porphyry systems over length of >700 km.*

Terry Hoschke (Consultant): 'Pathways to porphyries – mapping alteration and related mineralisation'

Hoschke began by highlighting the importance of subduction zones in the formation of porphyry deposits and how geophysics can map these important geological boundaries (Figure 4). With remainder of his talk, he focused on the geophysically mappable characteristics of porphyry systems. Unlike many other ore deposit styles, the porphyry copper deposit can have a very large primary alteration system, which can extend for several kilometres around the deposit. Even at considerable depths of burial the direct detection of a porphyry system is deemed a reasonable exploration proposition. The fact that the porphyry system is injected from below also means than the fairway for the individual deposit lies below the actual deposit itself.

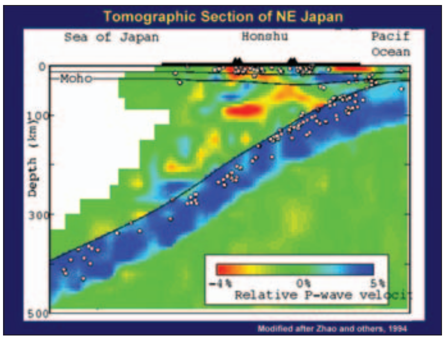

Figure 4. *Hoschke PPT Slide: Image of subduction zone NE Japan derived from seismic measurements.*

James Cleverly (REFLEX Geochemistry): 'Real time data and geologically meaningful bumps'

Cleverly outlined the revolution that is occurring in how geochemistry is being used to change the exploration process by making information on mineral chemistry available essentially in real time. Part of this is being driven by a major initiative within the DET-CRC to modify oil field tube drilling technology to minerals exploration. If successfully implemented, the tube drilling system will provide a stream of powder from the ground rather than traditional core or chips. Cleverly described an innovative technology called 'Lab-at-the-Rig' which would provide full analysis of the drill hole material at the drill site in a short time frame (Figure 5). As is often the case, Cleverley noted in his closing remarks that the success of this technology depends on there being a clear path forward as to how these exciting outcomes can be integrated with concurrently acquired geological and geophysical data to then effectively direct the exploration process in real time.

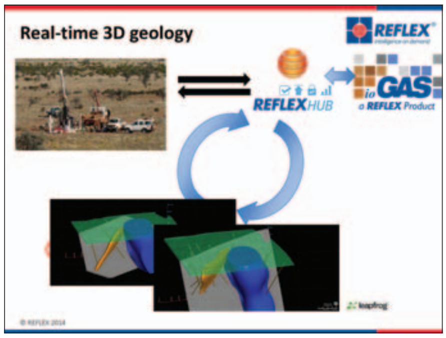

Figure 5. *Cleverly PPT Slide: Concept image showing recovery of detailed geochemistry and lithological information in real time at drill rig.*

Mark Jessell (University of Western Australia): 'From 3D geology to 3D geophysics, what next?'

The title of Jessell's talk could have been '3D geology; is it ready?' as the large part of the presentation dealt with the state of the art in 3D geological modelling and the impact that has on how this then links in with 3D geophysical modelling (Figure 6). Jessell showed that the world of geological modelling is moving beyond the single 'best guess' approach an individual might be expected to produce to schemes were multiple possible solutions are being automatically generated which in turn could be used as constraints for multiple geophysical inversion models.

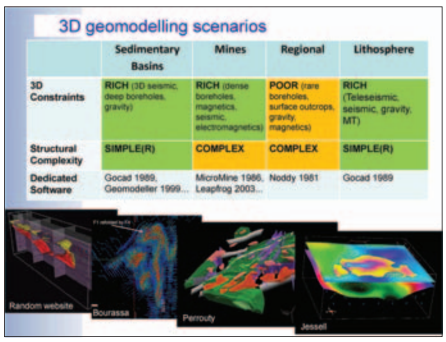

Figure 6. *Jessell PPT Slide: Outline of 3D geomodelling scenarios at various scales.*

News

Dave Clark (CSIRO): 'Petrophysical insights into targeting ore systems'

While the focus of Dave's talk was on the potential complexity of magnetic responses around deposits, much of the material covered district scale to more regional assessments and emphasised that, most times, interpreters are over-reliant on simple models for magnetic induction and ignore the effects of remanence, magnetite grain size and the often fickle nature of pyrrhotite (Figure 7). Numerous examples were shown where the 'one size fits all' approach to interpretation of magnetic data often fails to guide the user to the correct answer and can result in economically important targets being either misinterpreted or missed entirely. Remanence was pointed out to be a far more insidious factor in the assessment of magnetic data as it 'contaminates' likely 50% of all magnetic survey data, even if there are no 'telltale' strong negatives present in the data sets. This means that if this factor is left uncorrected inversion models will be geometrically distorted.

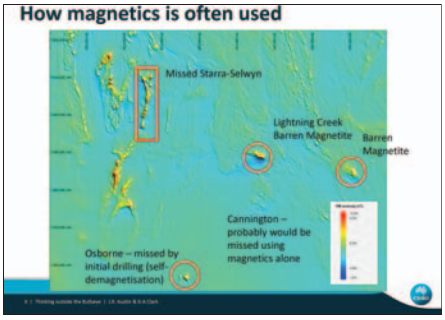

Figure 7. *Clark PPT Slide: Image of aeromagnetics from Queensland showing magnetic character of a number of deposits.*

Janne Kaukolinna (First Quantum Minerals): 'Finding the right bumps under glacial till in the Central Lapland Greenstone Belt'

Kaukolinna outlined the challenges of Ni exploration in northern Finland where the sought after target has strong geophysical characteristics (mag and EM, but so do many other features in the geological environment. Given the thin cover and a geophysically data-rich environment, a number of innovative processing techniques can be applied, which help narrow the search. A key component of this approach is a very large petrophysical data base acquired by the government.

Gavin Selfe (GRS Consulting): 'Following the mineral system and tracking it under cover – using every tool at our disposal'

Selfe presented four case studies from southern Africa that highlighted the need and value of combining a number of geophysical data layers and close integration with geology to develop effective exploration plays. The first example was from Mozambique and covered a large area, approximately 270 km by 220 km. Using a basic geological map, along with high quality aeromag and radiometrics data, Selfe was able to create a geo-interpretive map that was able to highlight areas prospective for mineralisation. The second project was in Botswana where the target was copper contained in conductive shales underneath a cover of Kalahari sediments. While the shales were easily mapped with EM, the challenge in this case was to define those parts of the stratigraphy close to the basement. This was achieved using a combination of careful analysis of the EM and air gravity data (Figure 8). The third example focused on a copper belt style play that straddles the Zambian-DRC border. Again, mag, EM and gravity were the key data sets but, in this case, the gravity provided a diagnostic response associated with the key breccia unit. The final example showed the work around a Ni deposit in north central Zambia. Here, careful ground geophysical work with modelling was used to define a complex ore zone in a graben structure.

Figure 8. *Selfe PPT Slide: Image of EM Tau Ternary image with structural interpretation added.*

Graham Ascough (Mithril Resources): 'Signatures of mineral systems; a perspective from the financially challenged'

Ascough indicated that the juniors made the majority of the mineral discoveries in the past decade but they have been 'unfriended' by investors in the past half-decade due to a perceived higher than acceptable risk. Historically low commodity prices and majors being distracted by their own issues has meant there has almost been a 'perfect storm' battering the juniors. It is not clear if a better geoscience story will do much to alleviate these concerns in the short term. Ascough then went on to show some examples where the junior sector was trying to be innovative in terms of both the commercial side and geoscience since, for the junior, these two factors must be in sync if they are to attract good investors and have the likelihood of producing satisfactory results. One example of this approach involved six companies pooling their properties in the prospective but remote Musgrave Block, in an area just east of the major Nebo Babel Ni-Cu deposit. They formed a new company and were able to do a $20M IPO which separately would have been impossible. Started in 2011, the project is now producing some spin-off plays with interesting and encouraging results.

The full set of talks is available on YouTube at:

https://www.youtube.com/playlist?list=PLUfG7j4LhdsdZ9CxKBPZh3qozAYXpLLPa

At the ASEG 2013 conference, a workshop with a similar theme was held and the proceedings were also recorded and are available on YouTube at:

https://www.youtube.com/playlist?list=PLUfG7j4Lhdscw0S3fgwhIewpV4KbYKcWN

The Decennial Minerals Exploration Conferences (www.dmec.ca) site also carries the links to these and other such topical workshop as well as a download point for the workshop handouts.

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ASEG-PESA-AIG 2016: news from the Conference Organising Committee

ASEG-PESA-AIG 2016
25TH GEOPHYSICAL
CONFERENCE & EXHIBITION
Interpreting the Past, Discovering the Future

It's been a busy few months as dates for various aspects of the conference are being set in stone.

Expressions of interest forms to run a workshop are available now from the conference website (http://www.conference.aseg.org.au/cfp.html). These must be returned to the Conference Organising Committee by 1 December 2015 so that the Committee can tailor the workshop programme.

The Call for Abstracts will open on 1 November 2015 so, please start thinking about what you would like to present at the conference! As with previous conferences you'll be able to download the abstract template through the conference website. We're allowing longer extended abstracts for this conference; no longer will you be limited to four pages!

Earlybird registration will open in January 2016.

The programme subcommittees are working hard to identify keynote speakers for the conference. If you have any suggestions please do not hesitate to contact the committee.

The sponsorship and exhibition prospectus has been distributed to interested parties. If you would like a prospectus, please visit the conference webpage to download the pdf (http://www.conference.aseg.org.au/prospectus.html). Also available on the website is the floorplan for the conference. We've taken aboard feedback from previous conferences and are including more room for delegates to sit down during the day.

Many of our deadlines revolve around printing deadlines for the conference edition of *Preview*, so it is imperative that if you're thinking of sponsoring or exhibiting that you meet the deadlines outlined in the prospectus. Failure to do so will mean your company will not be included in the conference edition of *Preview*.

Planning for the dinner is also well underway. We're booked in at the newly renovated Adelaide Oval, and will see a return to a more traditional dinner format.

If you have any thoughts, questions or comments regarding the upcoming conference, you can contact us via email or by social media. We have a LinkedIn page, a Facebook page, and a Twitter feed. Links to these can be found on the website.

This conference – the 25th of its kind – is panning out to be a major event. We're delighted to have PESA return as co-host, and with AIG on board too we hope to reach many more geophysicists in Australia.

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ASEG-PESA-AIG 2016
25TH GEOPHYSICAL
CONFERENCE & EXHIBITION

Interpreting the Past, Discovering the Future

August 21-24 Adelaide, South Australia

We would like to invite you to attend the 25th Geophysical Conference and Exhibition. This year the Australian Institute of Geoscientists (AIG) joins the Australian Society of Exploration Geophysicists (ASEG) and the Petroleum Exploration Society of Australia (PESA) to present a highly technical program. AIG is a professional institute representing geoscientists employed in all sectors of industry, education, research and government throughout Australia. The broad base of the AIG encourages transfer of technical expertise, experience and awareness of issues affecting all aspects of professional geoscience practice.

The ASEG-PESA-AIG 2016 Programme Committee will be working to attract abstracts in the three key areas of Petroleum, Minerals, and Near-Surface/Engineering geophysics. In each of these areas, super-themes will focus expertise into main avenues throughout the conference. We envision that many of the common technique-based themes seen at geophysical conferences will fit into these categories.

For further information on themes and subjects please visit http://www.conference.aseg.org.au/

CALL FOR ABSTRACTS OPEN 1 NOVEMBER 2015

PESA Petroleum Exploration Society of Australia

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UNCOVER: summary of presentations at a GA forum

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As part of the 2015 Mines and Wines Conference held in Queanbeyan over 2–4 September 2015, Geoscience Australia hosted a forum on its contribution to the UNCOVER multi-agency program (http://www.uncoverminerals.org.au/). The aim of UNCOVER is to deliver major new mines by locating and unlocking future mineral wealth, primarily from areas that are covered by regolith. There were 13 speakers and their presentations are summarised below.

Richard Blewett: 'The Minerals programme at GA: an UNCOVER overview'

Australian annual exports from the minerals and energy sectors are more than $190 billion and yet in recent years the discovery of new resources has declined. New discoveries require new exploration, particularly in the areas where the basement rocks are covered. Four themes are addressed by the UNCOVER forum presenters namely:

Theme 1: Cover

Science problem: ~80% of the continent is covered by post mineralisation material, which poses a major exploration challenge and opportunity. What is the thickness and character of cover at each drill site?

Solutions: Harness legacy data, benchmark methods of cover-thickness estimation, develop new techniques of cover characterisation and produce new predictive maps.

Theme 2: 3D architecture

Science problem: World class mineral deposits result from efficient focussing of metal, fluid and energy through the lithosphere into the upper crust. What is the architectural record of these fluxes, especially under cover?

Solutions: Map the lithospheric architecture, define the crustal architecture and integrate towards national 3D model.

Theme 3: Geodynamics and mineral system evolution

Science problem: Most major ore deposits formed during specific time periods, linked to stages in supercontinent cycles. Australia is endowed with a >3.8 billion year rock record, but where are the favourably aged rocks hosting mineral deposits?

Solutions: New determinations of geological ages (stratigraphy, rocks, events, mineral deposits, etc.), translating theory into practical maps for exploration area selection and assessments of Australia's mineral potential, greenfields and under cover.

Theme 4: Distal footprints and toolkits

Science problem: Ore deposits are small, and are often under cover. How do we see the larger signals (footprints) of mineral systems to reduce risk in selected regions?

Solutions: Collect new data to map prospective fairways under cover (drilling), maximise the knowledge: develop new exploration toolkits at a range of scales and deliver products including data.

Theme 1: Cover

Marina Costello: 'Airborne electromagnetic (AEM) – cover thickness, cover character, advanced processing, interpretations and case study exemplars'

Nine government and industry funded AEM surveys have been completed in the last 15 years. They cover ~555 000 km² and include 194 000 line-km, as shown in Marina's slide (Figure 1). AEM data are ideally suited to exploration in the top ~300 m of the Earth's surface where explorable depths are within easy reach of current drilling technology. Regional AEM data are able to improve undercover geological mapping, reduce exploration risk and stimulate investment by industry.

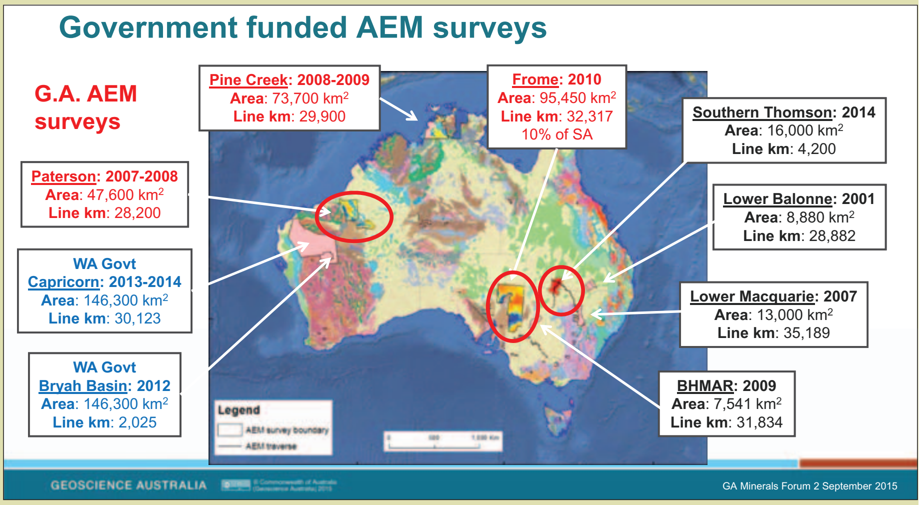

Figure 1. *Costelloe PPT Slide: Locations of recent AEM surveys, where the results are publicly available.*

Tony Meixner: 'Geophysics applied to variable cover: benchmarking multiple methods to known depths'

Depth to magnetic source methods can provide cover thickness estimation across most of Australia. Grid based methods of interpolation produce low reliability results – flight-line based methods produce higher reliability results, particularly where magnetic depth estimates can be geologically attributed. Passive seismic and refraction seismic can also be used to estimate basement depth. Tony showed an example from Stavely in Victoria where the magnetic depths are compared with the drilling results (Figure 2).

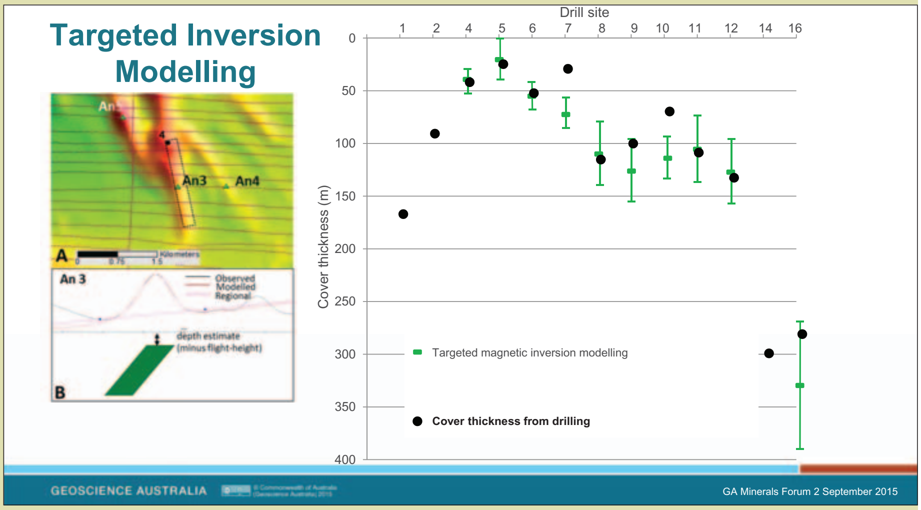

Figure 2. *Meixner PPT Slide: Inversion modelling from magnetics and drill hole results. Refraction seismic and passive seismic produce more accurate results, but are much more expensive to obtain.*

John Wilford: 'Towards a national cover thickness map using data mining: a model-based prediction of cover thickness'

Using 800 000 drill holes from the National Groundwater database, of which 350 000 have lithology available, together with the geophysical data bases and applying a cubist data mining technique the depth to the regolith has been estimated over the whole continent.

As an example John showed the Cenozoic depth boundary for the Murray Basin with estimated uncertainties.

Theme 2: 3D architecture

Richard Chopping: 'The magnetotelluric method to map near surface to deep lithosphere: case studies and new developments'

Large-scale regional and national MT surveys to investigate crustal and lithospheric architectures in Australia have been carried out in the last few years. These include 16 regional surveys (more than 3000 sites) across potential mineral provinces and frontier sedimentary basins. In addition the Australian Lithospheric Architecture Magnetotelluric Project (ALAMP), a collaborative national survey for acquiring data at approximately 2800 sites with a ~50 km grid spacing, is being undertaken. Because the MT frequencies range from 10^{9} to 10^{-6} there is huge scope for investigating the Earth, however, the modelling resolution is quickly degraded as the depth increases. The deep seismic surveys are crucial to interpret crustal and mantle structures and their results compliment the MT analysis. A conductivity model for the crust beneath Roxby Downs was shown in one of Richard's slides (Figure 3). The first state ALAMP survey is in Victoria.

There will be 7 months for data acquisition, 4 months for data processing and it is expected that the data will be released very soon.

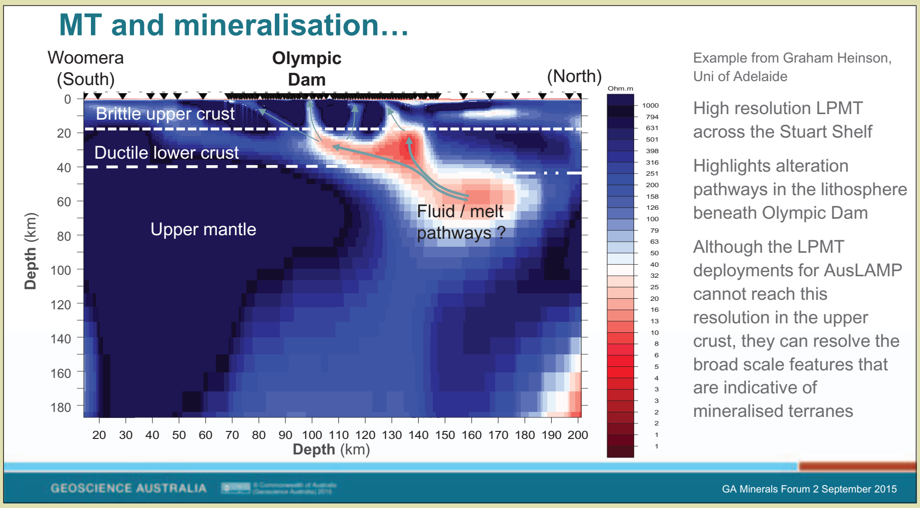

Figure 3. *Chopping PPT Slide: High resolution modelling across the Stuart Shelf highlights alteration pathways in the lithosphere beneath Olympic Dam obtained from MT data.*

Ross Costelloe: 'The seismic database of Australia: a continent in cross section'

Thousands of kilometers of deep crustal seismic data have been obtained in Australia since the 1950s (Figure 4). These data can be used to:

- *Image major crustal boundaries and faults*
- *Indicate potential fluid flow pathways, and*
- *Image under cover*

Processed data and images are available from GA website: http://www.ga.gov.au/about/what-we-do/projects/minerals/current/seismic

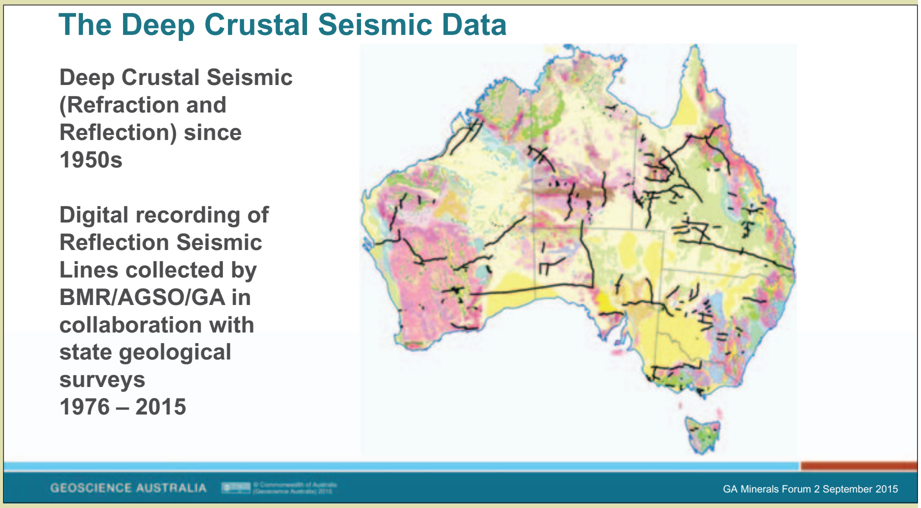

Figure 4. *Costelloe PPT Slide: Deep crustal recordings from 1950 to 2015. Explosives were used from 1976–1999, when Vibroseis took over.*

Karol Czarnota: 'Bringing it all together: the Australian Architecture Reference Model (AusARM)'

Using information from 7000 km of full crustal reflections a set of new comprehensive models of the crust and upper mantle beneath Australia have been produced. The results for the Moho were indicated on one of Karol's slides (Figure 5). Other models are available for different depth windows.

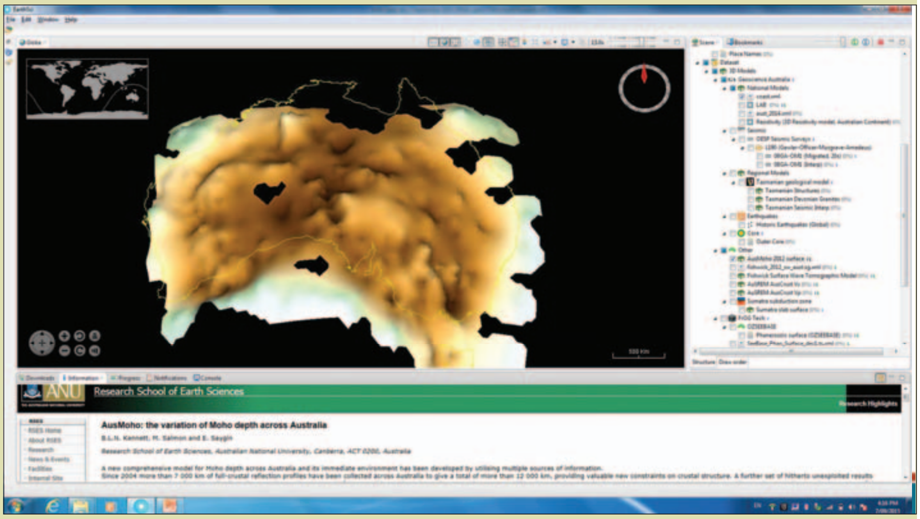

Figure 5. *Czarnota PPT Slide: Indicative variation of Moho depth across Australia.*

Theme 3: Geodynamics and mineral system evolution

Geoff Frazer: 'Australia through time: the U-Pb database of Australia, ASUD, GA's geochronology capability'

Dating specific geological events is crucial in developing models of mineralisation. Geoscience Australia has an in-house SHRIMP laboratory (~120 samples per year) and other in-house expertise (but not in-house analytical facilities) to use ID-TIMS U-Pb, Ar-Ar, K-Ar and Re-Os dating methods. More information can be obtained by contacting stratnames@ga.gov.au or geochronology@ga.gov.au.

Kathryn Waltenberg: 'Isotope geochemistry to map architecture and fertility: Sm-Nd, Pb and Hf'

The aim is to look 'through' the granite to date its source by timing when the crust was extracted from the mantle. The model ages approximate the bulk age of the crust. The technique is best used in relative terms and at regional scales. One of Kathryn's slides (Figure 6) showed an age map of the Australian continent, being built from the west to the east over about 3 billion years.

Lead isotopes can also be used in a similar way to the Sm-Nd method. It uses Pb-rich, U-free minerals (e.g. galena, feldspar) and is best used when the age of the system is independently known. Pb isotopes in feldspar can represent bulk-crust/mantle composition through time and Pb isotopes in galena provide direct information about crust/mantle input during mineralisation events. And finally, GA is using Lu-Hf and O isotopes and is maintaining a data base of samples and ages.

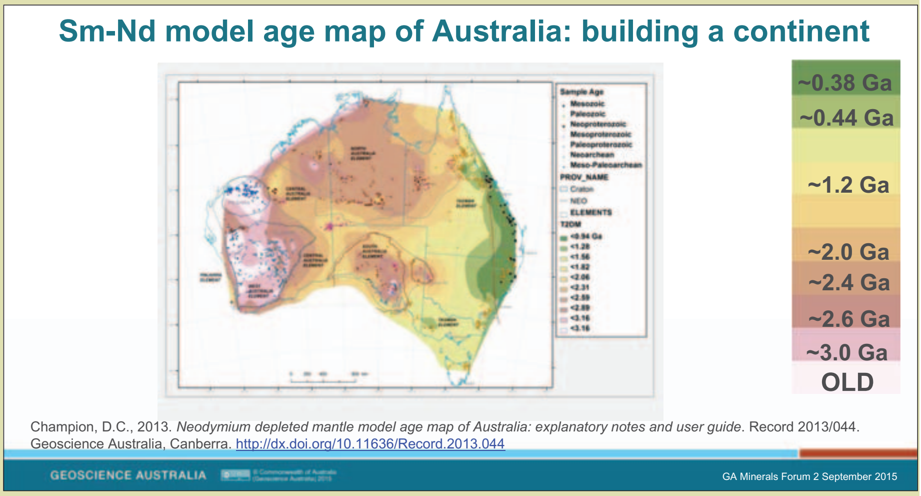

Figure 6. *Waltenberg PPT Slide: Sm-Nd age map of the Australian crust showing how accretion occurred from west to east over ~3 billion years.*

David Huston: 'Mineral systems as an area selection method at the national and regional scales: examples of magmatic Ni-PGE, IOCG and salt lakes'

The challenge is to develop dynamic models to describe the formation of mineral systems, so that geologists can search for analogues (Figure 7). I think that the models might be just a little too complex for geophysicists, but may as well be included for completeness. These methods appear to work in isolating more prospective areas.

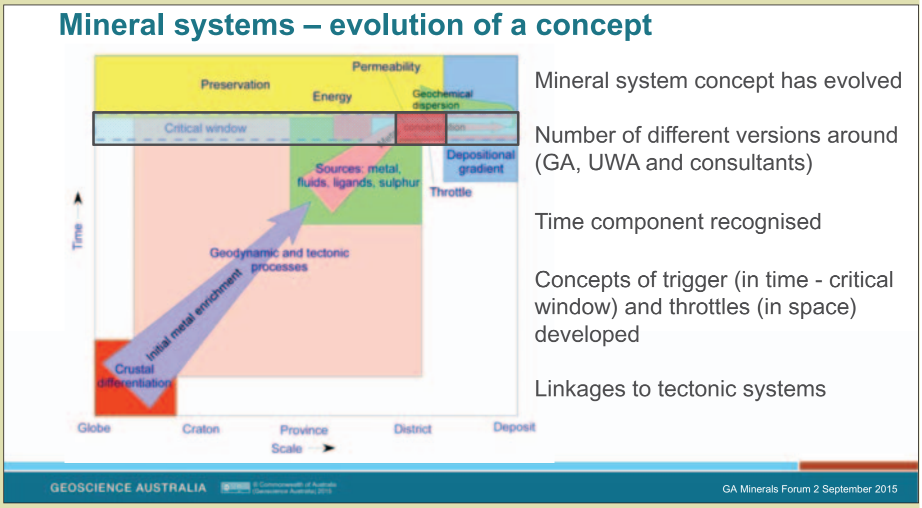

Figure 7. *HustonPPT Slide: Schematic of possible evolution of a mineral system.*

Theme 4: Distal footprints and toolkits

Anthony Schofield: 'Update on regional stratigraphic drilling projects: Stavely and Thomson'

In the end a borehole has to be drilled to test the modelling and 14 fully cored stratigraphic drill holes have been drilled at the Stavely Arc in Victoria (Figure 8). The drilling program included the deepest sonic hole drilled in Australia (212 m) and used a suite of logging techniques to detect lithological changes and distal signatures of mineral systems. These included: Lab-at-Rig® (geochemistry), AutoSonde™ (geophysics), Rock properties, HyLogger™ hyperspectral data and whole rock geochemistry.

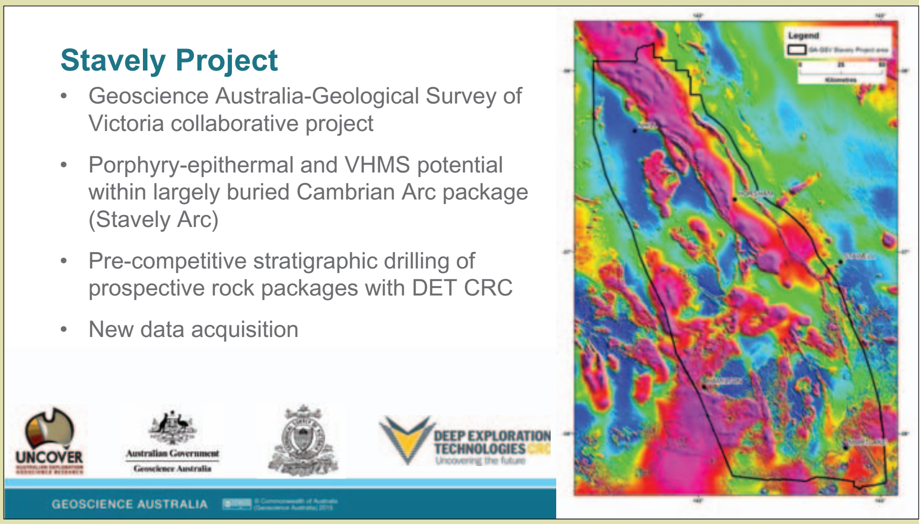

Figure 8. *Schofield PPT Slide: Location of Stavely project inside the black line on the image.*

James Goodwin: 'Lowering the entry level to big data and big compute: the Virtual Geophysical Laboratory and its future development'

There is an estimated 3 petabytes of publicly funded geoscience data in Australia, and most of these data are held by Geoscience Australia. In terms of geophysics this includes nationwide datasets of: gravity, magnetics, radiometrics, seismic, magnetotellurics, airborne electromagnetics (AEM) and satellite derived data. Big fast computers are needed to perform inversions on large data sets. GA uses RAIJIN, named after the Shinto God of thunder, lightning and storms; it is a Fujitsu high-performance, distributed-memory cluster, with: 57 472 computer cores; >10 petabytes Research Data Storage Infrastructure; peak performance of 1.2 PFlops; ranked 38th most powerful computer system in the world (Figure 9).

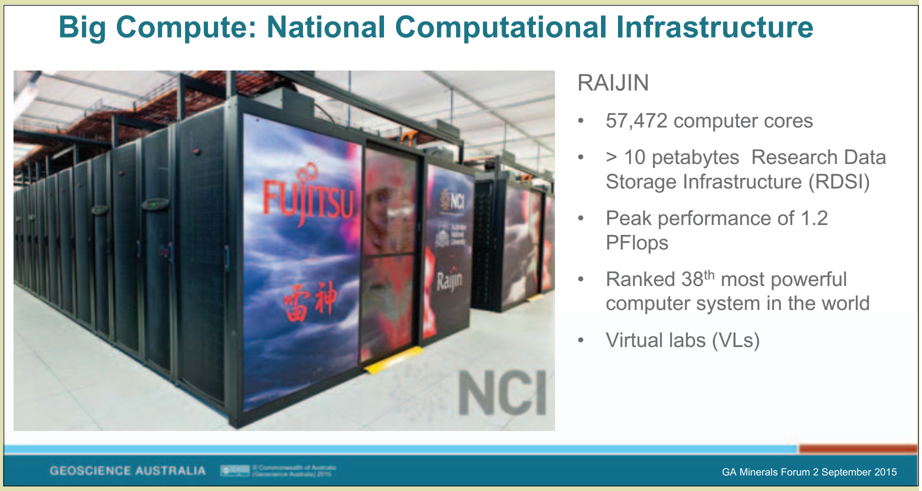

Figure 9. *Goodwin PPT Slide: Raijin, named after the Shinto God of thunder, lightning and storms.*

Ollie Raymond: 'Data delivery and discoverability: Rock Properties, Geoscience Portal, GADDS'

Finally there needs to be a way to easily access all that data.

GA is using OGC Web Services. This means that maps and data are broadcast over the internet, like streaming TV, using international standard protocols developed by the Open Geospatial Consortium (OGC). There are three main services:

- *WMS (Web Map Service): it delivers map data as an image, the data can be queried online, the data behind the WMS can be accessed if a link is provided in the WMS to a downloadable file, typically, symbolisation/legend is delivered with the WMS map and WMS maps are primarily used as query able backdrops in your GIS analysis.*
- *WFS (Web Feature Service): it streams data as XML, the live XML feed can be rendered, filtered, and queried by a mapping application, or, it can be consumed on-the-fly by analytical and modelling applications, or, it can be downloaded in various formats to your local PC (e.g. CSV, shapefile, gdb).*
- *WCS (Web Coverage Service): it delivers gridded (raster) data, the real data values, not just RGB pixel values, data can be queried and consumed for data processing online, data can be re-stretched by your mapping application, can be downloaded in various formats (e.g. NetCDF, geoTIFF).*

Geoscience Australia Web Services include:

- *Surface Geology of Australia (1:2.5M & 1:1M) – WMS*
- *Geological Provinces – WMS*
- *National Geophysical Grids – WMS*
- *Onshore Seismic Surveys – WMS*
- *Rock Properties – WMS & WFS*
- *Elevation and Bathymetry – WMS & WCS*
- *Topography and Infrastructure – WMS & WFS*

and over 100 more – just type 'web services' into the GA and use the website search tool.

So there you have it. All you need to know about the collection, analysis, storage and access to geoscience information at Geoscience Australia – a wonderful afternoon!

I would like to thank Geoscience Australia for providing copies of the PPT slides used in this article. For further information please contact the individual authors or Richard Blewett at Geoscience Australia.