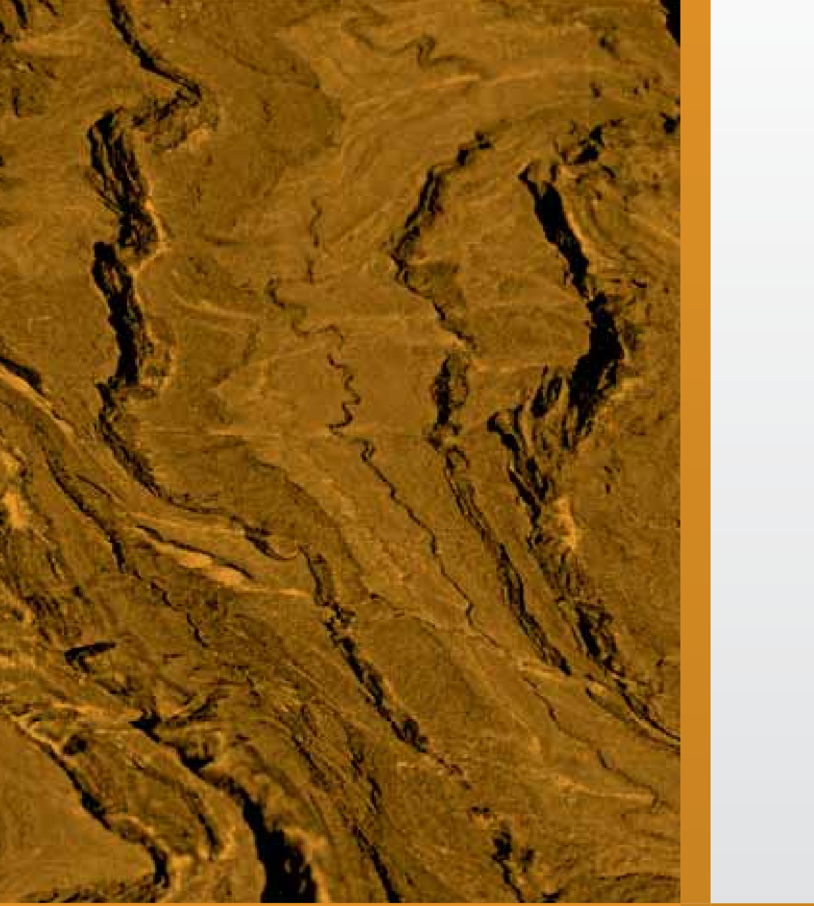


Australian Academy of Science

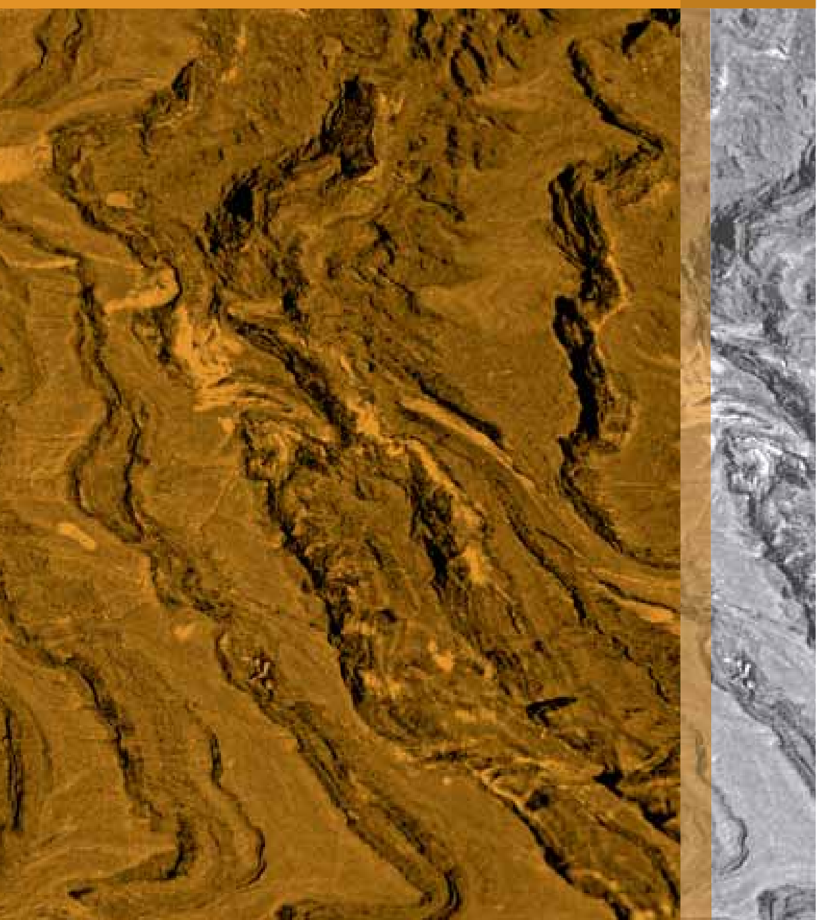
Theo Murphy High Flyers Think Tank 2010

proceedings

Searching the Deep Earth:

The Future of Australian Resource Discovery and Utilisation

The Shine Dome, Canberra
19–20 August 2010



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THE ROYAL SOCIETY

Think Tanks are supported by the Royal Society – the national academy of science of the UK and the Commonwealth – through the Theo Murphy (Australia) Fund.

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Executive summary

Sustaining Australia's wealth for the next century

Australia is an old continent and much of its remaining mineral wealth is masked by a thick cover of weathered rock, sediment and soil that poses formidable exploration challenges. Australia relies on its mining industry for economic prosperity but currently lacks fundamental data and scientific and technological tools needed to discover new, economically valuable ore deposits deeply buried beneath the cover.

In the 19th Century, individual prospectors discovered gold and base metal deposits at the surface through skill, perseverance and luck. Following their early successes, in the 20th Century our geological surveys systematically mapped Australia's surface. The nation's landforms, surface geological formations and structures were revealed on a continental scale, providing a scientific basis for commercial exploration on a much larger scale than before. The formations and structures discovered through this effort host the near-surface rich deposits that underpin our economy today.

These surface riches are running out. Exploration success in Australia is in decline as the challenge of seeing beneath the cover defeats the explorers. Sustaining our wealth in the 21st Century requires that we now produce the next generation of maps – maps that define the physical and chemical properties of the subsurface of Australia. To do this we need to find ways to sample and analyse the ancient covered land surfaces and to image the structures that trap deep fluids that transport economically important metals, allowing deposition of those metals.

The *2010 Theo Murphy High Flyers Think* participants propose that future exploration success can be realised through an innovative, well-defined and nationally coordinated strategy. They recommend bringing together the relevant expertise into a coherent, collaborative research network, working within a well-designed strategic framework or 'road map', to address the fundamental needs of the exploration industry. To prioritise search areas across the nation it is essential to know where the cover is thick and where it is thin. We need to deploy geophysical and geochemical tools in a coordinated manner to image and understand the deep crust and upper mantle, because these regions provide the context within which economic mineralisation occurs. We need to understand the large-scale forces and processes – geodynamics – that act on and within the crust and upper mantle, and so exert control on mineralisation. We must understand the background signature of geochemistry and mineralogy where economic deposits do not occur so that we can then recognise the distal footprint of commercially viable deposits at distance from their actual location. Finally, we must ensure that the knowledge gained is properly delivered and that there is an ongoing supply of well-trained and inspired geoscientists ready to take up the exploration challenge. To achieve these goals, several strategic initiatives are proposed.

The *2010 Theo Murphy High Flyers Think Tank* participants propose an integrated set of initiatives to address the challenge of 'seeing through' the materials that cover Australia's ore deposits.

We recommend a national road map for deep earth exploration that integrates components of the Federal innovation effort in a coherent deep earth mapping program.

The proposed road map would be underpinned by the following six initiatives:

1. A national map of the depth and character of the cover of Australia that will prioritise new areas for exploration and new directions for research.
2. A national map of the deep crust and adjacent upper mantle that will employ innovative methods to acquire new geophysical and geochemical data. This map will be supported by a competitive crustal drilling program to constrain the interpretations resulting from these new data.
3. A national 'distal footprints' program to detect the far-field signatures of giant ore systems in ancient land surfaces now buried by cover.
4. A national four-dimensional (3D plus time) metallogenic map that relates Australia's major mineral deposits to the geodynamic contexts in which they formed.
5. A national research network to bring the exploration community together and ensure we understand and exploit the available synergies.
6. A national education and technology transfer program to foster rapid uptake and application of the results and ensure exploration success.

These initiatives will open up new frontiers for mineral exploration and enable the private sector to undertake Australia's next phase of exploration competitively. The data and knowledge created through these initiatives will also assist in further defining our water, energy and land resources.

Seven principal national outcomes are anticipated:

- identification of new subsurface exploration frontiers
- discovery of a new generation of world-class mines
- realisation of the deep geothermal potential of Australia
- identification of deep groundwater resources and water quality
- improvements in earthquake prediction on the continent
- establishment of Australia as a world leader in deep earth science
- development of unique Australian mining and exploration sector expertise that will be deployable world wide.

By taking a national approach to integrating our world-class scientific expertise, we can help the local mining industry reveal what is hidden beneath us, achieve a better return on their investment, provide new wealth to the nation and continue to prosper in this century.

Detailed recommendations and initiatives

National road map for deep earth exploration

Australia has a vibrant and diverse geoscience research community that is currently studying many of the issues important to improving our ability to explore under cover for major new mineral resources. The community is made up of university geoscience departments, CSIRO, Geoscience Australia, seven state and territory geoscience agencies, the Deep Exploration Technologies CRC, the ARC Centre of Excellence in Ore Deposit Research (CODES, University of Tasmania), the Centre for Exploration Targeting (University of Western Australia), the Virtual Geological Observatory (VIRGO) in Sydney, the Sustainable Minerals Institute (University of Queensland) and the recently funded Centre for Core to Crust Fluid Systems ARC Centre of Excellence.

There is currently no national strategy that links these organisations and industry partners into a single coherent and efficient framework that would permit integration of the initiatives advanced here. We propose development of a road map that would facilitate broad consultation with all stakeholders, identify long- and short-term research objectives, identify critical paths in research strategy, allow consideration of outlier technologies or approaches that might otherwise be ignored, and provide a baseline reference for those thinking strategically about this area. The road map would be the overarching framework to guide research investment in the sector for up to 30 years, reflecting broad support amongst stakeholders.

Six initatives for searching deep earth

The following elaborates on the *2010 Theo Murphy High Flyers Think Tank* participants' six proposed initiatives that would underpin the national road map for exploration under cover:

1. National cover map
2. National map of the deep crust and upper mantle
3. National distal footprints program
4. National 4D metallogenic map
5. National exploration research network
6. Education and technology transfer program

1. National cover map

Following the discovery of gold in New South Wales by Edward Hargraves in 1851, a wave of prospectors swept over Australia. These hardy people found thousands of outcropping deposits, defining the birth of our mining industry. Next, in the 20th Century, state, territory and Australian Government geoscience agencies systematically mapped the surface geology of Australia and made these maps available to explorers, leading to a second wave of major discoveries in the near surface. Following World War II, new geochemical and geophysical exploration tools made it possible for the first time for industry to find covered deposits. Even with these tools, half of all discoveries made in the past 60 years were buried under less than 15 metres of cover and only 10% were found under more than 200 metres of cover (see Figure 1).

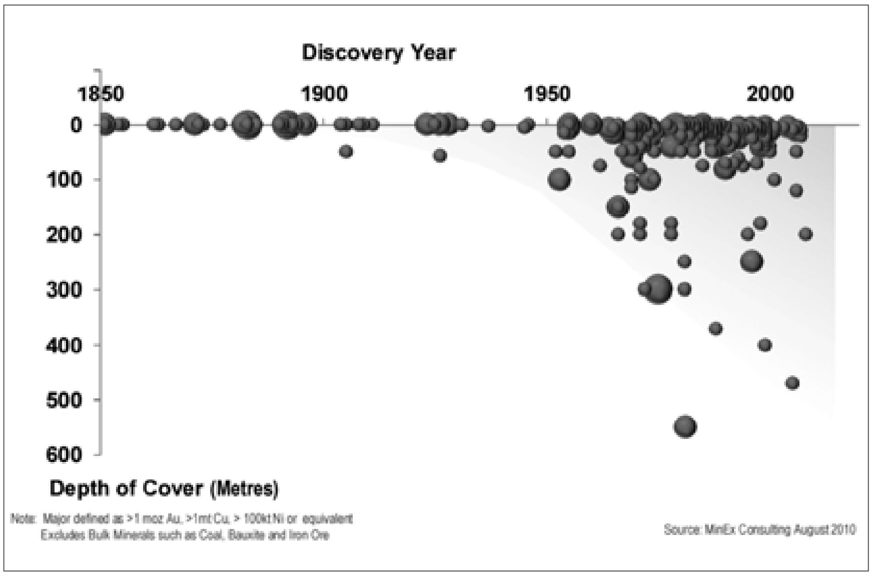

FIGURE 1 – Major mineral discoveries since 1850 with depth

Figure 2, a very crude cover map, shows that most deep discoveries are clustered where deposits were already known from surface outcrop and historic production. In other words, companies use the detailed geological knowledge from existing mines to find similar deposits in the local area. Although this 'brownfields' strategy demonstrates that deeply buried deposits can be economic, the exploration approach is not sustainable in the longer term. The future of our mining industry in the 21st Century will depend on deeper, 'greenfields' exploration to locate the next generation of deposits that are not associated with existing operations. Australia is underexplored, despite the inherent prospectivity of the covered areas.

Knowledge of the depth of cover is critical to the minerals industry for two reasons. First, the depth of cover is a clear indication of how difficult it will be to explore successfully in an area because the effectiveness of different exploration tools decreases and the cost of drilling increases with depth. Second, cover thickness dictates the minimum size and grade of a potential target needed for economic viability. Deeper deposits are more expensive to mine, but sufficiently high-grade deposits under even 500–1000 metres of cover can be viable.

We propose a high resolution 'national cover map' that will show the thickness and nature of the cover sequences across the continent. This depth to basement map would reveal where cover is relatively thin and enable identification of high-priority areas for exploration. As new tools for cheaper and more effective exploration under cover become available, new areas for exploration will become apparent.

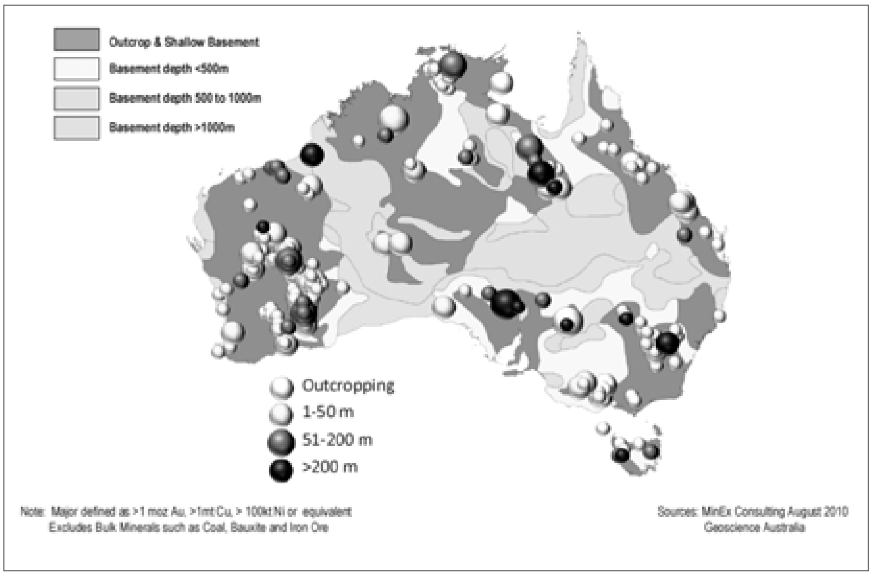

FIGURE 2 – Distribution of major mineral discoveries (geographic and with depth)

Cover depth can vary significantly on a local scale. For example, in the Gawler Craton of South Australia the depth to basement can vary from 100 to 1000 metres over just a few kilometres.

Knowing how much of the continent is covered by a thin (< 30 m) versus thicker layer of cover could be used to prioritise R&D programs and would have a big impact on future discovery. Where cover is relatively thin, biologically mediated physical and chemical processes can produce detectable surface geochemical signals of buried mineralisation. Research has indicated that, in favourable situations, termite mounds, *Acacia* leaf litter and *Spinifex* may signal buried mineralisation. This is important because surface geochemical sampling is far cheaper and disturbs less ground than drilling. For these reasons, recent research has been directed towards these thinly covered terranes. However, if the national cover map suggests that only a small proportion of prospective covered areas are shallow and the overwhelming majority realistically requires drilling-based exploration, this would reliably inform the strategic focus of our national research effort.

Knowledge of the thickness, nature and internal variations of the covering sequences will enable more effective exploration with stand-alone geophysical technologies, because the masking effects of cover can be understood and modelled. The older the cover, the more likely it is that geochemical signals will have migrated from the underlying basement rocks up into the surface layers and therefore give exploration companies a greater chance of detecting a signal of buried mineralisation. The interfaces between different parts of the covering sequences are likely to have localised both mechanical and geochemical signals from buried orebodies and therefore will be important sites for subsurface sampling. A better understanding of the distribution and nature of aquifers within the cover is critical to enable effective hydrogeochemical exploration for buried deposits. Fortunately, outback Australia has an extensive network of water bores that, when geochemically sampled across wide areas, can become an effective regional sampling tool to find buried giant ore deposits. An additional benefit will be a much better definition of groundwater resource potential.

Much of the data required to produce a national cover map is already available. This includes information from exploration and water-bore drilling that has penetrated cover sequences as well as relevant regional geophysical datasets, most notably electromagnetic and aeromagnetic data. These data are now held by various government geoscience agencies. A national effort to compile the various data sets and interpret the likely depth of cover at a local scale will help produce a single unified cover map of the country, in the same way that we now have unified geological, geophysical and radiometric maps.

The national cover map is one of the first enabling outputs from this initiative that could rapidly have a marked impact on the Australian mineral exploration industry and quickly deliver national economic benefit.

2. National map of the deep crust and upper mantle

Our international competitive advantage in minerals is based on huge, high-quality resources discovered long ago. Future exploration success requires opening the discovery space to greater depths.

Geophysical and geochemical methods are the cost-effective way to explore wider areas where cover is more substantial. Consequently a nationally coordinated approach to deployment of new geophysical tools (such as magnetotellurics and passive seismic), the collection of novel geochemical data (including stable and radiogenic isotope fingerprinting of rocks and minerals to help understand the evolution of the crust) integrated with a comprehensive drilling program is the optimal way to improve targeting success. The work plan is straightforward but, when collected on a large scale, will be of unprecedented scope. These new tools and sensors should be deployed to collect data on a comprehensive, continental scale. Next, using petascale computing, storage and network resources, these new data will be integrated with existing geophysical and geological information to create three-dimensional images of the deep subsurface. Finally, strategic drilling and logging will control and iteratively refine these subsurface images using physical properties from subsurface samples, constraining the interpretation of the geophysical observations and providing a basis for quantification of uncertainty.

Our proposed initiative is analogous to the highly successful and globally coordinated Integrated Ocean Drilling Program and its precursors, whose goal was a comprehensive understanding of the structure and evolution of the world's largely unknown ocean basins. By working on a continental scale and using multidisciplinary tools, subsurface geological imaging will drive exploration targeting and increase our knowledge of the mineral systems that produced Australia's hidden world-class ore bodies.

3. National distal footprints program

As exploration moves increasingly into covered areas, drilling costs increase significantly. Explorers will demand increasingly sophisticated targeting tools to constrain their drilling programs and will demand maximum benefit from drilling even when mineralisation is not intersected. It is therefore vital to understand the distal signature of major ore deposits well beyond the current approach of mapping local alteration and mineralisation styles. We must infer the likely proximity of giant ore deposits by interpreting subtle variations contrasted against a regional background.

To this end, we propose a 'national distal footprints program' that will provide a basis for detection of the subtle indicators of major ore systems preserved at and beneath the ancient land surface.

The program will be linked with existing geoscientific datasets, the proposed national cover map, the proposed 'Australian crustal drilling program', and the proposed 'national 4D metallogenic map' to establish the regional background in prospective terranes. Next, researchers will partner with the minerals industry, Geoscience Australia, and the state and territory geoscience agencies to perform integrated multidisciplinary case studies, studying drill transects that reach beyond traditional mineral system and ore deposit halos, well into the regional background. This research program will characterise:

- The eroded products of ore systems preserved in cover sediments and ancient thermal signatures;
- The regional geological, physical, chemical and mineralogical footprints of known deposits, relative to the background signature; and
- Maps of mineral system fluid recharge, source and transport pathways, looking for subtle indicators relative to the background.[1]

1 Examples might include copper, sulfur and hydrogen anomalies around gold and porphyry (deposits associated with an igneous rock having large crystals in a fine-grained matrix) systems; Platinum-group element (PGE) depletion patterns around nickel-sulfide deposits; and organic signatures around sediment hosted lead-zinc systems.

4. National 4D metallogenic map

It is increasingly clear that the geodynamic context in which ore deposits form is critical, particularly for very large deposits. Major ore deposits were formed only in a few very narrow time intervals, when large deposits formed at approximately the same time over wide areas. For example, the giant gold deposits of Western Victoria and the giant copper-gold deposits of eastern NSW both formed about 440 million years ago, even though they are separated by more than 500 km. These ore-forming periods represent unusual geological conditions that persisted only for geologically short time periods.

We already have some insights into these intervals; for example, they appear to be correlated with periods of major plate tectonic reorganisation.

Our challenge is to apply emerging insights to the practical task of mineral exploration. Significant progress has been made recently by developing 4D (that is, 3D plus time) dynamic models of the evolution of the Australian crust.

Simulation modelling provides a critical vehicle for synthesis of a wide range of observations and observation types within a sound theoretical framework and then allows us to ask sensible questions. It allows us to understand the consequences of the different structural (physical, chemical and thermal) configurations of the Australian lithosphere during the ore-forming periods. It can be used to predict the gravity, magnetic and electrical characteristics of potential ore systems so that explorers can readily compare numerical modelling results with commonly used exploration datasets. Consequently, ongoing developments in Australian computational information management and modelling advances will lead to enhanced exploration methodologies. The technologies developed while achieving this will have application universally across all systems, not just for the mining industry, and so will have a strong beneficial impact on the rest of Australia's industry and society.

In principle, this type of modelling could prioritise untested terranes and assist to predict the location of undiscovered mineral deposits, but the method has not yet advanced to the point where this can be achieved. Four advances are required:

- increased spatial resolution of and confidence in these dynamic models
- improvement in our knowledge of the basic building blocks of the Australian continent (knowledge that would be delivered by the 'national map of Australia's deep crust and upper mantle' proposed here)
- much closer integration between high-resolution radiometric ages dating ore body formation and 4D geodynamic models

- much closer integration between the geodynamic modelling community, the economic geology community and the exploration industry.

To achieve the above, we propose a 'national 4D metallogenic map for Australia' that will link Australia's major mineral deposits with the geodynamic context in which they formed. Development of the map is a cross-disciplinary initiative that will for the first time fully engage the geodynamic modelling community with the economic geology community on the regional scale most critical to predictive targeting. The project could deliver for the first time a clear spatial and temporal definition of the rare critical geodynamic conditions that created most of Australia's mineral wealth and hence will assist companies in targeting new giant deposits.

5. National exploration research network

The achievement of the 'national road map for deep earth exploration' would require a framework to integrate the aforementioned initiatives and bring together the world-class scientific expertise that exists in Australia for exploration geoscience research. The network would cross geographical and institutional boundaries and engender a national approach to exploration research. Formal activities will include:

- an annual meeting, that would be held in different Australian regional centres
- a nationally coordinated program of workshops and training courses for early- to mid-career researchers and industry explorationists
- cross-institution (including industry) study visits or secondments for researchers to collaborate across disciplines around the country
- regular public forums for dissemination of results to industry and the public.

At the annual meeting, the community will offer the opportunity to present research results to an informed audience all working towards exploration success. A public forum and media event at each annual workshop will develop better public understanding of the outcomes as well as closer engagement with the scientists and the science. The researchers will also be encouraged to use modern media (podcasts, vodcasts and social networking websites) to inform students about this exciting area of science. Particular emphasis will be given to early-career researchers, exploration geologists and postgraduate students.

The network will provide mentoring, workshops and opportunities for study visits to institutions across the country. It will be a contact base and resource for government policy makers, industry and researchers and become a forum for identification of opportunities for new research directions.

The ultimate objective of the research network is to ensure that the work done by local researchers is focused on identifying ways to explore under the cover in Australia.

6. Education and technology transfer program

A highly visible national geoscience effort should inspire young scientists and engineers with physics, chemistry and mathematics backgrounds to take up geoscience. These basic science skills are critical, to research and exploration and in the interpretation of large datasets produced by modern exploration programs. Through these initiatives, the next generation of researchers will develop greater capability for accurate and rapid decision-making, pivotal to support industry counterparts and to encouraging more rapid technology uptake and faster innovation in exploration.

The education and technology transfer program proposed here addresses three issues:

- *Practical inspiration*: summer schools, targeted bursaries, fee waivers for the promising international postgraduate students and a program of school visits to publicise and enhance the profile of geoscience.
- *School curriculum development*: Earth Sciences WA (ESWA) and the Teacher Earth Science Education Program (TESEP) support teaching of earth science in schools by developing teaching and learning resources including field trips for students. These initiatives, when executed on a national scale, will enhance recruitment and retention of talented young Australians.
- *National embedded researcher program:* post-doctoral researchers will be embedded in industry to work as part of an exploration team and promote rapid uptake of research products in the business of exploration. The resulting interactions will also ensure that researchers develop a better appreciation of the commercial aspects of their ongoing work. In a complementary fashion, industry exploration staff will be embedded in research institutions of the exploration research network to learn about and more rapidly deploy new research findings.

Introduction

Purpose of Think Tanks

The purpose of the Theo Murphy High Flyers Think Tank series is to bring together early- and mid-career researchers from a broad range of relevant disciplines to engage in thinking about novel applications of existing science (including social science) and technology to issues of national significance, and to identify gaps in knowledge that should be addressed. These events are a unique opportunity for career development and network creation amongst the nation's next generation of research leaders and their institutions.

Think Tanks are one of the premier events of the Academy's calendar and this year is the eighth that the Academy has held since 2002.

Previous Think Tanks

Previous Think Tanks have culminated in reports to government that have been timely, well received and instrumental in influencing policy development. Past Think Tank topics (found at www.science.org.au/events/thinktanks.html) have been:

2002 – Australia's national research priorities
2003 – Safeguarding the nation
2004 – Emerging diseases – ready and waiting?
2005 – Biotechnology and the future of Australian agriculture
2006 – Innovative technical solutions for water management in Australia
2007 – Extreme natural hazards in Australia
2008 – Preventative health: Science and technology in the prevention and early detection of disease
2009 – Agricultural productivity and climate change

2010 Think Tank: *Searching the Deep Earth: The Future of Australian Resource Discovery and Utilisation*

Effective minerals exploration has been central to previous and current mining booms. Australia's future economic prosperity will, to a large degree, depend upon future resource discoveries. Those mineral deposits that were easy to discover have been found and it is becoming increasingly difficult to find large new ore deposits that are economically viable. To continue previous successes in mining requires identifying and resolving the key issues impeding effective minerals exploration in Australia. This will involve exploration of potential cross-discipline opportunities to integrate and extend existing data; foreshadowing the technologies necessary for the next generation of minerals exploration; and putting in place a policy framework that will encourage effective science and successful exploration.

The 2010 Think Tank, *Searching the Deep Earth: The Future of Australian Resource Discovery and Utilisation*, is a valuable opportunity for some of Australia's leading early- and mid-career researchers to identify and propose new approaches to Australian minerals exploration. Participants will focus on identifying new approaches, technologies, data management systems, and policy innovations to facilitate science in delivering a better understanding of the deep Earth and ultimately helping to maintain mining productivity into the future.

The process

The Think Tank theme is introduced with a keynote address and five brief presentations. These presentations are aimed at stimulating lateral thought in the discussions that form the remainder of the Think Tank, rather than providing comprehensive coverage of the theme or any of the four specialist topics.

The afternoon session of the first day of the Think Tank is dedicated to discussions in small breakout groups. Each participant has been assigned to one of four breakout groups and each group will be chaired by the relevant topic speaker(s). Each group comprises a mix of skills and experience in order to stimulate lateral thinking and to challenge the participants to extend themselves and think dynamically. Each Chair has pre-selected a participant to act as the group's rapporteur. The role of the rapporteur is to collate the group's discussions and distil the discourse into a 15 minute presentation. The breakout groups are asked to examine and address their group's discussion questions (below) but are also encouraged to move beyond these questions to other topics identified during the discourse.

On the second day of the Think Tank, after a final review by the breakout groups, each of the four rapporteurs will present the findings of their breakout group. There will be an opportunity for questions and discussion after each presentation, during the general discussion, and in response to the final summing up.

Breakout groups

Group A **Computational, information management and modelling advances** **Chair** Professor Dietmar Müller **Rapporteur** Dr Thomas Landgrebe	**Name**
	Dr Graham Baines
	Dr Peter Graham Betts
	Tania Dhu
	Dr Weronika Gorczyk
	Dr Jane Hodgkinson
	Associate Professor Eun-Jung Holden
	Dr Margarete Jadamec
	Dr Thomas Landgrebe
	Dr Craig J O'Neill
	Dr Tim Rawling
	Dr Nicholas Rawlinson
	David Robinson
	Dr Gideon Rosenbaum
	Dr Nick Williams

Group B **Giant ore deposits** **Co-chairs** Richard Schodde and Dr Jon Hronsky **Rapporteur** Dr Rob Hough	**Name**
	Dr Tim Baker
	Christopher Chambers
	Dr James Cleverley
	Dr Robert Dart
	Assistant Professor Marco Fiorentini
	Associate Professor Klaus Gessner
	Dr Ian Graham
	Dr Anthony Harris
	Dr Rob Hough
	Dr Lawrence Leader

Group B (Continued) **Giant ore deposits**	Professor John McLeod Miller Thomas Poulet Dr Frank Reith Dr Simon Richards
Group C **Innovation and new technology** **Chair** Dr Tom Whiting **Rapporteur** Dr Katy Evans	**Name** Dr Benjamin Ackerman Dr David Beck Dr Elena Belousova Laurie Callaghan Dr Raj Das Dr Katy Evans Dr Ryan Fraser Dr Wojtek James Goscinski Dr Steven Micklethwaite Dr Anya Reading Dr Carl Spandler Dr Mark Symmons Dr Stephan Thiel Dr Mark Tingay
Group D **Exploration policy – the way forward** **Chair** Peta Ashworth **Rapporteur** Dr Chris Yeats	**Name** Dr Graham Begg Dr Stephen Beresford Dr Zhaoshan Chang Dean Collett Miles Davies Professor David Giles Aleksandra Kalinowski Dr Maxim Lebedev Professor T Campbell McCuaig Dr Kieren Moffat Professor Steven Reddy Dr Alanna Simpson Dr Hrvoje Tkalcic Dr Chris Yeats

Discussion questions

Group A – Computational, information management and modelling advances (specifically including geology, geophysical inversion, geochemistry and geochronology)

- With respect to minerals exploration, what is currently being well-achieved using information management, computational and modelling methodologies?
- What are the significant issues Australia's computational capability faces in becoming an effective tool for understanding crustal processes and identifying mineralisation niches? (Hardware, software, people?)
- Is there a need for a computational strategy to manage the increasing quantities of geological data? If yes, what shape should this strategy take?
- Ideally what systems (including software and hardware) need to be developed to advance this field in relation to minerals exploration?
- How can Australia's current and future computational capabilities be better integrated with the other topics of this Think Tank (Giant ore deposits; Innovation and new technology; and Exploration policy – the way forward)?

Group B – Giant ore deposits

- What successes have there been with regard to understanding the genesis of and exploration for giant ore deposits since the discovery of Olympic Dam, and what specifically supported these discoveries?
- What are the specific causes in Australia of poor progress in the discovery of giant ore deposits?
- How could a strategy be developed that better targeted available resources for future giant ore deposit discoveries?
- What additional resources are necessary to advance Australian minerals exploration, particularly for giant ore deposits?
- How can Australia's current and future mineral exploration capabilities be better integrated with the other topics of this Think Tank (Computational, information management and modelling advances; Innovation and new technology; and Exploration policy – the way forward)?

Group C – Innovation and new technology

- Where in Australia have innovation and/or new technologies been well-utilised to improve Australia's mineral exploration capability?
- What has impeded the innovation and development of new technologies that would improve and enable Australian minerals exploration?
- What key innovations or new technologies will be necessary to advance Australian minerals exploration in the near and distant futures?
- How can investments be strategically made to achieve these new innovations/technologies?
- How can Australia's current and future innovation and new technologies for minerals exploration be better integrated with the other topics of this Think Tank (Computational, information management and modelling advances; Giant ore deposits; and Exploration policy – the way forward)?

Group D – Exploration policy – the way forward (particularly the need for scientists to communicate effectively with politicians and the community at large regarding both the impact and value of searching the deep Earth)

- What is the current state of exploration policy in Australia, including engagement with key stakeholders?
- What policy impediments are there to minerals exploration in Australia?
- What type of strategy is necessary to integrate the views of the various key stakeholders (community, government, industry, academia/research)? How could such a strategy be implemented?
- What policy tools could be invoked to improve Australia's research capability in understanding the crust and in improving our exploration success? In particular, what policy levers could be used to drive more effective integration of the other topics of this Think Tank (Computational, information management and modelling advances; Giant ore deposits; and Innovation and new technology)?

Outputs

The proceedings will be taped, transcribed and made available on the Academy's website. This includes all presentations (verbal and PowerPoint slides), breakout group reports from the second day of the Think Tank, general discussions, and the final summing up. The event proceedings, available in electronic and print formats, will also provide contextual information, identify knowledge gaps and summarise the major outcomes from the Think Tank. These proceedings will offer options for a 'way forward' and subsequently can be used to underpin policy development and research prioritisation.

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Think Tanks are supported by the Royal Society – the national academy of science of the UK and the Commonwealth – through the Theo Murphy (Australia) Fund.