Australian Geoscience Council Inc.

The Council of Earth Science Societies in Australia

AGC

Committee Secretary
Standing Committee on Science and Innovation
House of Representatives
Parliament House
CANBERRA ACT 2600
Email scin.reps@aph.gov.au

Dear Committee-members,

I am pleased to provide the response of the Australian Geoscience Council to the Inquiry by the House of Representatives Standing Committee on Science and Innovation into Australian technological innovation and pathways to commercialisation.

The Australian Geoscience Council is the Peak Council of geoscientists in Australia. It represents nine major Australian geoscientific societies and has a membership of over 7000 professionals. We believe that the geosciences are critical for Australia, as shown by the accompanying sample of innovative technology case studies in the geosciences.

Our submission is made in four parts:

- **This cover letter and a one page Executive Summary containing the Geoscience Council's eight recommendations,**
- **Eleven pages responding to the eight Terms of Reference for the Inquiry and developing the rationale behind the Geoscience Council's recommendations,**
- **Twenty one appendices (pages 14 to 46), each providing a summary case study of technological innovation in the geosciences,**
- **Appendix 22 (page 47) which describes a relevant activity from another country.**

The resource industry in Australia is characterised by sustained innovation, and the sector continues to create new wealth for Australia with long lead times. Resources (including gold) achieved more of Australia's export earnings in 2004 than any other sector, while also delivering employment and other flow-on benefits to the community in both urban and remote regions.

However, these achievements derive from successful exploration of decades past. In order to project past performance into the future, Australia needs greater innovation in technologies, concepts and knowledge, as well as sustained levels of qualified people.

We thank you for this opportunity to demonstrate the substantial role of the geosciences in Australia.

Yours sincerely

Mike Smith
President

"Technological Innovation and Pathways to Commercialisation" – a submission by the Australian Geoscience Council

EXECUTIVE SUMMARY

The resource industry in Australia is characterised by sustained innovation to meet competitive pressures within the country and internationally. Creative geoscience is typically funded at the margin of financial capacity and is subject to constant re-assessment of the merits of the research. It involves industry, government and universities in a strategic partnership each with particular roles.

The resource sector continues to create new wealth for Australia with long lead times. Unlike other business sectors, the industry generates new money which did not exist before the discovery, delineation and development of our natural resources. This capability, together with the high resource endowment of our geological terranes, has led to the continued delivery of superior export earnings for Australia.

The Australian Geoscience Council encourages government support for innovation in this highly productive sector. Specifically, we advocate government action to implement the recommendations of the Strategic Leaders Group of the Minerals Exploration Action Agenda, established by Minister Ian Macfarlane in 2002 to address the recent decline in mineral exploration investment in Australia. Australia's share of the global investment dollar for resource exploration has steadily declined in recent years; action must be taken now to arrest this trend.

We therefore recommend the following actions by government:

Recommendation 1: Government and the Australian Research Council encourage partnerships between industry, universities and government research institutions that foster the undertaking of research of immediate relevance to the resources industry.

Recommendation 2. Intellectual property rights are granted to the performing organisation while ensuring that individual researchers or research teams can share in the rewards.

Recommendation 3: Government develops a national program to support the development of best practice commercialisation capabilities in universities and scientific institutions.

Recommendation 4: Government develops a national program to improve science teaching capability and to attract highly qualified students into the study of science and engineering.

Recommendation 5: The Government introduces an Australian flow through share scheme for specified exploration expenditure for resource exploration and extend the concept to companies with a research commercialisation focus.

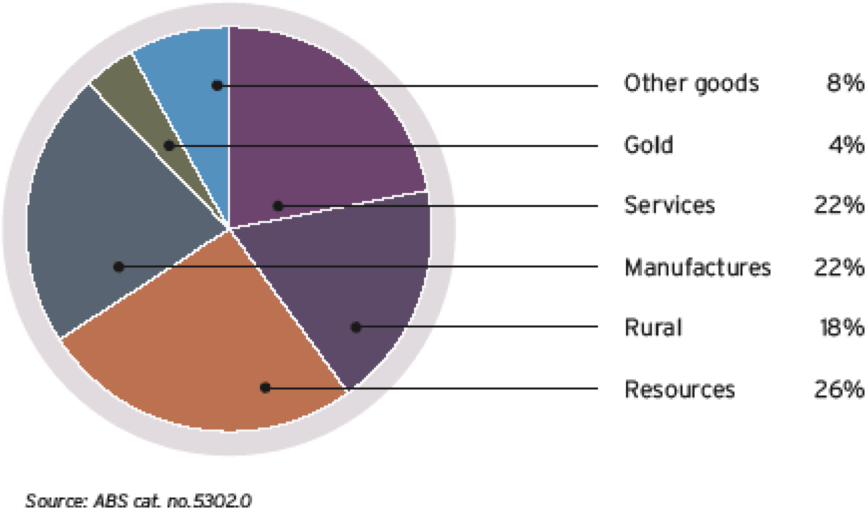
Recommendation 6: The Government increases the funding for the acquisition of precompetitive geoscience by Geoscience Australia to attract mineral exploration investment to the unexplored part of Australia's mineral provinces that exist beneath the un-prospective weathered surface cover.

Recommendation 7: CSIRO in partnership with industry and with appropriate universities expands its capability to develop new techniques and technologies to facilitate the new frontier of mineral exploration under cover.

Recommendation 8: Government develops criteria for assessing publicly funded research which will ensure that the innovation system is able to support and engage strategic sectors of the economy, including the resources sector.

"Technological Innovation and Pathways to Commercialisation" – a submission by the Australian Geoscience Council

The commercialisation of geoscience innovations and the accumulation of the knowledge of the geology of the nation are major contributors to the generation of growth in the resources sector, and to environmental sustainability of resource developments. Australian exports reached $152.5 billion in 2004, one of the highest levels on record, with resources exports growing by 13 per cent. Resource exports valued at $39.6 billion accounted for 26 per cent of total exports for 2004. As shown in the graph below, the categories of Resources plus Gold achieved 30% of Australia's export earnings, while also delivering employment and other flow-on benefits to the community in both urban and remote regions.



Reference: "TRADE 2005 Australia's export success and the Government's policy goals for trade in the coming year". A statement by Mark Vaile, Minister for Trade, Department of Foreign Affairs and Trade, published at www.dfat.gov.au/trade/trade2005/

The resource sector delivers considerable value to Australia's social well-being. As indicated in the National Strategic Plan for the Geosciences, published by the Academy of Sciences in October 2003, geoscience also has a fundamental contribution to make to the sustainable use of the Australian environment. The tools and techniques developed in resource exploration have widespread application in developing the scientific knowledge to underpin natural resource management. Geoscience, therefore has wide application across the government's research priorities.

This submission describes selected case studies of successful technological innovation and knowledge generation in the geoscience sector. Not all innovations have resulted in commercialisation at the time of writing, but some are expected to do so in one to two years. Others present examples where commercialisation has not eventuated. There are several examples of where knowledge generation through research has led to commercial outcomes. Furthermore, there are numerous innovations in geoscience that are not included in this review, just because it is not practical to compile every case study, in the time provided. In particular, innovations in the practice of drilling, mining methodologies, mine safety, materials handling, ore extraction, hydrocarbon stimulation and extraction and more are not addressed. The web site of Innovations Australia (www.stroudgate.net/innovation/) hosts descriptions of some of these developments. A number of valued high technology research facilities are also not covered including the Australian Synchrotron, SHRIMP age dating, ANU/GEMOC's laser ablation mass spectrometry, CSIRO's proton probe for x-ray mapping, and others.

The 2003 National Strategic Plan for the Geosciences reports that Australian geoscientists receive significant government research funding, allocated through ARC Discovery and Linkage grants for strategic and applied research. The Strategic Plan details activities accomplished in critical areas such as groundwater delineation and management, dryland salinisation, soil acidification, urban and coastal development, the analysis, forecasting and mitigation of geohazards, and practical responses to greenhouse warming.

The National Strategic Plan for the Geosciences also highlights the importance of geoscience issues in the Government's December 2002 National Research Priorities, in particular sustainable water usage, land degradation, and developing deep earth resources. The latter issue requires high-technologies exploration methodologies for imaging and mapping the deep earth and ocean floors, and novel efficient ways of extraction and processing for minerals, oil and gas.

Australia has developed a highly innovative resource industry which continues to provide one of the most important sources of export revenue and sustains the national balance of payments. We emphasise that Australia needs to discover new mineral and energy resources to ensure Australia's future wealth and sustainability. Resource discoveries represent some of the highest impact innovations in the commercial history of the nation and are unlikely to be replaced by alternative income generators in the coming decades.

Technological innovation and the development of the knowledge of potentially prospective areas are critical to global competitiveness in the development and marketing of Australia's natural resources. Australia has been and is expected to continue as a world leader in minerals research, with striking value-added results for our sector and our economy. For example, gold production has jumped six fold in the past 20 years to $5 billion/year, driven by a range of new exploration and processing technologies. Australia is also a pioneer in mining technology services, an emerging industry which ABARE (April 2005) reports as accounting for $1.1 billion dollars worth of exports last year. We have consistently been one of the world's largest suppliers of commodities such as coal, alumina, bauxite, coal, copper, diamonds, gold and iron ore. We are also a world leader in other ores and metals, such as manganese, mineral sands, nickel, tantalum, uranium, zinc, lead and silver. However, in recent years, Australia has progressed in other related fields and now produces 60% of the world's mining software. It is apparent that the minerals sector has become an exporter of knowledge and service, as much as an exporter in commodities.

Similarly, Australia has become a major supplier of traded liquefied natural gas internationally and has sustained a high level of crude oil self – sufficiency over the last 40 years.

Continued investment in research is crucial to the sustainability of the resources sector and our ability to generate rewards from our natural resources. Austmine Chairman Alan Broome commented in an article in the Australian Financial Review on 21 March 2005, "Mining is not just about the end product. It is a complete knowledge suite from exploration to mine design, smart processing and value adding technologies."

The Australian Geoscience Council agrees that Australian companies will face increased international competition. The future prosperity of Australia is dependent on our capacity for technological innovation, and for applying this knowledge commercially.

Australia's strength in the resource sector today is due largely to ongoing R&D development through collaboration by industry, government and universities, and resulting technology adoption in all stages of the mineral supply process. R&D expenditure in Australia is crucial for sustainability of the sector, especially in the area of greenfields exploration. Near surface mineral deposits of some critical commodities have been largely exhausted in Australia; the next generation of deposits will be buried deep beneath the surface. The surface of much of Australia is covered by 100-200 metres of unprospective weathered material, or by greater thicknesses of younger rock units. There is no reason to believe that there will not be as much mineral wealth under this cover as there is in the areas where the prospective rocks are at the surface. This cover is the greatest single impediment to continued success in resource exploration in Australia, and provides particular challenges to the creativity of Australian geoscientists. In the case of petroleum it is widely acknowledged that Australia's reserves of crude oil are declining and that unless replaced by new discoveries, Australia will be faced with a growing import bill and security issues for oil supply. At the same time there are large frontier areas in Australia's Marine Jurisdiction where the geology is poorly known and virtually no exploration has occurred. They may well contain new oil deposits sufficient to offset Australia's reserves decline.

Discovering these mineral and oil deposits requires new data acquisition tools, new analytical methods and exploration models, and new geological knowledge to be developed. New and more efficient methods of minerals processing will be needed to render the activity of development of smaller or lower grade deposits economic and innovation will be required to develop remote hydrocarbon resources. Without a continuation of investment in resources R&D the sector is set for a steady decline and the technology and geoscience knowledge to address natural resource management issues which are unique to Australia will not be available.

The Australian Geoscience Council is the Peak Council of geoscientists in Australia. It represents nine major Australian geoscientific societies and has a membership of over 7000 professionals. We believe that the geosciences are critical for Australia. The mineral and petroleum industries are the main export earners and underpin the nation's current and future wealth creation.

The following pages address the Inquiry's Terms of Reference

1 PATHWAYS TO COMMERCIALISATION

NATIONAL RESEARCH AGENCIES

Collaboration with national research bodies, especially CSIRO, has both positive research and commercialisation impacts. Writing in Australasian Science in September 2003, CSIRO Chief Executive Geoff Garrett states "One of the major reasons for CSIRO's existence is to deliver research outcomes to our stakeholders. The bottom line is that we need teams with complementary skills to fully leverage our world-class research and maximise its benefit for the organisation and for the nation". It is logical to expect several valued outcomes from CSIRO work and three case studies of commercialisation of research initiated at CSIRO are provided:

Appendix 1 - Case Study: Sirotem and TerraTEM are Australian transient electromagnetic exploration tools, developed and refined for the specific difficult conditions of Australian terrain, and have been efficiently and effectively delivered to industry.

Appendix 2 – Case Study: The Hymap Hyperspectral Airborne System is one of the world's most advanced airborne hyperspectral sensors, for quickly mapping rock types close to the surface. **The PIMA Portable Field Spectrometer** is widely applied by industry for rapid mineral identification. Both were developed at CSIRO and commercialised through the spin-off company Integrated Spectronics.

Appendix 3 – Case Study: Superconducting SQUID magnetometers. In the field of geophysical characterisation, CSIRO is a world leader in the development of Superconducting Quantum Interference Device (SQUID) sensors for geophysical exploration. SQUID magnetometers are the most sensitive and accurate magnetometers available for exploration. Some SQUID based instruments are finished to the commercial stage, others are under refinement.

Innovations generated in universities can be further developed either in the public or private sector. The unique case of nuclear waste disposal illustrates some of the complexities in commercialisation of sensitive technologies and points to the need for a flexible innovation and comercialisation system.

Appendix 4 describes the development of "SYNROC" at ANU and ANSTO for the safe storage of nuclear waste products, an outstanding example of significant innovations to emerge from university research. This technology is currently under the administration of the Australian Nuclear Science and Technology Organisation (ANSTO) which recently announced a collaborative agreement with Nexia Solutions to use a synroc glass-ceramic waste form to immobilise up to 5 tonnes of impure plutonium waste, currently stored at Sellafield in the United Kingdom. ANSTO will be involved in design of both the waste form and the process line. This work should provide a firm foundation to exploit other emerging opportunities for synroc waste forms among the new nuclear waste cleanup initiatives in the U.K.

The international market for exploration investment has never been more intense. National and state governments in Australia support the research and field surveys to develop the fundamental understanding of geology in order to provide the basic geoscience information which allows companies to make informed decisions as to where to invest their exploration dollars. Provision of this precompetitive information by government contributes to Australia's competitiveness in attracting increasingly mobile exploration capital.

Appendix 5 demonstrates the extremely high value of pre-competitive geoscience data delivered by Geoscience Australia and the State Geological Surveys. Regional aeromagnetic maps and regional gravity maps were used by geoscientists employed by Western Mining Corporation to infer the presence of the huge multi-metal deposit of **Olympic Dam** at the very substantial thickness of 300 metres of unmineralised cover rocks. The resource is now known as Olympic Dam and was the subject of the recent battle to acquire the assets of WMC by Xstrata and BHPBilliton. This information will remain a huge national resource both for exploration and for managing our land and water resources.

Appendix 6 demonstrates the value of pre-competitive geoscience research and surveys in stimulating petroleum exploration. Regional studies of petroleum potential and the collection of new data by Geoscience Australia has resulted in the discovery of major new gas and condensate reserves off Western Australia. The Blacktip field is scheduled for commercial development in the near term through a trans-Northern territory pipe line to the alumina refinery at Gove. These studies have also opened new areas for petroleum exploration in the Great Australian Bight.

Appendix 7 reviews research work conducted by Geoscience Australia in geohazards which resulted in a forecast that a tsunami might occur in the Indian Ocean just three months before the devastating earthquake and tsunami of 26 December 2004. A large part of the research program focuses on the needs of developing countries in the region, disaster assistance, and raising community awareness. The program has achieved national and international recognition for its innovative achievements in these areas and the benefits it has delivered to communities to make them safer and more sustainable through the adoption of informed risk-reduction strategies.

COLLABORATION BETWEEN INDUSTRY, UNIVERSITIES AND NATIONAL RESEARCH INSTITUTES

Considerable progress has been made in recent years in strengthening the collaboration between universities, industry and the government sector both through formal programs such as the Cooperative Research Centres (CRC) program and newer programs such as the ARC Linkages program, but also through informal mechanisms.

AMIRA International is an industry association which manages collaborative research for our members in the global minerals industry. By taking a partnership approach to research and development which is managed by AMIRA, members enhance their competitive position through access to leading edge technology.

The following are examples of such effective collaboration but, in the view of the Australian Geoscience Council, the full potential of collaborative opportunities for innovation is yet to be fully realised.

Appendix 8 demonstrates the discovery of substantial new wealth in minable gold which resulted from a sustained multi-disciplinary program of geoscientific innovation in a particular portion of Western Australia. The discovery process earned several prestigious scientific awards.

Appendix 9 describes a successful case study of CRC-CSIRO-Industry collaboration in the new field of Predictive Resource Modelling: **The discovery of the Golden Gift deposit in the Stawell Gold Field in Western Victoria** was a very rewarding collaborative initiative between industry and academia, a true partnership in the gathering and integration of geological data. The task entailed systematic underground structural mapping where extension veins, striations and conjugate joint sets associated with different sets of faults allowed us to construct a robust structural model. This structural model was then integrated with a 3-dimensional concept for a truncated doubly plunging dome, leading to a successful ore delineation program. The successful collaboration was recognised by an industry award in 2004.

Appendix 10 describes **Carbon Dioxide Sequestration** including the development of capture and storage technologies for CO_2 that are cost effective, safe, sustainable and acceptable to the community, and could represent an important step to moving the world's energy system to low-emission systems, including hydrogen-based energy systems. The success of this R&D effort is critical to Australia's intention to continue generating energy by burning coal for the foreseeable future.

Appendix 11 discusses the recognition that hot granitic rocks exist at depth in central Australia suitable for generating large quantities of renewable geothermal energy. The heat inside these granites is trapped by overlying rocks which act as an insulating blanket. The heat is extracted from these granites by circulating water through them in an engineered, artificial reservoir or underground heat exchanger. Commercialisation of these concepts is well advanced by the recently listed public company Geodynamics Pty Ltd. Other companies are being established and funded to pursue this exciting new field of no-polluting energy generation.

Appendix 12 describes innovative procedures developed at the Centre for Ore Deposit Research (CODES) in Tasmania, in conjunction with a group of exploration companies, to establish guiding vectors for economic mineralisation. Very accurate and controlled measurements of trace elements in pyrite ("fool's gold") allow researchers and company staff to predict the most likely distribution of valuable metals for further drill-testing.

RESEARCH WITHIN INDUSTRY

Major companies have the capacity to conduct in-house research to create a specific technical advantage over competitors. In many cases a formerly confidential technology is sooner or later transferred to the private contractors permitting wide availability of the innovation. One option for acquiring capital for concept development and proving is through an ASX listing if the commercial benefits are very clearly defined and explainable.

Appendix 13 - Case Study: Falcon Gravity Gradiometer. An instrument that could be used to measure gravity from an aircraft has been the geophysical "Holy Grail" for over 50 years. The key technology was designed by Lockheed-Martin for use in the US Navy's Trident submarines. The adaptation of this technology as a radical new airborne exploration system was achieved by BHP, and then licensed to the newly listed company Gravity Capital (now Gravity Diamonds).

Appendix 14 describes the **Hoist-EM** helicopter based system whose development was funded by Newmont Exploration, and which has recently been made available commercially. This is used in rugged terrain where fixed wing aircraft cannot effectively operate.

Appendix 15 describes MIM’s development of the **MIMDAS geophysical system** and its subsequent commercialisation, which resulted in part through the takeover of the original researching organisation by an overseas company. The distributed system avoids multiplicity of cables attached to sensors and the inherent capacitative coupling problems. The data from each channel is collected simultaneously which offers considerable noise cancellation benefits.

The appendix discusses a similar instrumental development, referred to as the **GEOFerret,** which was funded by Western Mining Corporation, in conjunction with the geophysical instrumentation and software specialist Electromagnetic Imaging Technology Pty Ltd. The system collects fixed loop time domain EM data with a signal to noise ratio up to an order of magnitude better than equivalent conventional systems and can achieve this with up to five times improved productivity and mobility. This tool has yet to be made available for companies other than WMC.

INDIVIDUAL COMMITMENT TO RESEARCH

In some cases, superior technologies or processes owe their innovation more particularly to the achievement of particular individuals or companies, who persevere because of a personal conviction of the merits of the projects. Two case studies are provided:

Appendix 16 describes innovative R&D into titanium mineral beneficiation by a small publicly listed company, which has relied almost entirely on equity to fund operations. The issuing of new shares has been the successful strategy to date for generating research funds, with a small contribution received through the Government’s R&D tax rebate program. The patented synthetic rutile process produces the world’s highest grade synthetic rutile, together with a valuable iron pellet co-product, adding value to raw ilmenite resources, and has potential to unlock refractory ilmenites such as those of the Murray Basin. The absence of any solid or liquid wastes means huge environmental benefits.

Appendix 17 describes processing and interpretation methodologies with engineering and petroleum applications. Dr Derecke Palmer commenced development of the Generalised Reciprocal Method (GRM) during postgraduate studies. GRM is now recognised as one of the most significant innovations in exploration refraction seismology in more than fifty years. It has achieved international acceptance, a claim which very few other Australian innovations can make, and is described in numerous text books for its applications in geotechnical, groundwater and environmental investigations.

SUMMARY

The resources industry is large and diverse and is a major contributor to Australia’s wealth and export income. As the examples show, the lead times in exploration, development and commercialisation are often very long, and innovation is continuous and occurs at all stages of the value chain. The examples of research, innovation and knowledge transfer illustrated above indicate that success of the Australian industry as a source of wealth for the nation has been and will continue to be in the future dependent upon a partnership of government, university and industry at all levels. The innovation system that supports the success of the resources industry must be sustained for the long term and must comprise:

- Capability in national institutions to research the fundamental geology of Australia which houses Australia's natural endowment of mineral wealth.
  - Funding for Geoscience Australia's minerals program has diminished in recent years at the very time of the need for renewed research into the geology of potentially prospective areas under cover.
  - Geoscience Australia has received additional funding for 4 years to open up frontier areas for petroleum exploration. This will need to be sustained for the longer term if the full potential of the frontiers is to be realised.
- Capability in national institutions and universities to develop the technologies and models appropriate for Australian conditions.
  - There are no universal exploration techniques which are applicable worldwide. Because of the intense weathering profile and the arid nature of Australia, exploration techniques and understanding have to be developed for Australian conditions. These can only be developed in Australia.
  - Partnerships between industry, government institutions and universities whilst respecting the specific roles of the various entities.
  - Recognition of the requirements of research and innovation is fundamental to a successful innovation system meeting the needs of industry. This is best achieved through systems and processes that encourage dialogue, cultural alignment and partnership.
  - Companies and government institutions are fundamentally dependent upon the trained personnel with knowledge and research experience in Australia that are produced by our universities.

Accordingly the AGC recommends:

Recommendation 1: Government and the Australian Research Council encourage partnerships between industry, universities and government research institutions that foster the undertaking of research of immediate relevance to the resources industry.

2 INTELLECTUAL PROPERTY (IP) AND PATENTS

Patents are critical, but very costly to maintain, and IP is almost impossible to defend for a small company. **Appendix 18 - Case Study: Rio Tinto versus RGC** over the SREP technology.

IP disputes may arise through collaboration with national research agencies which are desperate to gain industry funding.

Intellectual Property may inadvertently fail to protect Australian investment in innovation as described in. **Appendix 19 - Case Study:** CSIRO and the former World Geoscience Corporation developed the **TEMPEST airborne system** for the CRC Australian Mineral Exploration Technologies during more than six years collaborative R&D. However, the takeover of World Geoscience by a non-Australian company has resulted in the technology being managed from Europe, which has a different approach to the application of the Australian research product due to ownership of equivalent competing systems.

It is very important that appropriate arrangements are in place to protect intellectual property, particularly when private and public investment is involved. The government could assist by developing pro forma contracts for IP sharing to facilitate collaborative research projects. AGC therefore recommends:

Recommendation 2. The intellectual property rights are granted to the performing organisation while ensuring that individual researchers or research teams can share in the rewards.

3 SKILLS AND BUSINESS KNOWLEDGE

Australia is a pioneer in mining technology services, an emerging industry which accounted for $1.1 billion dollars worth of exports last year. Australia produces 60% of the world's mining software. It is apparent that Australia has commenced an era when the minerals sector is an exporter of knowledge as much as an exporter in commodities.

Appendix 20 describes "Encom Discover" as become the GIS software of choice for the exploration industry. Australian exploration geologists regard a copy of Encom Discover as essential a tool as a hammer, hand lens or compass. It is now in use by thousands of geoscientists across 80 countries.

Appendix 21 is the Case Study of Fractal Graphics which delivers world class 3-Dimensional data management and visualisation software, and has just been named as a finalist for the coveted 21st Century Achievement Award from the Computerworld Honors Program for its visionary use of information technology.

The Australian resources industry is a major user of technology and is constantly looking for innovation to maintain its competitive edge in the world market. It is essential therefore that its workforce must be appropriately trained. The direct link between teaching, high quality research and the application of research must be maintained for the geosciences. Teaching-only universities as currently proposed must be linked to research universities to ensure the quality of graduates needed for the geosciences.

Training of sufficient personnel for replacement technologists in the resource sector is uncertain and potentially critical. The AGC supports the industry proposal that the Australian Government assists 50 new geoscience graduates to be rotated through research groups and industry to gain valuable experience.

Whilst business knowledge is/may be lacking in research agencies and universities, the culture of academics and many scientists is such they are not frequently motivated by business or commercial issues. Further, it may be quite inappropriate for the imposition of systems that force a commercialisation focus because it may be counterproductive to the very innovation process that generates the new approaches in the first place. Rather it is essential for universities and research institutions to encourage an applied focus whilst developing commercialisation arms that can effectively bridge the gap between the R&D processes and their commercial development.

Attracting top students into physics, chemistry and mathematics is a major problem in many developed countries, including Australia. It is highly unlikely that Australia's position as an advanced technologically literate nation will be maintained unless more students are attracted to study science. To compound this problem it has been observed that there is an emerging shortage of scientifically trained teachers. The AGC endorses the recommendations of the Australian Council of Deans of Science (ACDS), contained in the report published in January 2005 entitled "Who's Teaching Science – Meeting the Demand for Qualified Science Teachers in Australian Secondary Schools". The report highlights "a number of serious problems that will inhibit the growth of Australia, both economically and culturally". The ACDS "is particularly concerned about the teaching situation for the enabling disciplines of chemistry and physics", fields which are critical for Tertiary studies in geology and geophysics.

The AGC therefore recommends:

Recommendation 3: Government develops a national program to support the development of best practice commercialisation capabilities in universities and scientific institutions.

Recommendation 4: Government develops a national program to improve science teaching capability and to attract highly qualified students into the study of science and engineering.

4 CAPITAL AND RISK INVESTMENT.

Innovative resource development requires funding. The cyclicity of the market's capacity to supply venture capital for resource exploration is a continuing problem for the Australian exploration industry because of the inherent risk of failure in resource exploration and development. AGC supports flow through share arrangements and a tax deduction for specified expenditure on greenfields exploration (the search for new resources well away from any known resource). The commercialisation of research is also an inherently risky business. A flow-through share scheme may also be justified for all technological listings.

It is significant that the case studies presented in this submission include no technological innovations from the petroleum sector, and yet the petroleum exploration industry contains mind-boggling high technology, which is in a constant state of evolution. It appears that virtually all innovation is conducted by international corporations and contractors, because of the high cost of these clever developments and, in contrast to the minerals industry, the petroleum industry in Australia represents less than 2 percent of the global industry. A key requirement for Australia to remain competitive is to have universities and national institutional capability that is embedded in the global market for petroleum innovation.

The AGC therefore recommends:

Recommendation 5: The Government introduces an Australian flow through share scheme for specified exploration expenditure for resource exploration and extend the concept to companies with a research commercialisation focus.

5 BUSINESS AND SCIENTIFIC REGULATORY ISSUES

The resource industry in Australia incurs significant costs in complying with the requirements of the Native Title Act in securing critical access to land for exploration.

Suggested Improvements:

1. *Implement the full deductibility of all costs associated with native title requirements*

6 RESEARCH AND MARKET LINKAGES

It is important that Government acknowledges that CSIRO, GA, ANSTO, universities and CRCs conduct valued long term research as shown in the limited case studies of innovations in this document.

The AGC endorses the recommendations made by the Strategic Leaders Group of the **Minerals Exploration Action Agenda**, established by Minister Ian Macfarlane in 2002 to address the recent decline in mineral exploration investment in Australia. In particular, we support the creation of a *deep ore discovery program* to support and increase public sector investment in R&D to equip mineral explorers in Australia with the tools for exploring through thick cover and at depth. Australian innovators have the capacity to develop new techniques to hunt for large hidden deposits that will create new wealth for the nation. We support the establishment of a **new Research Flagship within CSIRO**, referred to as **"Minerals Down Under",** with a focus on exploration technologies for deeply buried resources.

The AGC emphasises the very high value of precompetitive geoscience datasets in encouraging investment in the discovery and management of natural resources in Australia. We believe that it is essential to promote continued cooperation between the States/Territories and the Commonwealth, to complete basic geoscience survey programs, augmented by new mapping technologies.

Accordingly the AGC recommends:

> **<u>Recommendation 6:</u> The Government increases the funding for the acquisition of precompetitive geoscience by Geoscience Australia to attract mineral exploration investment to the unexplored part of Australia's mineral provinces that exist beneath the un-prospective weathered surface cover.**
>
> **<u>Recommendation 7:</u> CSIRO in partnership with industry and with appropriate universities expands its capability to develop new techniques and technologies to facilitate the new frontier of mineral exploration under cover.**

7 FACTORS DETERMINING SUCCESS

At the national level there is clearly a requirement for an integrated system of research effort to support the development of the resources industry. As outlined above the examples of research, innovation and knowledge transfer illustrated above indicate that success of the Australian industry as a source of wealth for the nation has been and will continue to be in the future dependent upon a partnership of government, university and industry at all levels. The innovation system that supports the success of the resources industry must be sustained for the long term and comprise:

- Capability in national institutions to research the fundamental geology of Australia which houses Australia's natural endowment of mineral wealth.
- Capability in national institutions and universities to develop the technologies and models appropriate for Australian conditions.
  - Partnerships between industry, government institutions and universities whilst respecting the specific roles of the various entities.

Coupled with this system is the private company commitment to develop in-house competitive skills and the individual tenacity, persistence and grit of the innovators and commercialisers of research, as demonstrated in the case studies in **Appendices 13 to 16**.

The existence of a high level champion for innovative work despite the absence of an obvious and immediate commercial return is often crucial (Refer to **Appendix 13** Case Study: BHP's Falcon airborne gravity gradiometer and **Appendix 15** Case Study: M.I.M.'s MIMDAS geophysical acquisition system).

However given the cross-cutting nature of the research and innovation system, it is essential that national government develop robust measures of the efficacy of the research, innovation and commercialisation system as it pertains to sectors of the economy such as the resources sector. Such an approach would assist in the identification of emergent issues allowing strategic steps to be taken as issues arise. The AGC supports the Government's current initiative in developing a Research Quality Framework (RQF) to deliver an improved assessment of the quality and impact of publicly funded research and an effective process to achieve this. The RQF could incorporate both academic and corporate priorities.

> **<u>Recommendation 8:</u> Government develops criteria for assessing publicly funded research which will ensure that the innovation system is able to support and engage strategic sectors of the economy, including the resources sector.**

<u>8 STRATEGIES IN OTHER COUNTRIES OF INSTRUCTION TO AUSTRALIA</u>

Appendix 22 presents a brief Case Study of Canada's flow-through share system. The Canadian exploration industry reports that in 2002, while commodity prices were still low, Canada narrowly surpassed Australia as the leading exploration jurisdiction in the world. The Prospectors and Developers Association of Canada reports "**This ended an eight year run by our biggest competitor, which does not have a flow-through program. Canada convincingly beat Australia in 2003".**

The gap between Canadian and Australian exploration expenditure increased further in 2004 with Canadian minerals exploration being 33% greater than Australian exploration expenditure. Clearly there is a valuable lesson to be learned from the Canadian achievement.

APPENDICES

The accompanying twenty two appendices provide:

- **Twenty one summary case studies of innovation in the geosciences**
- **One appendix describing a relevant activity from another country**

APPENDIX 1

TEM TO TERRATEM – 30 YEARS OF CONTINUAL DEVELOPMENT IN AUSTRALIAN GEOPHYSICS

The Need.

Australian geology is unlike that of most other countries in the world in having at its surface, a thick layer of electrically conductive soil and rock. This presents a challenge to electrical and electromagnetic methods of geophysical prospecting in that it is difficult to penetrate and so be able to analyse the formations underneath. Instruments initially imported from Russia and later North America were, for well-understood technical reasons, not capable of meeting this challenge. In particular, in the early 1970s, the Australian Geological Survey possessed a Russian made transient electromagnetic (TEM) instrument, which was inadequate and difficult to use. What was needed was an instrument with greater sensitivity so as to read signal from below the conductive overburden.

Meeting the Challenge.

From 1972-76, the CSIRO Division of Mineral Physics under the expert leadership of Dr. K. G. McCracken and with the financial assistance of some major Australian mining companies through AMIRA, designed and tested a more sensitive and easier to read, digital instrument which was called SIROTEM. It employed some of the very latest technology of the time including a CMOS microprocessor. This was probably one of the first times microprocessors were used in a field instrument. Certain particularly unique aspects of the design were patented in Australia and USA and it won an IR100 award for excellence in industrial design in 1979.Three prototypes were built and tested at mine sites all over Australia with the cooperation of many major mining companies who appreciated its superior capabilities. Many technical papers were published describing these ‘case-histories’, which proved very valuable to gain the acceptance of the system worldwide.

Commercialisation.

As required of a Government development, the commercialisation of SIROTEM was tendered to private industry in 1976 and a record number of companies responded. Geoex Pty. Ltd. based in Adelaide was successful in gaining the licence and immediately commenced production of 10 systems, essentially as copies of the prototypes. Some of these were sold to the companies in AMIRA that had supported the development and others to the Geological Surveys of other countries. These Mk I units could soon be improved with new technology and in the early 1980s, a Mk II was designed by Geoex. It employed the best available devices at the time– a battery operated paper printer to view the data and a cassette tape to store the data. Fifty Mk II units were sold, mostly overseas to 20 separate countries before further advances in technology required its redesign. In the late 1980s, a Mk 3 model was designed, this time with a LCD display screen and solid-state memory. Over 50 of this model were sold, some to previous users and some in multiple quantities. The 100th sale was celebrated by the designers and some users as one of the great successes for the export of Australian instrumentation.

The Value of SIROTEM to Australia.

SIROTEM contributed to Australia’s economy in two main ways. One was the export revenue received from the export of over 70 units at an approximate total value of over $2M. The other was in its use, either in the direct discovery of new minerals or in its contribution to their discovery. The design of a drill hole receiver enabled some ore-bodies to be detected at distances from the drill hole of the order of 100s of metres. This greatly extended the value of the instrument and led to the holding of special workshops on this topic.
In addition to its value in the search for metal, SIROTEM has also repeatedly demonstrated its application in the search for ground water, coal and oil-shale, shallow hydrocarbons, diamonds, and geothermal deposits.

Continued Development.

1. **Airborne SIROTEM.**

While essentially required as a ground based system, it was thought that to make it able to be used on an aircraft would greatly speed up survey coverage. However, the best results from TEM require a transmitter of large area and this made it difficult to use on an airborne platform. An airship flying over Sydney in 1989 did offer a large area

with which to attach the transmitter loop and one SIROTEM survey was conducted in this way. This particular innovation was the subject of a report on the ABC-TV science program, Beyond 2000.
A means of towing the TEM transmitter loop by helicopter has been developed and is described using the same technology in Appendix 5.

2. Distributed Acquisition.

In the mid-1990s it was again evident that SIROTEM needed to be up-dated. By then notebook computers were commonplace in the mineral exploration industry and it was noted that they provided the display and storage aspects of the SIROTEM console. In this case only the transmitter and sensors needed to be redesigned and incorporated with an off-the-shelf portable computer.
Furthermore, at this time the concept of multiple sensors with the one source field, or distributed acquisition, was gaining in popularity. In much the same way as seismic signals are recorded on multiple sensors (geophones in this case), another innovation stemming from the original SIROTEM was to design special EM sensors that could be deployed in arrays. It was required that they be relatively inexpensive so that quantities could be used and they were positioned by GPS receivers. Each sensor stored the acquired data that was then harvested by a non-special notebook computer. This development was called ARTEMIS standing for Array Receiver TEM Intelligent System. Unfortunately its development to production stage was curtailed upon the acquisition of the Australian developer, GeoInstruments Pty. Ltd., by a foreign-based company.
This also prevented the application of ARTEMIS to a semi-airborne use whereby the array of receivers would detect the signals produced by a loop towed above them by helicopter.

3. TerraTEM.

The curtailment of what was to be a replacement for SIROTEM as described above, meant that for a few years, there was not an Australian made TEM unit available for purchase. Apart from a completely new concept such as an array of receivers, what was need was an up-date of the SIROTEM console with the same general principle of operation but with modern components. To fill this gap, geoscientists at Monash University, who owned SIROTEM, designed TerraTEM with a Pentium processor and touch screen for control and data display. Thus each iteration of SIROTEM has incorporated the very latest technology of the time. TerraTEM was commercialised in 2004 by Alpha Geoscience of Sydney, a company whose personnel had previous experience with the marketing of SIROTEM.

APPENDIX 2

CSIRO SPIN-OFF COMMERCIALISATION OF HYMAP HYPERSPECTRAL SENSOR AND PIMA SPECTROMETER

A world-leading CSIRO optical sensor development team has formed Optical Engineering Associates Pty Ltd (OEA) as a leading R&D provider in remote sensing and related applications. This CSIRO team is internationally recognised for its achievements in optical sensor development, astronomical optics, aerospace optics and remote sensing. "Our expertise centres around the design and manufacture of optical systems, for civil and defence applications, such as airborne hyperspectral sensors," says OEA company director Dr Ian Wilson. "Our world-class facility for the design and development of optical equipment will now be opening its doors to international clients and market forces on a commercial basis."

Among the group's achievements is the co-designer of HyMap™, one of the world's most advanced airborne hyperspectral sensors, developed with Integrated Spectronics Pty Ltd (IS). IS was spun off from CSIRO in 1989 and is now one of the world's leading manufacturers of field portable and airborne remote sensing equipment.

HyMap™ creates thematic maps of the earth's surface by measuring the wavelengths of visible and infrared light reflected from the terrain. This spectral data can be processed to yield mineral abundance, soil and vegetation species maps by identifying the spectral signatures of different materials. For example, healthy green vegetation can be mapped by measuring the distribution of chlorophyll pigment, which is found in leaves.

"HyMap™ and related products have captured 40 per cent of world sales for airborne hyperspectral sensors. These systems have proved to be sensitive, cost-effective tools for mineral and oil exploration, geological mapping, and environmental surveys," says Dr Wilson.

"The success of HyMap™ is due to its exceptional sensitivity, spectral resolution, image quality, and world-class optical and electronic engineering by CSIRO and IS."

Hyperspectral cameras can "see" inside objects by analysing different types of light. Attached to a plane or satellite, hyperspectral sensors can detect minerals, chemical pollutants, sediments in waterways and even levels of nutrients in crops and forests.

At present, high resolution hyperspectral imagery collected from aircraft mounted sensors is commercially available through Australian companies such as HyVista Corporation in Sydney.

The Future for Hymap: CSIRO and Australian commercial operations are participating in a Japanese feasibility study involving the use of hyperspectral sensors in space. If all goes well, the first commercial hyperspectral satellite could be launched by 2008. Mounting hyperspectral sensors on satellites will allow Australia to perform this function for other countries.

The PIMA Portable Field Spectrometer for Rapid Mineral Identification is another CSIRO spin-of technology. Spectroscopy is a commonly used technique for analysing the composition of materials. Through industry-funded AMIRA projects, CSIRO conducted the initial programs of research which led to the concept for a Portable Infrared Mineral Analyser (PIMA). Taking the CSIRO research to the commercial world, Integrated Spectronics has developed a sophisticated shoe-box sized field-portable spectrometer for measuring the infrared spectra of rocks, especially in remote locations.

The PIMA SP is a short wave infrared reflectance spectrometer which operates in the wavelength region 1300 to 2500nm. Minerals that contain hydroxyl radicals (eg clays, amphiboles, some sulphates) and carbonate radicals absorb incident radiation at specific wavelengths and in relative amounts that are diagnostic. Borates, phosphates, vanadates and ammonium minerals also produce diagnostic spectra. The PIMA SP records the reflectance spectrum showing the wavelengths, shapes and depths of absorption features. This allows rapid identification of the mineral, often difficult in the field when dealing with fine-grained mineral species. Additional information can often be obtained about crystallinity and composition.

CSIRO Image Analysis has developed a sophisticated software package, The Spectral Assistant (TSA), which quickly and reliably identifies the constituent minerals of a rock sample from its PIMA spectra. Using a database of about 500 samples representing natural variation in 42 pure minerals, TSA uses modern and fast multivariate statistical techniques to find the most likely pure minerals and the most likely mixtures of two minerals.

Uses for the PIMA spectrometer include rapid, consistent and accurate mapping, reliable geochemical analyses, identifying vectors to mineralisation, interpreting proximity to mineralisation, conducting mining grade control and discriminating between weathering and alteration.

Benefits are low cost per analysis, field portable, in situ analysis, minimal sample preparation - measurements are made simply by placing a dry sample surface on the measurement port, the pima accepts a wide range of sample types, is reliable and robust and the unit offers several power source options.

The commercialisation of the instrument is conducted by Integrated Spectronics, which has a permanent staff holding professional qualifications in physics, electronic engineering, computer programming and geology. Additional skills are contracted in on an as-needs basis or obtained through strategic alliances, such as with the Optical Systems Engineering Group of CSIRO.

In 1992, the company shipped units from the first production run of the **PIMA II** field portable spectrometer to Australia, USA, Chile and South Africa. Over 100 units have been shipped, most to overseas locations, and the PIMA spectrometer has had a profound effect on the way many mining and exploration companies now conduct their day-to-day field operations.

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APPENDIX 3

SUPERCONDUCTING QUANTUM INTERFERENCE DEVICE (SQUID) SENSORS FOR GEOPHYSICAL EXPLORATION

CSIRO Minerals has a number of technology capabilities including electro magnetic sensing, ultrasonics, acoustics and surface indentation measurement.

CSIRO conducts government funded strategic research, and also carry out research services for industrial clients and government agencies. Often this research culminates in the development of a special purpose instrument for detecting or measuring some physical quantity.

Although these instruments have generally been developed to address particular industrial applications within Australia, they are often built on a technology platform that can be adapted for applications in other industries. CSIRO welcomes approaches from organisations interested in commercialising our technology, including the instruments mentioned above.

In the field of Geophysical Characterisation, CSIRO is a world leader in the development of Superconducting Quantum Interference Device (SQUID) sensors for geophysical exploration. Several SQUID based instruments are finished to the commercial stage, an operational stage, others are under development.

SPINMAG is a spinning rock magnetometer for laboratory characterisation of mineral samples is fully developed and both cheap and easy to use. It has an automated loader, uses liquid nitrogen coolant with a fully enclosed sample capsule to prevent contamination. The single SQUID system minimises operator intervention for complete sample characterisation by the planetary rotational motion of the sample giving all three magnetization components from one measurement cycle. Software tracks sample progression through treatment cycle. This system is completely developed and available for sale.

LANDTEM is a portable B-field geophysical sensor for mineral prospecting. It is fully developed and used operationally in Australia and Canada. It is licensed to Outer Rim Developments in Townsville who offer LANDTEM for sale or as a rental system. There are now four LANDTEM systems in operation globally, with a fifth in production. The success of LANDTEM in Canada has become particularly noticeable over the past 12 months. While Falconbridge is the main user of LANDTEM, a number of Canadian juniors are contracting Crone to survey their ground with the SQUID sensor. LANDTEM provides a direct replacement for coil sensors for TEM systems, has been proven for field use in the harsh environments of Raglan, Quebec. 1, 2 or 3 axis sensors systems are available with auto-tuned Superconducting QUantum Interference Device (SQUID) electronics. It is the first real world commercial sale and use of any SQUID system outside a hospital or laboratory.

GETMAG is under development within a CSIRO led consortium and aims to develop an airborne magnetic gradiometer to measure the earth's magnetic field tensor. This technology has application in mineral exploration, defence, security and environmental areas. GETMAG™ is aimed at the development of an airborne magnetic gradiometer to measure the earth's magnetic field tensor. This project is undertaken jointly with CSIRO Exploration and Mining. It has an industrial consortium contributing both funds and advice on the project. Consortium members are: BHP-Billiton, MIM Exploration, WMC, de Beers Australia and Newmount Exploration. It is based on a new concept axial gradiometer sensor, which is rotated to achieve the necessary sensitivity. The data is then interpreted using a new approach that enables better characterisation of the target such as providing information on its depth and orientation with fewer measurements.

APPENDIX 4

SYNROC – SECURE STORAGE OF RADIOACTIVE AND OTHER WASTE PRODUCTS

- **Synroc is the single most effective and durable means of immobilising various forms of high-level radioactive wastes for disposal.**
- **It is a ceramic made from several natural minerals which together incorporate into their crystal structures nearly all of the elements present in high level radioactive waste.**
- **Recent developments are of specialised forms to immobilise plutonium, and of composite glass-ceramic wasteforms.**
- **ANSTO has recently signed a collaborative agreement with Nexia Solutions, part of the British Nuclear Fuels Group, to use synroc-type waste forms to lock up tonnes of impure legacy plutonium currently stored at the Sellafield site..**

Introduction

Synroc is a particular kind of "Synthetic Rock", invented in 1978 by the late Professor Ted Ringwood of the Australian National University (ANU). It is an advanced ceramic comprising geochemically stable natural titanate minerals which have successfully immobilised uranium and thorium for billions of years. These can incorporate into their crystal structures nearly all of the elements present in high-level radioactive waste (HLW) and so immobilise them. In 1983, Prof Ringwood predicted synroc would play a major role in the future of nuclear waste management because of its ability to resist leaching at very high temperatures. He said this characteristic was important because it enabled final geologic disposal of synroc to be carried out deep in the earth, for example at the bottom of a 4-km deep drill hole. The original synroc formulation was designed for high-level waste (HLW) from the reprocessing of spent nuclear fuel, but many countries, including the United States, do not reprocess their waste. At the time decisions on HLW waste forms were made in the early 1980s borosilicate glass was chosen because it was the most technically mature technology.

Through its development at the Australian Nuclear Science and Technology Organisation (ANSTO), synroc technology has matured, its advantages over borosilicate glass in many areas confirmed, and a wide range of synroc formulations developed to cope with a diverse range of problematic radioactive waste streams.

The synroc approach to HLW waste form development seeks to deliver both technical and economic benefits to waste owners. The waste form is the key component of the immobilization process, as it determines both waste loading, which directly impacts cost, as well as the chemical durability, which determines environmental risk. To achieve maximum cost savings and optimum performance the synroc waste forms are tailored to suit the particular characteristics of nuclear waste to be immobilized rather than adopting a single one-size fits all approach. The combination of comprehensive underlying science and the fact that synroc waste forms are built on demonstrably durable mineral analog phases also promotes greater stakeholder acceptance of these waste forms.

Background to the Research Project

Research and development on Synroc and its properties has been carried out at the ANSTO Research Laboratories at Lucas Heights, NSW, and at ANU in Canberra. From the early 1980s funding was provided by the Australian Government. A pilot plant to manufacture synroc using only non-radioactive material was designed and constructed at Lucas Heights. Synroc became the flagship of an ANSTO program which has now broadened into other wasteforms and maintains an international profile.

At the Australian Government's request, a Synroc Study Group (SSG) was set up in 1989 by four Australian companies, BHP, CRA (now Rio Tinto), Energy Resources of Australia (ERA) and Western Mining Corporation (WMC), in association with ANSTO and ANU to consider commercialisation. The situation was complicated by the fact that existing spent fuel reprocessing plants in France and the UK, and the plant now being built in Japan, are committed to the use of borosilicate glass for immobilisation.

Although the advantages of the synroc approach have been well recognised internationally, billions of dollars have been invested in glass technology for HLW arising from the reprocessing of nuclear fuel. Whilst glass is appropriate for a large fraction of HLW, considerable quantities of waste exist that are very difficult to incorporate in glass and it is these waste streams in particular that ANSTO is targeting, with its tailored range of waste forms.

One example of synroc capabilities was the major role played in the development of a waste form for the immobilization of surplus weapons plutonium in the US in the late 1990s. To meet the obligations of the arms reduction treaties signed in the early to mid 1990s, the U.S. undertook an extensive program aimed at developing a method to safely dispose of approximately 50 tonnes of excess weapons plutonium. Two routes were chosen. One route involved burning "clean" plutonium of the right isotopic content in nuclear reactors as part of a PuO_2-UO_2 mixed oxide (MOX) fuel to produce electricity. The second route involved immobilising the less pure or isotopically unsuitable plutonium in a solid waste form. Approximately 17 tonnes of plutonium were originally proposed for disposal via the latter route.

In 1997 the DOE competitively selected the synroc pyrochlore ceramic waste form developed by ANSTO in combination with Lawrence Livermore National Laboratory (LLNL) and Savannah River National Laboratory (SRNL), as the means of immobilising impure surplus weapons plutonium. This was a great result for the team as there were over 70 other waste forms considered for the job. However, the deal never became a reality. By April 2001, the Department of Energy said it was deferring its immobilisation plans, highlighting the political nature of nuclear waste cleanup. While this was disappointing, ANSTO is again discussing the use of its technologies with the Department for a range of problematic HLW in the U.S. primarily arising from Cold War nuclear activities. The impure plutonium waste streams are still currently in storage in the US and represent an increasing proliferation and storage risk to the government. Community pressure is mounting to reinstate the immobilisation option.

Long-term commercial prospects as perceived by Synroc Study Group (SSG)

In 1991 the SSG published a Progress Report, identifying five options for the commercialisation:

- Licensing of the Synroc patents and "know-how" overseas;
- Participation by Australian companies in overseas plant(s) using Synroc;
- Establishment in Australia of an international toll reprocessing plant for spent fuel, with immobilisation of the separated HLW in Synroc and its return to the customers along with recycled fuel (uranium and some plutonium);
- Establishment overseas of an integrated spent fuel management industry. This would take spent fuel from customers, provide transport, temporary storage, reprocessing and immobilisation of HLW in Synroc, with the return of recycled fuel to customers, and final geological disposal of the immobilised HLW;
- Establishment in Australia of an integrated spent fuel management industry with both Australian and international participation, with final disposal of HLW immobilised in Synroc on an Australian territorial site.

The SSG found the potential economic benefits to Australia much greater for the fifth option, although the political obstacles were recognised to be substantial.

The concept of long-term storage and/or final disposal in a country which is neither the original user of the fuel nor its reprocessor was not new; - it was proposed by China in the early 1980s. This option is now being explored further on a non-commercial basis by Pangea's successor, ARIUS, and by Russia.

Future Directions:

To assist with the commercial development of synroc waste form technology ANSTO has recently formed the *synroc*ANSTO business team. This team is working to develop and exploit its waste form expertise in partnership with engineering contracting companies involved in nuclear waste cleanup around the world. Initial focus has been on the US, which is the largest and most active market, although ANSTO has also been working commercially in the UK over the last two years.

ANSTO recently announced a collaborative agreement with Nexia Solutions, part of the British Nuclear Fuels Group, to use a synroc glass-ceramic waste form to immobilise up to 5 tonnes of impure plutonium waste, currently stored at Sellafield in the United Kingdom. Under this deal, ANSTO will be involved in design of both the waste form and the process line. This represents a longer term commitment between Nexia Solutions and ANSTO. This work should provide a firm foundation to exploit other emerging opportunities for synroc waste forms among the new nuclear waste cleanup initiatives in the UK.

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APPENDIX 5

THE CRITICAL ROLE OF PRE-COMPETITIVE GEOSCIENCE DATA IN THE DISCOVERY OF OLYMPIC DAM

The Olympic Dam copper, uranium, gold and silver deposit is one of the world's largest known accumulation of metals, with reserves of 580 Mt of ore containing 12 Mt of copper, 0.35 Mt of uranium (U_3O_8), 350 t of gold and 2800 t of silver. Western Mining Corporation (WMC) discovered the deposit in 1975. Underground mining commenced in 1988, and a major expansion program from 1997 to 1999 has lifted annual production capacity to ~9.2 Mt of ore yielding 200 000 t of copper, 4600 t of U_3O_8, 78 000 oz of gold and 850 000 oz of silver.

The discovery of the Olympic Dam deposit, three hundred metres below the surface of the Stuart Shelf, was made in a Melbourne Office, because the resource is completely unrecognisable among the red dunes of the South Australian desert.

WMC spent six years analysing Geoscience Australia's pre-competitive geological and geophysical maps developing geological models for large scale copper resources. The aeromagnetic and gravity data provided WMC with sufficient encouragement to take out Exploration Licence 190 in 1975, and to commence drilling in June of that year. The first hole, (RD1) was a failure, but WMC persisted and by the ninth hole discovered evidence of what proved to be one of the world's largest, nearly seven kilometre long, four kilometres wide and one kilometre deep.

Early 1980 saw the completion of facilities for a hundred men, including prefabricated housing, power, water supplies, workshop, plant store, sample preparation block and a 1500 metre airstrip. During 1981 it was decided to sink a shaft to a depth of 500 metres, which was completed in September 1982. Horizontal drives were started at the 420 metre level, allowing underground development to commence in 1982. In mid 1983, a pilot processing plant commenced testing metallurgical processes.

By 1984 more than three hundred people were living at Olympic Dam, a pre-school centre was opened and primary students were transported every day 32 km to nearby Andamooka. That same year a copper concentrator was commissioned to produce concentrates for Finland were they were subjected to smelting tests. CSIRO Mineral Chemistry developed a process for the removal of uranium from the mine's concentrates in 1985 using the hydrometallurgical treatment process. By this time more than $150 million had been used in the discovery, exploration, evaluation and feasibility studies of the mine.

The project was announced to be economically viable on 11 June 1985. Ten years had passed since the discovery. Ten years of investing millions of dollars without a guarantee of a profit or even recouping the money. Ten years of public debate, political manoeuvring, uncertainties and protests. Ten years of drilling, testing, exploring, evaluation, feasibility and environmental impact studies. Never had any mining company invested so much time and money in proving a deposit before it started mining it. WMC has spent $5 billion-plus to bring its Olympic Dam project up to nameplate capacity of 235,000 tonnes of copper annually.

The Olympic Dam deposit is hosted by a large, broadly zoned hydrothermal haematite–granite breccia complex comprising a barren core of haematite–quartz breccia flanked by 1–2 km wide mineralised zones of haematite-rich breccias intermingled with altered granitic breccias. Ore mineralisation mainly comprises disseminated and fragmental chalcocite, bornite, chalcopyrite, pitchblende and finely disseminated free gold, with sulphide veinlets developed locally.

There has been a substantial follow-up search for similar style deposits in the district, with various encouraging initial results. In November 2001, Minotaur Resources drilled to test a discrete gravity anomaly leading to the identification of the Prominent Hill prospect. The results from the discovery hole, URN 1, include 20.2m at 3.03g/t from 107m, 107m at 0.65g/t Au and 1.94% g/t Cu from 200m and 152m at 0.61 g/t Au and 1.10% Cu from 492m. Mineralisation is Olympic Dam style with chalcocite, bornite, chalcopyrite and gold disseminated within the matrix of a massive haematite supported breccia.

APPENDIX 6

THE ROLE OF PRECOMPETIVE GEOSCIENCE RESEARCH AND SURVEYS IN PETROLEUM DISCOVERY

Surveys and studies have been carried out by Geoscience Australia (and its predecessors) and States' Geological Surveys and equivalents over much of the last century and up until now, to provide data and information to reduce the geological risk in petroleum exploration. A key to providing pertinent geoscience information to reduce risk and encourage exploration lies in consultation with industry and the wider geoscientific community to define the major risks to exploration in a given area, and then to design a relevant geoscientific research program that addresses these impediments. This approach is indicated by a number of recent examples showing how research undertaken by Geoscience Australia has contributed to reducing the risk for exploration.

Bonaparte Gulf: $96 million exploration investment plus future revenue and national benefit from major new discovery

In 1995-96, Geoscience Australia conducted a regional study costing less than $1.5 million of the Petrel Sub-basin offshore northwestern Australia. A new potential petroleum system in the basin was identified; this was actively promoted during the1997 and 1998 releases of offshore permit areas. In 1998-99, Woodside was awarded three permits based on a total exploration program of $83 million. Subsequently, the company made a gas discovery at Blacktip-1 with estimated reserves of 1 trillion cubic feet.

Woodside is currently in the early stages of commercial development of this field. A further investment of $13 million is forecast in a nearby exploration permit which was subsequently awarded. Woodside acknowledged Geoscience Australia's role in contributing to their initial interest and their subsequent exploration program.

Timor Sea: more than $140 million exploration investment, plus future revenue from newly discovered giant gas/condensate field

In the early 1990's, Geoscience Australia began to systematically market petroleum exploration opportunities to the Japan National Oil Company (JNOC) and associated private companies including INPEX. Off a very low base, Japanese exploration investment in Australia has gradually increased In the period 1996-2000, Japanese companies represented the largest source of new exploration funds through the up-take of new leases in Australia.

INPEX has been particularly successful and has discovered a gas-condensate resource off northwest Australia representing around 10-15% of Australia's currently defined reserves of petroleum. In 2000 alone, the cost of the exploration effort was $130 million. Publicly available conservative estimates of reserves in the Dinichthys–Gorgonichthys–Titanichthys field are around 10 TCF gas and 300 million barrels of condensate, representing a very substantial petroleum resource and significant levels of future revenue from production.

Geoscience Australia's research and surveys of the Browse basin was acknowledged by Inpex as being instrumental in attracting their interest and their bid for Browse Basin acreage. Based on a cost to Geoscience Australia of less than $2 million over the two years of the study, this constitutes an exceptionally high return on investment.

Great Australian Bight: Expected Exploration Investment of $90 Million in New Petroleum Province

A Geoscience Australia study of the frontier region of the Great Australian Bight (1998-2000) was made at a cost of $5.5 million over two years. It addressed critical perceptions of risk to the exploration industry. Although the presence of a major sedimentary basin in the region was known prior to the study, the basin had only two wells drilled in 1975 and 1980. Large areas of the basin had not been under exploration permit since the 1970s to early 1980s.

Geoscience Australia designed a program to address the key scientific questions to support the release of new acreage in the area. The study provided new data sets and interpretations of the age, thickness and nature of the sediments contained in the basin, models for oil source rock distribution, and evidence for oil having been generated in the basin.

In July 2000, three new exploration permits were awarded to a consortium of three companies (Woodside Energy, Anadarko and Encana) with an expected investment of $90 million over 6 years, including the commitment to drill one well. This well has since been completed with preliminary indications of some hydrocarbons. Geoscience Australia's role in attracting new industry investors to the area and country was acknowledged by the consortium.

APPENDIX 7

AUSTRALIAN GEOHAZARD RESEARCH, BEFORE AND AFTER THE BOXING DAY TSUNAMI

In September 2004, research staff of Geoscience Australia (GA) published a forecast that a tsunami might occur in the Indian Ocean just three months before the devastating earthquake and tsunami of 26 December 2004. Numerical modelling of the open ocean propagation of the tsunami that accompanied the 1833 Sumatra earthquake, showed that the waves are large enough to affect the entire Indian Ocean.

GA has been involved in geophysical monitoring and earthquake hazard assessment for more than 60 years. Development of GA's Geohazards Program was shaped to a significant extent by the International Decade for Natural Disaster Reduction (IDNDR). The Program has shown remarkable growth since 1995 and today spans a remarkably comprehensive range of scientific activities:

- monitoring of natural hazards in the Australia region (mainly earthquakes, landslides, tsunamis, volcanic events, sea level rise, and geomagnetic storms)
- research into the nature, origin, and occurrence of the hazards themselves (especially floods, earthquakes, severe winds, and landslides)
- modelling of the vulnerability of buildings and infrastructure
- integration with socio-economic models of community vulnerability
- development of risk models and delivery of multi-hazard risk assessments to communities and emergency managers
- development of information management systems to improve access to and usage of information, and
- education, training, and awareness-raising.

A large part of the program focuses on the needs of developing countries in the region, disaster assistance, and raising community awareness. The program has achieved national and international recognition for its innovative achievements in these areas and the benefits it has delivered to communities to make them safer and more sustainable through the adoption of informed risk-reduction strategies.

The program has succeeded in providing risk assessment tools and information to the whole region. It excels in providing a comprehensive scientific knowledge base on which emergency managers can base decisions about preparedness and mitigation. It has also increased the understanding and awareness of natural hazards among communities and managers in terms of alert systems, the likely occurrence and impacts of natural disasters, alert systems, and improved information management and access capability.

Included in the 2004-05 work program of the risk research group of GA's Geohazards Division is the provision of accurate and timely information on past, current and probability of future occurrence of earthquakes in and around Australia. The work will assist in improved response of emergency managers and disaster relief authorities to earthquakes and tsunami events in the Australian region, enable an enhanced capacity for earthquake and tsunami hazard assessment, and deliver high quality fundamental data supporting earthquake hazard assessment.

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APPENDIX 8

ACCELERATED GOLD DISCOVERY IN THE YANDAL GOLD PROVINCE OF W.A.

Western Australia supplied around 69% of **Australia**'s total **gold production** in 2002 and about 8% of the world's gold production. Western Australia in its own right is the world's third largest producer behind USA and South Africa.

A major geoscientific success story is the recognition, delineation and commencement of mining of gold in the Yandal gold province of WA. This is a region of very limited bedrock exposure, of extensive younger sand and lake cover and of deep and variable weathering of the target host rock units. The presence of sheets of covering sediments and the deep weathering meant that 19th century prospectors were unable to recognise the potential of the area despite having discovered the Wiluna goldfield in 1896 some 50 km to the west.

In 1990 gold production in the Yandal gold province was 1.5 tpa and the known resources of gold totaled less than 30 t.

By 2000, gold production was 25 tpa and a gold endowment of 470 t had been demonstrated. The area will continue to produce several hundred million dollars worth of gold annually for several years.

This dramatic success over a short period of time must be attributed to many factors including management commitment, persistence, tenacity, teamwork and good science. While drilling was the key tool in proving up these very substantial reserves of gold, it is the influence of the geoscientists who directed the placement of the drill holes and who interpreted the resulting information that is highlighted in this appendix.

The innovative strategy of the highly effective Yandal exploration effort comprised multidisciplinary facets, including:

- Systematic data collation including information sharing by competitors
- Coordinated research into the structural regimes controlling host formations
- Improved use aeromagnetic data to discriminate deep and shallow sources
- Enhanced data collection, verification, storage ad utilisation
- Collaboration with expert geoscientists working at CRC LEME, CSIRO Exploration and Mining and UWA
- Participation in exploration-oriented symposia conducted by professional societies, notably the Australian Institute if Geoscientists
- Review and refinement of genetic models for the formation of Archaean greenstone gold deposits
- Development of alteration patterns linked directly to the activity of potential gold-bearing fluids, favourable host rocks, fluid channelways, and deeper crustal processes that generated auriferous fluids
- Increased understanding of the character of the regolith and the dispersion of gold within the weathered zone
- Implementation of regional structural and mine scale syntheses which changed historic concepts on the likely location of gold mineralisation
- Identification of similarities between the Yandal region and the famously productive Golden Mile at Kalgoorlie
- Instructive comparisons of the newly discovered resources of the Yandal gold province with major gold deposits of the Timmins goldfield in Canada
- Recognition of previously unknown subordinate structural shears which had an important influence on gold distribution
- Prediction that potential existed for deep underground gold resources, subsequently tested and proven correct by high grade drill intersections and new gold resources

The exploration success in the Yandal gold province is attributed to the integration of a whole series of innovative ideas that arose from geoscience R&D rather than any single new technology. New ideas regarding the magmatic crystallisation of dolerites and thermodynamic databases played an important role in success just as new drilling and geochemical techniques did. Importantly, there is very little that was specific to the Yandal region and almost all of the exploration methodologies are transferable to other parts of Australia. This predictive approach has already been used in the Stawell goldfield of western Victoria where mine geology and leading-edge structural geology have resulted in the Golden Gift discovery.

Key ingredients in Yandal province success have included first class fundamental research, transfer of that information to the company environment utilizing skilled geoscientists in universities and at the mine, and an effective innovation uptake strategy to ensure the information was fully utilised in the exploration environment.

Recognition

In 1994, the Sir Ian McLennan Achievement for Industry Award was awarded to Dr Ray Smith and the Lateritic Environment Team, CSIRO for contributions to the gold industry in Australia; and to AMIRA Ltd in recognition of the part played by AMIRA in the development.

In 1996, Mr Ed Eshuys was awarded the Geological Society of Australia's Joe Harms Medal for excellence in mineral exploration and contributions to ore discovery in Australia, particularly in the Yandal Province of W.A.

In December 1997, a CSIRO Medal was awarded to Dr Ray Smith, Director of the Cooperative Research Centre for Landscape Evolution and Mineral Exploration and a chief research scientist in CSIRO's Division of Exploration and Mining, based in Perth. The award recognised the achievements of Dr Smith's team whose research has so far contributed to the discovery of more than $5 billion worth of gold, mainly in Western Australia

APPENDIX 9

INDUSTRY-CRC COLLABORATION LEADS TO RICH GOLD DISCOVERY IN VICTORIA

Professor Chris Wilson, Dr John Miller and Industry Representative Jon Dugdale (Exploration Manager MPI Mines, now known as Leviathan Resources) were awarded the GSA's prestigious Joe Harms Medal at the society's conference in Hobart in 2004. This medal awards innovation and success in mineral exploration and was awarded based on the work done by these researchers that lead to the discovery of the Golden Gift gold deposit at Stawell in Western Victoria. The following text is from the response of the research collaborators to the award of this honour.

The discovery of the "Golden Gift" ore body at Stawell was certainly a collaborative initiative between industry and academia, a true partnership in the gathering and integration of geological data. We would like to particularly thank all of the staff from MPI Mines Ltd and at Stawell Gold Mines, both past and present, who have made this partnership work so successfully.

Had we not had the support and vision of the late Ken Fletcher as Managing Director of Mining Project Investors Pty Ltd, David Burt the Exploration Director and Dean Fredericksen as Chief Mine Geologist at Stawell, then this rich gold-bearing orebody would still be eluding the geologists. With the first production from the Golden Gift mineralization having commenced in December 2003, some three years after its discovery and at more than 900 metres below the surface, we feel exalted by this result.

The commitment of substantial funds and support from MPI management to an ARC research project, coupled with the willingness to drill test geological concepts, led to this successful discovery, at a time when the gold price was at a recent historical low. MPI Mines allowed us flexibility in the research program and provided resources well beyond that requested in the initial ARC application and allowed us to apply modern structural geology techniques to help resolve a vexed question at Stawell. Is there an ore-body beneath the system of faults that truncate the known ore-systems, and if so, where is it? We then undertook systematic underground structural mapping where extension veins, striations and conjugate joint sets associated with different sets of faults allowed us to construct a robust structural model.

This structural model was then integrated with a 3-dimensional concept for a truncated doubly plunging dome (initially based on a watermelon) to become one of the key pieces of information used by Jon Dugdale to define the highly successful drilling program. We all knew that it was a risky and costly drilling program, as it meant drilling some very deep diamond drill holes of approximately 1.5 kilometres length on the basis of conceptual predictions.

What made this collaboration so successful was the level of engagement between MPI and the researchers where drilling results and interpretations were discussed on a daily basis and both sides were kept fully abreast of developments. Unlike many researchers, where timelines are not always aligned with exploration timing, research deliverables were presented and acted on by the Company fairly soon after the commencement of the research project.

This level of researcher-company integration is rarely achieved, and is testament to a well-established relationship between the University of Melbourne and MPI that made this an extremely exciting and rewarding period for all of us. This has established a new benchmark in researcher-company integration that has continued through a further ARC Linkage research project and a specific terrane study within the pmd*CRC "targeting new mineral deposits in Western Victoria". This has already yielded very encouraging results for MPI Mines that may represent the first significant goldfield discovered under the Murray Basin cover in Victoria.

A formal Co-operative Research Agreement has now been established between MPI/Stawell Gold Mines and the University of Melbourne that not only supports geology but is also supporting environmental, metallurgical, mining, rehabilitation and social programs. This has now cemented the partnership between the University of Melbourne and MPI. It is a partnership with a shared vision where research initiatives and results will benefit Australia's mining industry and our community for many years to come.

Recognition

See award of 2004 Joe Harms Medal in first paragraph above

APPENDIX 10

AUSTRALIAN RESEARCH INTO CARBON DIOXIDE GEOSEQUESTRATION

The following text is taken from the Innovation Australia web site www.stroudgate.net/innovation/

Energy is a key determinant of Australia's future economic growth. Australia's raw energy resource base is very rich, blessed with abundant coal and natural gas reserves, and we enjoy among the lowest energy costs in the developed world.

Australia produces among the world's highest levels of greenhouse emissions in proportion to its GDP, which offsets the benefit of our current low energy costs. Hence Australia is conducting significant research into alternative energy sources and pollution reduction, notably CO2 capture and storage at the generation stage.

A CSIRO Flagship program – Energy Transformed – has the mission of developing low-emission energy technologies and systems that lead to the widespread use of hydrogen as a clean, safe and efficient energy carrier across the economy. The Energy Transformed Flagship, undertaken by leading Australian scientists, will work towards:

- doubling the efficiency of fuel use (natural gas and eventually hydrogen) by the generation of power/heat/cooling at point-of-use;
- developing and implementing technologies leading to near-zero emissions power from fossil fuels and eventually, large-scale hydrogen generation;
- developing cost-effective electricity and hydrogen from renewable sources; and
- increasing the fuel and traffic management efficiency of urban transport leading to an eventual transition to hydrogen-powered vehicles.

The likely reality is that the bulk of Australia's energy will be supplied by fossil fuels and especially coal (black and brown) over the next 20 years and beyond. Coal-fired power was responsible for 38% of Australia's total greenhouse gas (GHG) emissions in 2000 – Australia's largest single source. The extraction, processing and transportation of coal are relatively minor GHG contributors.

It is at the stage of power generation from coal or oil that new technologies are required, either to increase the efficiency of conversion or to prevent the combustion product, CO2, from entering the atmosphere.

A recent review of energy R&D in CSIRO specifically identified coal gasification and carbon dioxide geological sequestration (leading to zero-emissions power) as a key component of the Energy Transformed Flagship. There is now intense interest in Australia in the setting up of either a demonstration or full-scale gasification/ sequestration plant in Australia. Sequestration technologies will also be important in securing future markets for Australia's LNG and coal.

A carbon capture and storage technology roadmapping exercise was coordinated by the Cooperative Research Centre for Greenhouse Gas Technologies (CO2CRC) during the second half of 2003. CO2CRC has built on the work conducted between 1999 and 2003 by a large number of Australian researchers participating in the GEODISC program of the former Australian Petroleum Cooperative Research Centre. Specifically, the preliminary work of GEODISC:

- developed an understanding of CO2 storage among a large group of geologists, geophysicists, modellers, reservoir engineers and economists;
- determined that Australia does have very significant potential for geological storage of CO2, particularly in saline formations in the western half of the continent (with more work required to establish potential storage sites in eastern Australia);
- showed that geological storage is likely to be technically viable as a long-term option.

What GEODISC did not address were issues relating to the capture and separation of CO2 from flue gases or other emissions. However it was recognised that there was a significant skill base in Australia in relevant technologies such as solvents, membranes, pressure swing adsorption and cryogenic separation.

CO2CRC was formed in October 2003 to research the issues – logistic, technical, financial and environmental – of storing industrial carbon dioxide emissions in deep geological formations. It will also address the capture and separation of carbon dioxide from industrial systems.

CO2CRC is a joint venture between industry, government and research institutions, which combines the research-user focus of 10 major petroleum, oil and power companies with the research-provider strengths of universities, research organisations and the private sector. It also has strong links with leading overseas research institutions.

The development of capture and storage technologies that are cost effective, safe, sustainable and acceptable to the community, could represent an important step to moving the world's energy system to low-emission systems, including hydrogen-based energy systems.

References: More complete discussion of the issues of carbon dioxide capture and storage are available on the following web sites www.stroudgate.net/innovation/, www.co2crc.com.au and www.csiro.au

APPENDIX 11

RENEWABLE ENERGY FROM HOT DRY ROCKS IN CENTRAL AUSTRALIA

The Problem

Electricity demand continues to expand worldwide, with consumption projected to grow by nearly 100% by 2020. Electricity generation generally relies on burning fossil fuel which produces carbon dioxide (CO2) as one of its waste products. Concern has developed over the last decade about the effects of carbon dioxide (a greenhouse gas) on the atmosphere, particularly with respect to global warming.

As a result of these environmental concerns, the world is facing an energy production dilemma. There is an increasing worldwide demand for energy to maintain and expand economic prosperity, whilst at the same time there is general agreement that global warming and pollution are harming the global environment in which we live.

The Solution

Hot Dry Rock (HDR) geothermal energy relies on existing technologies and engineering processes, and is the only known source of renewable energy with a capacity to carry large base loads.

The concept behind HDR geothermal energy is relatively simple. Heat is generated by special high heat producing granites located 3km or more below the Earth's surface. The heat inside these granites is trapped by overlying rocks which act as an insulating blanket. The heat is extracted from these granites by circulating water through them in an engineered, artificial reservoir or underground heat exchanger.

HDR geothermal energy relies on existing technologies and engineering processes such as drilling and hydraulic fracturing, techniques established by the oil and gas industry. Standard geothermal power stations convert the extracted heat into electricity. HDR geothermal energy is environmentally clean and does not produce greenhouse gases. It has been classified as renewable by National and International authorities.

The Australian Company

Geodynamics Limited was registered as a public company in November 2000. The Company was formed solely to focus on developing renewable geothermal energy generation from hot dry rocks (HDR) in Australia. The Company was formed by Dr. Doone Wyborn and Dr. Prame Chopra from the Australian National University in Canberra (leading experts in HDR geothermal energy), and Dr. Bertus de Graaf, who has a track record in resource development.

Geodynamics was funded by initially raising more than $1 million dollars in seed capital in 2001. It then secured two geothermal exploration licences in South Australia and two in New South Wales, including its outstanding world class resource in the Cooper Basin. After successfully raising $11.5 million, Geodynamics listed on the Australian Stock Exchange on 12 September 2002, and together with a $5 million R&D Start grant from AusIndustry it initially had gross funds of $16.5 million for its Stage 1 development program.

Stage One of the Company's Business Plan is now in full progress. Habanero #1 well was spudded on 15 February 2003 and completed on 14 October 2003. It was drilled to a depth of 4,421 metres making it one of the deepest wells ever drilled onshore Australia. The Hydraulic Stimulation Program (fracturing of granites underground) commenced following the completion of Habanero #1 in October 2003 and was completed on 23 December 2003 with a stimulated zone achieved four times larger than expected.

The Company spudded Habanero #2 on 9 July 2004 and completed the well to a depth of 4,350 metres on 28 December 2004. The completion of the well was delayed due to the loss of 800 feet of drill collar in hole and the requirement to drill a side track which was successful. While commercialisation of energy derived from Australian HDR resources has yet to be achieved, Geodynamics is well positioned both technically and financially to achieve the company’s ambitious goals.

APPENDIX 12

NEW APPLICATIONS OF LASER ABLATION SPECTROMETRY FOR GOLD AND BASE METAL EXPLORATION

The Research Concept

Pyrite, although itself not an ore mineral, is usually associated with base metal, gold and other ores, but is far more widely distributed. For example, pyrite occurs in rocks in alteration haloes far outside the main ore zones of many major deposits. The idea that the trace element contents of pyrite in different settings may be a very powerful vector towards ore was thwarted by the need to analyse pyrite for the low abundance trace element contents. Thirty-five years ago in the School of Earth Sciences at the University of Tasmania, Geoff Loftus-Hills attempted to use pyrite trace element compositions (Ni, Co, Se) to elucidate the origin of diverse orebodies in western Tasmania. He attempted to collect ultra-clean separates from both ores and their host rocks, and to analyse them for trace element content. Some useful relationships were discovered, but problems with sample purity, zoning of individual grains, and relatively insensitive analytical procedures all conspired to diminish the usefulness of this technique.

Innovative Application of Modern Instrumentation

The development of a new in-situ microanalytical tool known as Laser Ablation Inductively Coupled Plasma Mass Spectrometer (LA-ICPMS) is enabling ore deposit researchers to implement the philosophy that underpinned LoftusHills' work. In 1999, the Centre for Ore Deposit Research (CODES - a Federal Government funded SRC), purchased an Agilent HP4500 quadrupole ICPMS, and a New Wave UP213 nm Nd:YAG laser in 2002, the key requirements of a LA-ICPMS system. This instrumentation uses a laser to energise and ablate minerals, producing ultra-finely comminuted material which is drawn into a mass spectrometer and analysed for about 33 elements simultaneously. Since then, CODES researchers have achieved the development of new procedures to use the LA-ICPMS facility to measure the trace element compositions of different sulfides, for innovative and cost-effective application in diverse exploration and ore genesis studies. With a beam resolution as low as 5 microns, low detection limit microanalysis of a wide range of elements is made possible for very fine-grained sulfides (e.g. Carlin, McArthur River), and element zoning in individual sulfide grains can be accurately measured. This has produced data of considerable interest to the exploration industry, which now funds a number of related projects. Essential stages in establishing this new exploration capability incuded:

Development of a suitable range of primary standards, since standards commonly used for analysis of silicate phases are not well characterised for chalcophile elements such as Cu, Pb, Ag and Zn. Since natural materials are either heterogeneous or do not carry a useful range of elements at sufficient concentrations to make them useful as primary calibration standards, doped glass standards were developed and repeatedly analysed by both solution- and LA-ICPMS.

Evaluation of the analytical errors caused by matrix-dependent laser-induced fractionation, which allow quantitative correction factors to be introduced for analysis of each sulfide mineral.

Determination of the optimum operating conditions for the laser for each sulfide.

These non-trivial pre-requisites have been successfully achieved, providing confidence that this analytical system was delivering quality data. CODES researchers have recently developed a number of new applications, including microanalysis of:

Fine-grained pyrite from the very rich Deep Star Carlin-type deposit in Nevada, to determine the residence sites) of gold,

Chalcocites from the Mammoth (Gunpowder) deposit, to distinguish primary from supergene mineralisation,

Pyrite in Victorian lode gold deposits, to compare gold contents of pyrite in different parageneses, including pyrite associated with marker beds, in the host metasediments and in the ores,

Enargites from the Lepanto high-sulfidation deposit (Philippines), to evaluate spatial compositional zoning outwards from the main Far Southeast porphyry host and correlations with fluid salinities determined by infra-red microthermometric studies of the same grains, Pyrite and chalcopyrite in the Rosebery VHMS system in western Tasmania, to distinguish Cambrian mineralisation from later, less economically important mineralisation associated with nearby Devonian granite emplacement,

Pyrite from Kanowna Belle, Cadia Far East and Sunrise Dam gold deposits in Western Australia, to evaluate the potential and usefulness of trace-element compositions as vectors to mineralisation.

Commercialisation

Mainly via the ARC Linkage project mechanism, more than ten sponsor companies are presently involved in CODES core and non-core projects based on LA-ICPMS of sulfides, and the range of applications of this exciting methodology is increasing monthly.

One case study is outlined below, focusing on the important Carlin-type deposits, which represent one of the most important sources of Au worldwide. In over 40 years, more than 2000 metric tones of gold have been produced from these deposits. The ores typically consist of gold-rich arsenic-bearing pyrite or marcasite, which commonly occur as fine (<5 pm) rims on coarser grained diagenetic pyrite. It is the fine-grained nature of the ore and gangue mineral assemblages in Carlin-type deposits that have hindered analytical investigations into the ore paragenesis of these deposits. Laser ablation ICPMS can overcome these problems by providing low limits of detection at high spatial resolution. With this in mind, a pilot study was undertaken to determine the sites of element residence in the pre-ore and ore related pyrite from a Carlin-type gold deposit, and to obtain a qualitative analysis of the arsenian pyrite rims.

The Deep Star Au-deposit is located in the northern part of the Carlin Trend, Great Basin, N. Nevada. As of 2000, the deposit had produced 37.8 t of gold, with an average grade of 34 g/t Au. Initial work using back-scattered SEM imaging revealed the euhedral pyrite crystals to have As-rich rims. Prior to analysis by LA-ICPMS, the pyrites were analysed by electron microprobe to obtain a Fe concentration that could be used as an internal standard. The pyrites were then analysed by LA-ICPMS for Fe, As, Sb, Au, Pb, Cu, Zn, and Tl. Using a laser beam diameter size of 8 microns, the analytical approach was to ablate the core of a rimmed pyrite crystal and, given the compositional contrast, recognise from the counts spectrum when ablation reached the As-rich rim directly beneath the surface. The results show the pyrite core to contain higher counts for Fe, As and Pb, whereas the highest counts for As, Tl, Au, Sb and Cu are in the arsenic-rich rim. From a single ablation and ICPMS spectrum, it is possible to obtain qualitative analyses from those parts of the spectrum that correspond to different regions of the pyrite crystal. The calculated results show the diagenetic pyrite core to contain the highest concentrations of Pb (600 ppm) with 2640 ppm As. The arsenic-rich rims contain 3.6 wt% As, 1600 ppm Tl, 1200 ppm Au, 1000 ppm Sb, 730 ppm Cu and 350 ppm Pb. The extraordinary composition of these pyrite rims highlight the critical importance of the late stage Au-As-Sb-TI hydrothermal event that concentrated gold in the Carlin ore systems.

Keys to Success

The pilot study done at CODES shows that, given compositional contrast, it is possible to obtain qualitative analyses of ultra-fine pyrite bands using LA-ICPMS at high spatial resolution. Such applications are clarifying the controls on, and localization of gold in important ore deposits, as well as having diverse applications to base metal mineralisation exploration.

The key development work in this research is funded by an ARC Linkage grant supported by Newmont Mining, BHP Billiton, Anglo American, AngloGold, Placer Mining, and Newcrest Mining.

Reference

Norman, Robinson and Clark (2003) 'Major- and trace-element analysis of sulfide ores by laser ablation ICP-MS, solution ICP-MS and XRF: new data on international reference materials' The Canadian Mineralogist 41

APPENDIX 13

THE FALCON AIRBORNE GRAVITY GRADIOMETER SYSTEM

The Technical Need

FALCON™ is a story of technology breakthroughs, synergies, teamwork and success in achieving desired goals. It was a high risk, high reward research and development project, the successful outcome of which was then coupled with an innovative commercial model.

For the last 50 years airborne geophysical techniques, which allow rapid, low cost surveying of large areas, where access problems can be difficult and expensive, have been developed as one of the most important tools in the mineral explorer's armoury. During the 1990s cheap and effective magnetic, radiometric and spectral scanning techniques were further progressed by using GPS technology, advances in computer speed and power and improvements in instrumentation. Airborne EM also progressed rapidly with better instrumentation, visualisation and interpretation techniques.

High resolution, airborne gravity was the missing element, almost the Holy Grail for mineral explorers. Such a tool, in the form of a gravity gradiometer, would allow rapid detection and improved discrimination of mineral deposits, especially when coupled with other techniques such as airborne magnetics and EM. This is particularly the case in Australia (or similar terranes), where much of the continent is covered by a pervasive regolith, and where land gravity surveys are slow and expensive, even with the recent developments in GPS technology.

Project Development

The technical challenges to achieving high resolution airborne gravity gradiometry appeared to be insurmountable. If we examine the gravity anomalies associated with major mineral deposits we can see that we need a system with sensitivity of around 10 Eö over approximately a 200 m resolution to achieve results that allow not only detection of these deposits, but also discrimination from other geological sources of gravity anomalies.

The main milestones in the development of the Airborne Gravity Gradiometer are shown below:

- 1970 Bell Aerospace US Navy GSS gravity gradiometer program
- 1989 Berlin Wall falls
- 1990 Discovery of Cannington Ag-Pb-Zn deposit
- 1991 BHP Billiton begins feasibility studies on Bell Aerospace technology
- 1996 Construction of FALCON™ AGG system begins
- 1999 Demonstration airborne survey over the Bathurst Camp
- 2000 Two FALCON™ AGG systems in routine operation
- 2004 Delivery of digital system

The fall of the Berlin Wall may appear to be an odd event in this succession, but without the end of the Cold War it probably would not have been possible to obtain the Bell Aerospace technology, which had been developed for the US Navy's nuclear submarines. We were able to use the window of opportunity between the Cold War and the War on Terror.

As a result of being able to adapt existing technology, there was a significantly reduced development risk with US$200M having already been spent on the existing system. The reduced capital cost required to modify the system amounted to approximately US$30M and the time frame from concept to production was only eight years.

The discovery of the Cannington Ag-Pb-Zn deposit near Cloncurry in Queensland (now the world’s largest Ag deposit) under 40 m of Cretaceous cover, gave BHP Billiton the technical and exploration management resolve to pursue airborne gravity gradiometry. This capability was seen as a key element to driving further discovery of world class deposits under cover in similar settings across the globe.

Technical challenges were not the only ones to overcome, the project was nearly stopped a number of times during the eight year development period. Without an inspiring high level champion, we would have probably failed. BHPB shares did not perform well in the 1997/1999 period, and although the noise reduction in the gradiometer was spectacular, it was not a good time for R&D investment.

Commercialisation

FALCON® has since proven its capabilities with new discoveries of iron-ore and diamonds, and through numerous orientation tests over well known orebodies such as Ekati, Cannington and Ernest Henry.

Following BHPBilliton's substantial investment in the development of the technology, the company has chosen to optimise its technological advantage by agreeing to a negotiated share of the cost of a Falcon survey over third party minerals rights, in exchange for a negotiated participation interest in deposits discovered using Falcon technology. Gravity Diamonds Limited (formerly known as Gravity Capital Limited) is a company exploring for diamonds in Australia and the Democratic Republic of Congo. Key to Gravity’s business strategy is alliance agreements with BHPBilliton and the Australian program is based on the deployment of the FALCON® airborne technology.

Recognition

In 2004, the Falcon development team was awarded the prestigious **Grahame Sands Award** by the Australian Society of Exploration Geophysicists. This award is made to one or more geoscientists who introduce a significant practical development or innovation of benefit to applied geoscience in Australia

APPENDIX 14

HOISTEM TIME DOMAIN ELECTROMAGNETICS

The Innovation: The Hoistem time domain helicopter-borne EM system was developed by Normandy Exploration Ltd. (now Newmont) as part of its commitment to establishing new exploration techniques via in-house research and development. These new geophysical techniques were considered to provide a competitive advantage for both direct mineral detection (e.g. massive sulphides) as well as indirect mineral detection by my mapping both geology and regolith characteristics.

Hoistem uses an in-loop transmitter-receiver system which provides the optimum configuration for mapping, with high spatial sampling and a typically symmetrical response regardless of flight direction. The power and elegant simplicity of HoistEM allows conductive units to be seen only hours after the helicopter lands. It is perhaps best applied to copper and nickel sulphide exploration and finding water channels, but it is also a great mapping tool and as such is proving invaluable for gold exploration as well as for iron ore and manganese discovery.

The Research Process: Normandy Exploration has funded (A$ 1 million per annum) geophysical research since 1990. During this time the major developments were a helicopter (towed bird) magnetometer system and a high powered, very accurate ground Time Domain Electomagnetic System. Since all airborne TDEM systems were high speed, high altitude fixed wing systems it was decided that a combination of our helicopter mag and TDEM could be used to provide a slow flying, low altitude airborne TDEM system.

No external funding was sought or received for in-house geophysical research. However the 150% R&D tax deduction was claimed every year and management regarded this deduction as an important incentive for funding the R&D.

All geophysical R&D at Normandy was intended to be privately used. During the recession in the minerals industry around 2000 (and the consequent decline in mineral exploration) the developments of the R&D group were not being fully utilised. A proposal was put to management to commercialise the Hoistem system. The aims of the commercialisation were threefold.

1. To generate an income stream to partially fund ongoing R&D. This was seen as important to guarantee the future of the group.
2. To reward the researchers by profit sharing.
3. By having the equipment fully utilised the R&D group would be fully committed with morale etc. kept high.

Key aspects contributing to the success of the development were keen management support, direct relevance to corporate objectives, and a dedicated team of people, special knowledge plus grit and bloody-minded perseverance

Commercialisation: The system was joint ventured via a three way joint venture between GPX Airborne Surveys (now known as WorleyParsons-GPX following the merger of GPX with Worley Parsons Limited), Normandy Exploration Ltd. and Geosolutions Pty. Ltd. GPX were to provide the marketing and operation of the system only. Normandy was to provide the hardware; Geosolutions was to provide the software and necessary training. Geosolutions also represented the interests of the researchers. GPX have no access to any of the technology involved in the HoistEM system.

Subsequent to commercialisation, 50,000 line kilometres have been surveyed within Australia between years 2002 and 2005 indicating strong industry acceptance.

The joint venture document (agreement) was the most important issue with the transfer of the innovation from private to commercial use. This document was very carefully drafted so that the interests and obligations of all parties was clearly stated and could not be varied without consent from all three parties. This document has proved invaluable since the Newmont takeover of Normandy as management at Newmont would rather not have any commercialisation.

Recognition

In 2003, the Australian Society of Exploration Geophysicists selected Mr Graham Boyd to receive the prestigious **Grahame Sands Award** which is made to a geoscientist who introduces a significant practical development or innovation of benefit to applied geoscience in Australia. The 2003 presentation was made for Mr Boyd's leadership role in the development of HoistEM helicopter TEM system which is now in commercial use.

Reference

G W Boyd "HOISTEM – A New Airborne Electromagnetic System" Pacrim Conference 19-13 September 2005

APPENDIX 15

MT ISA MINES MIMDAS GEOPHYSICAL ACQUISITION SYSTEM

What motivated the Innovation

Resource exploration in Australia requires a capacity to discover totally covered deposits using indirect geophysical methods to infer subsurface properties. As the amount of cover increases in both the vertical and horizontal dimensions, the basic requirements for any exploration method are threefold:

1) As the targets get deeper, the signals get smaller, requiring the measurements to be accurate and reliable
2) At times the areas to be explored are very large requiring the measurement procedure to be affordable.
3) It is essential that some model that reflects physical reality is derivable from the measurements taken and that this model can be used in exploration. The measurements must be interpretable.

These goals required the development of new instrumentation which could be deployed in the multichannel array styles, in a manner that has become commonplace in the seismic method used in the oil industry. To complement the new hardware that is capable of resolving smaller signals is the vast reserve of signal processing software largely developed for use in other disciplines to improve signal to noise ratios.

M.I.M. Exploration Research Program

In 1994, M.I.M. Exploration Pty Ltd (MIMEX) assessed that existing exploration systems suffered from a lack of penetration and lack of spatial resolution due to effects caused by conductive overburden and the limited specifications of the collecting systems. M.I.M. decided to design and build a multichannel aquisition system to collect measurements that are accurate and affordable and at the same time pursue the required interpretational and display tools. This has resulted in products which allow a 3D style interpretation. The ultimate goal was to produce 3D geology maps interpreted from 3D discretized physical property block models. While achievable the 3D interpretive schemes are not widely available. However, in certain instances very usable models have been assembled from 2D interpretations displayed in a 3D sense.

The hardware for the system was built in conjunction with Refraction Technology. It has been named **MIMDAS** – **MIM D**istributed **A**cquisition **S**ystem and was designed to collect array style measurements using any commonly available sensor type. MIMDAS has been used to collect controlled source electromagnetic data, resistivity and induced polarization data including spectral IP, and magnetotelluric data. The system is sufficiently flexible that it could collect other data sets such as seismic if required.

The system is based upon single channel distributed acquisition units (DAU's) that collect 19/24 bits (depending on sampling frequency) of non-aliased linear data with a bandwidth of 0 - 20 kHz. This data is relayed to central recording unit (CRU) in a recording truck, via local area network (LAN) cables. Each distributed acquisition box is accurately synchronized and the data buffered in each unit is transmitted to the CRU at the end of each event. The acquisition software allows interrogation of each box and can display raw data as it arrives. The data is processed on site and field plots produced. One value of recording and storing complete time-series data is that it allows re-processing at later times. For controlled source surveys at least one channel is devoted to accurately monitoring the input current from the transmitting source. This current data is then used to deconvolve the input data and compensate for non-ideal transmitted waveforms.

The distributed system avoids multiplicity of cables attached to sensors and the inherent capacitative coupling problems. It also means expandability as the number of units/sensors is limited only by logistics, and the number of available DAU's. The data from each channel is collected simultaneously which offers considerable noise cancellation benefits. The time series data allows simple signal processing procedures to remove cultural noise, which when combined with selective stacking routines and other remote reference noise cancellation schemes produces very high quality data. Considerable area or line kilometers of quality data can be captured rapidly.

In a parallel development to the hardware, considerable effort was spent in assembling a suite of software that could make use of the increased volume and quality of the data. As well as the new processing software, a large number of interpretation and modelling programmes that had been acquired through collaborative research and development projects (AMIRA, CSIRO) were able to be brought to use.

Key Factors in Success of Project

As a one of Australia's largest mining houses, M.I.M. was well positioned to undertake a major project to increase the effectiveness of its investment in exploration. Nevertheless, budgets always fluctuate with commodity prices, and expenditures with no immediate commercial return are subject to cuts. The MIMDAS project benefited from the keen support of Mr Ross Fardon whose support at Board level helped to ensure the continuity of the research effort. The calibre and capabilities of the geophysical team was another important factor in sustaining the project. A third factor was that a risk was taken in applying the prototype equipment on real exploration projects, and achieving good data to impress company management.

Commercialisation

Following the takeover of MIM Holdings and its subsidiaries by Xstrata in 2003, a group of former MIMEX employees, with local commercial backing, formed GRS Pty Ltd and successfully negotiated an asset sale agreement that gave GRS the right to offer MIMDAS surveys commercially world wide.
Since February 2004, GRS has been operating the MIMDAS equipment (now ~200 channels) throughout Australia and Chile. In May 2005, a unit will begin surveys around Sudbury in Canada.

During the period of its operation, the effective depths of exploration in the notoriously difficult regions of NW Queensland, the MacArthur River Basin in the NT, the Kurnamona region of SA and parts of WA have been increased by as much as two or three hundred metres.

WMC'S GEOFERRET TEM SYSTEM TO HUNT FOR WEALTH

A new distributed array geophysical data acquisition system, dubbed GEOFERRET, was unveiled at the Prospectors and Developers of Canada (PDAC) meeting in Toronto in March 2005. Developed by WMC Resources Ltd (WMC) in conjunction with the Western Australian-based geophysical instrumentation and software specialist Electromagnetic Imaging Technology Pty Ltd (EMIT), GEOFERRET is a distributed array time domain EM system that employs newly developed sensors combined with smart real-time data processing and long occupation times to collect fixed loop time domain EM data with S/N up to an order of magnitude better than equivalent conventional systems. The technology has been shown to achieve this with up to five times improved productivity and mobility, deployed regularly with up to 20 simultaneous measuring stations.

The system comprises, at each measuring station, a single axis coil with an autonomous electronics box, or *node* that stores data internally until such time as an operator harvests the data using a Personal Digital Assistant (PDA) equipped with wireless networking capability. Timing and transmitter synchronisation are accomplished with an on-board GPS receiver with a backup 10 MHz crystal clock. Each receiver electronics node hosts four 24 bit input channels with a bandwidth of DC – 50 kHz. Location is automatically recorded using a GPS. New single-axis low-noise aluminium wire receiver coils have been designed for use with GEOFERRET. Measurements using the coils routinely achieve noise levels of 1 pT/A.s. Fluxgate magnetometers have also been successfully trialled with the GEOFERRET system.

GEOFERRET is 100 percent owned by WMC, which has been working on the technology since late 2000, Field trials began at the Cliffs nickel sulphide prospect (south of WMC's Mt Keith Nickel Operations in Western Australia) in mid-2003. GEOFERRET has assisted in the discovery of the North Cliffs extension and the Olympia nickel sulphide prospect at Collurabbie, also in Western Australia. The system is currently restricted to WMC and its joint venture partners.

APPENDIX 16

EMERGING TITANIUM BENEFICIATION TECHNOLOGY COMPANY AUSTPAC RESOURCES NL

The Demand

The market for titanium dioxide has grown over the last 25 years by 3% per annum and is now worth $US8 billion annually. Titanium dioxide is the superior white pigment used in paints, plastics, paper and printing inks. Austpac Resources aims to become the world's largest producer of very high grade feedstock called synthetic rutile for the titanium dioxide industry.

The Technologies

Austpac's patented ERMS (Enhanced Roasting and Magnetic Separation) SR Process is technologically superior and more cost effective than any other technology for producing high grade feedstock for the production of titanium dioxide pigment or titanium metal. Austpac has also developed a reactor for Continuous Leaching of ilmenite, making ERMS SR the only continuous process in the world. A third technology, EARS (Enhanced Acid Regeneration System), is an extremely economical and environmentally friendly process for acid regeneration that produces super-azeotrope hydrochloric acid and iron metal pellets, greatly increasing the financial returns from processing operations that consume hydrochloric acid. These technologies are covered in part or whole by patents.

A further innovation entails new specialised applications of Low Temperature Roasting (LTR) of titaniferous ores, yielding beneficiated products suitable for both the chloride and sulfate route processes of pigment production.

Key attributes are:

- The processes add value to raw ilmenite resources
- They unlock refractory ilmenites such as those of the Murray Basin
- Austpac produces the world's highest grade synthetic rutile
- Sales of the high grade iron metal co-product cover all plant operating costs
- The acid regeneration system is applicable to other industries
- No solid or liquid wastes mean huge environmental benefits.

Research Process

The company has conducted its R&D at a six story facility on Kooragang Island at Newcastle This plant is unique in Australia, allowing Austpac to maintain leadership in ilmenite processing. Austpac's team of engineers has substantial experience in mineral processing, innovative research and technology development, which has enabled the company to achieve major technological breakthroughs.

Development of the processing technologies has been funded through shares issued in the ASX-listed company. A small but value expenditure recovery has been possible through the Government's stringently administered R&D tax rebate program.

The Future

The Company is planning to construct the first commercial ERMS SR plant with an annual production capacity of 30,000 tonnes. This plant will produce the world's highest quality synthetic rutile that will be used as a feedstock to help meet the world's future need for titanium dioxide pigment. The scale-up ratio from demonstration plant to this commercial plant is only 20:1 which is acceptable to financiers, but Austpac still needs to lock down funding to finally prove the ERMS SR Process at a commercial scale.

Reference: www.austpacresources.com

APPENDIX 17

GENERALIZED RECIPROCAL METHOD OF REFRACTION SEISMOLOGY

The Generalized Reciprocal Method (GRM) is an Australian innovation employed for the processing and inverting of seismic refraction data. Refraction methods were the first seismic techniques applied to petroleum exploration more than 70 years ago, and currently they find extensive use in geotechnical and groundwater investigations, and in the processing of seismic reflection data for coal and petroleum exploration.

GRM is recognised as one of the most significant innovations in exploration refraction seismology in more than fifty years. It has achieved international acceptance, a claim which very few other Australian innovations can make. It satisfies the criterion of being a significant Australian innovation, that has achieved international acceptance by both academia and industry, and which is being used regularly by Australian and International explorationists." The GRM has been adopted by the American Society for Testing Materials as part of their Recommended Practices for geotechnical investigations.

The GRM was the basis for a special monograph published in 1980 by the Society of Exploration Geophysicists in Tulsa. This monograph has been through several reprints and it is widely regarded as a seminal work on exploration refraction seismology. Dr Palmer wrote a more extensive book "Refraction Seismics" as part of a twenty volume series on seismic exploration published in 1986 by Geophysical Press and later, by Pergamon Press.

The GRM is used extensively in the definition of the near surface weathered layer for geotechnical, groundwater and environmental applications and for statics corrections for seismic reflection surveys. The new systems for recording seismic data for oil exploration, such as the Western-Geco Q system, use single geophones and 20,000 channels. They generate 0.7 Tera Bytes of data a day! That data is ideally suited to processing with the GRM.

More recent research has included the resolving power of refraction methods for detecting narrow low velocity intervals for detailed geotechnical applications, the ambiguities in determining overburden velocities, and the GRM in the context of general inversion theory and statics computations. Most seismologists regard the GRM as one of those innovations which is both a valuable generalization and a practical interpretation method in itself. The GRM is now an essential component in the standard seismic texts and commercial seismic software systems.

Recognition

Derecke Palmer received the **Grahame Sands Award for Innovation in Applied Geoscience** at the 1992 Conference and Exhibition of the Australian Society of Exploration Geophysicists held on the Gold Coast in October. The award is made to a person responsible for a significant practical development of benefit to Australian applied geoscience, in the fields of instrumentation, data acquisition, data processing, interpretation or theory.

In 1995, the U.S.-based Society of Exploration Geophysicists (SEG) acknowledged this innovation through the **SEG's Reginald Fessenden Award** which is granted to selected scientists for a unique technical contribution to exploration geophysics, such as an invention or a theoretical or conceptual advancement.

The GRM has been included within recent exploration geophysics text books, such as:
. Burger, H R, 1992, Exploration Geophysics of the Shallow Subsurface, Prentice Hall, 489p.
. Cox, M J G, 1999, Static corrections for seismic reflection surveys, Geophysical reference series, No. 9, Society of Exploration Geophysicists, 531p.
. Keary, P, and Brooks, H, 1991, An introduction to geophysical exploration, 2nd edition, Blackwell.
. Reynolds, J M, 1997, An introduction to Applied and Environmental Geophysics, John Wiley & Sons, 796p.
. Sheriff, R E, and Geldart, L P, 1995, Exploration seismology, 2nd edition, Cambridge University Press
. Ward, S H, (Editor), 1990, Investigations in Geophysics: No. 5 Geotechnical and Environmental Geophysics, vol 1 - Review and Tutorial, Society of Exploration Geophysicists, 1050p.
. Yilmaz, O, 1987, Seismic data processing, Investigations in Geophysics: No. 2 Soc. Expl.Geophysicists, Tulsa.
. Yilmaz, O, 2001, Seismic data analysis, Investigations in Geophysics: No. 10 Soc. Expl. Geophysicists, Tulsa.

GRM capabilities are included in most shallow refraction software, such as:
GREMIX by Interpex, and statics software by Green Mountain, and WesternGeco.

APPENDIX 18

1994 DISPUTE OVER PATENT ON MINERAL SAND PROCESSING SETTLED IN 2003

Back in 1994, a dispute developed between Rio Tinto and RGC Mineral Sands over over a mineral sands processing patent and ownership issues.

In 2003, Iluka Resources Limited and Rio Tinto Iron and Titanium Inc agreed to end all litigation between the two companies with respect to the synthetic rutile enhancement process (SREP), HYBRID and RUTILE patents.

The dispute has run on so long it dates back to the days when CRA (since taken over by Rio) and Renison Goldfields Consolidated (since taken over by Iluka) were kicking around. CRA got the ball rolling in July 1994 when it issued an action in the Federal Court in Melbourne claiming that RGC was infringing a patent it held for the production of synthetic rutile, the main raw material in the world pigment industry.

RGC/Iluka produces synthetic rutile at its operations in Western Australia and at the time was introducing the SREP. CRA claimed that the process infringed a patent it took out for a process developed to overcome the fine-grained nature of the huge mineral sands deposits it found in the 1980s near Horsham in north- western Victoria. The sand grains in the Horsham deposits were about one-quarter the size of conventional beach sand minerals. That causes mineral separation and upgrading problems.

To create a product acceptable to the pigment producers, CRA tested at the pilot-plant level various flotation options and agglomeration of the fine particles - SREP by another name. As it turned out, CRA did not proceed with its $1 billion plans for a mineral sands business in north-western Victoria based on the Horsham deposit. The running on that score has since been taken up by others but it is based on ancient and buried beach strands of the coarse-grained sand with which the mineral sands industry is more used to dealing.

When Iluka Resources and Rio Tinto settled their long-running dispute over the mineral sands processing patent, industry commentators decided that Rio had emerged the victor, receiving a $US15 million ($26.7 million) cheque from Iluka to bring the 1994 dispute to an end. Both will continue to have a half-share in the patent. Under the terms of the agreement, the SREP patent will be jointly owned by the two companies and Rio Tinto will receive the payment of US$15 million from Iluka. Payment will occur in two tranches consisting of US$10 million (payable in December 2002) and US$5 million (payable in March 2003). This payment does not affect Iluka's 2002 full year profit target of A$104 to A$105 million.

Iluka, however, can take solace from the ending of the dispute, as it gives the company certainty over the use of the so-called synthetic rutile enhancement process (SREP). The Perth-based Iluka was also able to claim that the payment of the settlement in two tranches ($US10 million now and $US5 million in March) would not affect its 2002 full-year profit target, estimated to be within a tight range of $104 million to $105 million.

References

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APPENDIX 19

TEMPEST AIRBORNE EM

TEMPEST airborne EM is the culmination of many years research by CRCAMET, World Geoscience Corporation and CSIRO.

The TEMPEST system was developed to combine the capabilities of a high frequency near surface electromagnetic system, (eg SALTMAP) with those of a low frequency sine wave time domain system such as QUESTEM 450.

Airborne electromagnetic surveying is a well established practice in the mineral exploration industry and used extensively in relatively resistive terrains to prospect for base metal orebodies at depth. Conductive overburden has continually posed a problem for exploration in the use of airborne EM to detect conductors below surface. Developments in airborne EM have *either* improved the penetration of the regolith to map conductors at depth *or* focussed on the regolith itself to map near surface salinity.

The TEMPEST airborne EM system is the end product of research refining the acquisition, processing and modelling of EM data from other airborne EM systems. It provides the significant advantages of broad bandwidth and low noise.

TEMPEST airborne EM data are processed with routines designed to suppress sferic, powerline,VLF and coil motion noise and to stack the data. Stacked data are deconvolved using the high reference waveform, the “primary” field is removed and the ground response or “secondary” field data are transformed to B field response for a perfect 100% duty cycle square wave. The 1500 samples per half cycle are binned to 15 windows.

The raw windowed data are corrected for variation in transmitter loop (Tx) terrain clearance, Tx pitch and roll and transmitter-receiver (Tx-Rx) geometry variation. Both raw and corrected data are then available for applying modelling routines to assist interpretation.

The termination of the CRCAMET and the takeover of World Geoscience Corporation by a non-Australian company have resulted in full ownership of the Tempest technology by a foreign organisation which also owns and operates competing airborne EM technologies. It would seem that the technological advantage of an independent exploration system developed specifically for Australian conditions by CRCAMET will not be available to compete independently with other systems.

APPENDIX 20

INTEGRATED GIS FOR THE GEOSCIENCES - ENCOM TECHNOLOGY PTY LTD

Encom Discover is the desktop Geographical Information System (GIS) designed especially for the geosciences, providing the tools to effectively compile, visualise, analyse and map spatial geoscience data.

The software was developed in response to resource industry needs and requests. Geoscientists gather and analyse large quantities of spatial data such as geological mapping, geochemistry drilling, remote sensing and geophysics all of which is vital for effective exploration and mining.

Since its release in 1994, Encom Discover has become the GIS of choice for the exploration and mining industry. It is now in use by thousands of geoscientists across 80 countries and sold via an extensive network of authorised Encom partners.

Encom Discover is integrated with the MapInfo GIS from MapInfo Corporation in New York, USA. Discover is used by geologists, environmental scientists, cartographers, etc, to:

- Build geological datasets
- Compile drillhole cross-sections and plans
- Produce high-quality scaled maps, with geological symbols and linework
- Create analytical graphs with maintained spatial links
- Create, manipulate, contour and profile gridded surfaces
- Grid and filter point and line datasets

Encom Discover Mobile and Discover 3D provide corporate workflow solutions that service the field geologist and advanced desktop analyst.

Encom Discover Mobile - the companion to Encom Discover, provides data capture and visualisation tools for the geoscientist in a field environment. Running on a handheld computer, Discover Mobile is fully GPS-enabled and can be used for in-field data capture, sample logging, mapping and navigation. The data integrates directly with the desktop solution.

Discover 3D – an extension module for Encom Discover, provides powerful 3D visualisation of GIS, geophysics and other geoscience data, all tightly integrated with the standard 2D desktop GIS.

Key Aspects of this Innovation

The technology development responded directly to the demands of the exploration and mining industry, with early support from CRAE (now Rio Tinto) and others giving Discover "first mover" status. This lead provided Encom with a very competitive position in a market where the key players offered only expensive general GIS solutions.

Encom engineers its software in a team environment where geologists and geophysicists work closely with the sales and software engineering teams to implement client requests and drive new product ideas forward with advances in hardware and software technology. Encom employs a diverse group of geoscientists, professional software engineers and theoreticians to keep its software at the forefront of our industry. Continual development of new geoscience tools since 1994 has made Discover a very rich and practical environment in which to work.

The Australian Industry Research and Development Act provides a **125% tax deduction** for original research which eases the burden of competitive R&D activities. A recent change allowing unrealised tax losses to be crystallised in the year of the expenditure, benefits small companies that may have to carry the research cost for several years before realising a cash flow on new R&D.

Encom has also benefited from the **Export Market Development Grant** (EMDG) which has made it attractive to target overseas marketing initiatives such as major conferences and promotional tours. Even though the Internet has shrunk the world, Australia, is a long way from everywhere and the EMDG grant is an important boost for globalisation of domestic products. Our international competitors often obtain substantial foreign government incentives for marketing into Australia and other global markets and EMDG helps us compete on equal terms.

Recognition

2002: Encom Technology awarded MapInfo Corporation's (Troy, NY, USA) "Global Contribution Award" at its international partner conference in San Diego. The award recognised the vital role that the Encom Discover solution had played, and continues to play, in building MapInfo's global position in the resources sector.

1996: Encom Discover awarded the "Solution of the Year" prize at MapInfo Corporation's Asia-Pacific conference.

General: The best recognition is the vote of thousands of clients from 80 countries who continue to maintain and purchase new products at an increasing rate.

APPENDIX 21

WORLD CLASS 3-DIMENSIONAL DATA MANAGEMENT AND VISUALISATION FROM FRACTAL TECHNOLOGIES

Perth-based mining technology company Fractal Technologies has developed a niche in the competitive mining technology industry by bringing data from various systems into one consolidated interface. The company develops 3-dimensional data management and visualisation software for the geosciences.

The flagship product suite, FracSIS, combines a powerful object-oriented database specifically designed to store geological, geochemical, and geophysical data with an interactive 3D visualisation environment. FracSIS is designed for use by all mining professions (for example, geologists, engineers and geoscientists) and across a range of mining software packages including mine planning, modelling, exploration, GIS, data processing and database packages. The group also provides services in the areas of custom software development, training, database creation, and data validation.

Fractal Technologies Pty Ltd was borne in 2002 out of Fractal Graphics, a leading geoscientific consultancy established by in 1992. Fractal Graphics built a world-class reputation as leaders in the application of 3-dimensional visualisation technology as applied to the interpretation of complex geoscientific models.

Exports account for 65 per cent of Fractal Technologies' sales. Future directions for the group include increasing its global deployment of software and products, the development of a 3D GIS software package and the fast tracking of the world's first truly 4-dimensional spatial information system. The diversification into non-geoscientific markets is a potential growth area.

Recognition

GoldCorp Prize In 2000, GoldCorp offered a challenge to exploration experts anywhere in the world, offering US $500,000 in prize money to help find the next 6 million ounces of gold at its high-grade gold mine at Red Lake, Ontario, Canada. A valuable geological database as well as software to visualize and analyze the data was made available via the internet. More than 1,400 corporations, consultants, agencies and universities from 50 countries registered for the challenge. After qualifying for the finals Fractal Graphics re-visited and refined some of the models and interpretations to include animations and images taken directly from the three-dimensional model. An updated pdf document was also submitted. In the finals judging, Fractal Graphics was voted unanimously number 1.

Start Grant In 2003, Fractal Technologies was awarded the $0.9M AusIndustry research & development Start Grant to extend the FracSIS software to become the world's first comprehensive 3D GIS (Geographic Information System) software package. This new development will provide a quantum shift in the way three-dimensional data is managed, analysed and interpreted.

On 5 May 2005, Fractal Technologies was named as a finalist for the coveted 21st Century Achievement Award from the Computerworld Honors Program for its visionary use of information technology in the Environment Energy & Agriculture category. The nomination recognises Fractal's contributions to the global information technology revolution and its positive impact on society.

The winners will be announced at an awards gala at the National Building Museum in Washington, D.C. on June 6, 2005. Fractal Technologies was one of 160 laureates from over 300. Of these 160 laureates, Fractal Technologies is one of 48 finalists, in 10 categories, chosen by a panel of distinguished judges to attend the June 6 event. These awards are presented to individuals around the world who have made outstanding progress and whose visionary use of information technology produces and promotes positive social, economic and educational change," The finalists are recognized as true revolutionaries in their fields."

APPENDIX 22

CANADA'S "SUPER" FLOW-THROUGH PROGRAM

Flow-through shares facilitate the ability of exploration companies to raise equity capital, even in the absence of revenue producing assets. Companies are able to raise this money by "flowing-through" the tax deductions associated with their exploration expenses to their investors. In addition to receiving a tax deduction, investors stand to see their investment appreciate in value in the event of successful exploration activities.

Canada's Financial and Taxation Committee continues to build upon its successful partnerships and relationships that resulted in the introduction of the Investment Tax Credit for Exploration in Canada, known more generally as the "super" flow-through share program.

Since October 2000 over $900 million has been raised by flow-through financings. Before the upswing in most commodity prices in 2003 and 2004, which re-kindled investor interest, flow-through acted as a life-line for many junior mineral exploration companies, service sector firms and consultants.

In 2002, while commodity prices were still low, Canada narrowly surpassed Australia as the leading exploration jurisdiction in the world. This ended an eight year run by our biggest competitor, which does not have a flow-through program. **Canada convincingly beat Australia in 2003.**

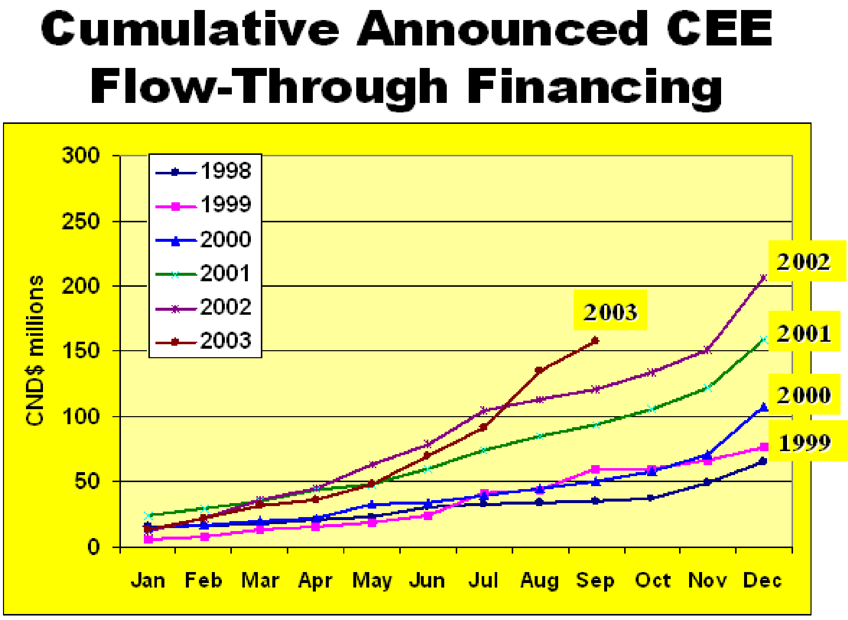
Previous lobby efforts in 2003 and 2004 resulted in two extensions to the "super" flow-through share program. The PDAC is now planning another lobby effort in 2005 (the last year of the program) to make the program permanent.

In 2000, the Canadian government introduced a 15% non-refundable tax credit over and above the existing 100% deduction for eligible exploration expenditures. This new program, known as **the 'super' flow-through program**, has been very successful in helping junior companies raise much needed funding for mineral exploration.

Here is some evidence.

The chart demonstrates the cumulative amounts of Canadian Exploration Expense, or CEE funding, raised in financings each year since 1998. The amounts included are all flow-through financings raised by companies (regular flow-through as well as enhanced).

As you can see, the impact of the enhanced program has been significant. Before its introduction, annual financings typically reached $70 million. The enhanced program has clearly boosted exploration funding in this country to a level now in excess of $200 million. The enhanced program is clearly working.



Data Source Gamah International

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