Australian Institute of Geoscientists

AIG NEWS

Quarterly Newsletter No 100 May 2010

Australian Geoscientists Condemn Government's "Mining Super Profits Tax" Proposal

PROFESSIONAL GEOSCIENTISTS employed in Australia's resource industries are shocked by the Commonwealth Government's proposal to impose a "super profits tax" that will have a profound negative impact on resources industries, the geoscience profession and the Australian community more generally.

"More than 85 percent of Australia's geoscientists, professional geologists and geophysicists work in the exploration, mining and energy resource industries", according to AIG Vice President, Mr Andrew Waltho.

AIG members are individuals employed in all sectors of industry, government, research and education throughout Australia. The Institute has no corporate members nor affiliations. "AIG members understand what this tax, as currently proposed, will do to Australia's resource industries, their employment and career development prospects, their families and communities in which they live" Mr Waltho said. "A loss of jobs in mining and exploration contributes directly to a three- to four-fold loss of jobs in literally every area of business activity throughout Australia".

"Our members are concerned about the manner in which this proposal has been formulated, proposed and justified by the Prime Minister Kevin Rudd and Treasurer Wayne Swan in particular" Mr Waltho said. "We do not accept that mining companies have been exploiting resources in a manner that has essentially 'short changed' the Australian community".

"Australian resource companies are, by and large, public companies owned by shareholders, either directly or through managed investments, including superannuation". "Company performance is directly linked to shareholder returns in the form of dividends and increased share values which are passed on to investors". "Companies pay company tax and their employees pay income tax, as do companies and workers that service or are employed indirectly through the multiplier effects of exploration and mining" Mr Waltho said.

"Using the term 'super-profit' to describe any return on investment exceeding the Commonwealth Bond interest rate is also misleading" Mr Waltho said. "Commonwealth bonds are a risk free investment while investors in mining projects must accept technical risks, country risks, including instability and inequity in taxation arrangements, and the risk of being unable to secure the skills needed for project development which necessitate achieving a higher rate of return". "If investors do not expect to achieve a return that accounts for these risks they will invest elsewhere rather than in mining". "Reduced investment will produce a very different industry to that which Australia has today".

"Taxes are a component in project costs which impact directly on the conversion of resources to reserves – the portion of a resource that can be mined economically" Mr Waltho said. "Australian geoscientists, working in conjunction with colleagues in mining engineering and mineral processing and beneficiation, are renowned for their resource engineering skills and capabilities". "Every mine in Australia strives to optimise the value of the resource on which it is built – this is fundamental to remaining competitive and staying in business". "If costs are increased, the proportion of the resource that can be mined economically, production quantities, revenue, mine life and returns to stakeholders all decrease". "The government's proposal will reduce the value and potential returns that could be generated by Australia's resources".

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Resource Exploration Rebate Falls Well Short

THE AUSTRALIAN INSTITUTE OF GEOSCIENTISTS (AIG) is a not for profit professional institute representing geoscientists employed in all sectors of industry, government, research and education throughout Australia. AIG members are individual geoscientists. The Institute does not have, and does not allow, corporate members.

"More than 85 percent of Australia's geoscientists, professional geologists and geophysicists work in the exploration, mining and energy resource industries", according to AIG Vice President, Mr Andrew Waltho, with the majority of AIG's members working in exploration roles.

"As a professional institute we are very concerned about the ramifications of changes to Australian taxation law for exploration activity in Australia" said Mr. Waltho. "Exploration activity already suffers from significant volatility, with increasingly exaggerated cycles of boom/bust affecting geoscientists' careers and their ability to find the next generation of orebodies".

AIG says whilst it welcomes the concept of a Resource Exploration Rebate (RER), as announced by the Commonwealth Government in its response to the Henry Review of the Australian taxation system, AIG believes that the RER falls well short of past Government promises and of what the Australian resource exploration sector needs.

Furthermore, there is a real risk that negative reactions stemming from the Government's proposed Resource Super Profit Tax will badly affect the level of exploration activity within Australia, and this negatively impact the jobs and careers of AIG members.

"The proposed RER will enable companies to carry forward a proportion of exploration expenditure to be offset against future income, which will be of benefit to companies actually developing new mining projects," AIG Vice President, Mr. Andrew Waltho, said today.

"However, it falls well short on what is needed to help reduce volatility in exploration investment, an issue that remains a serious impediment to greenfields resource discovery in Australia."

AIG's stance on the rebate follows its recent report "Market Failure in the Australian Mineral Exploration Industry" that assessed several mechanisms to promote greenfields exploration investment and address the systemic inability of current market financing to adequately fund the type of exploration necessary to sustain and grow Australia's resource sector into the future.

AIG, in conjunction with other resource industry groups, has consistently promoted the adoption of a Flow-Through-Shares (FTS) scheme as a model that could be applied effectively in Australia to address the market failure in exploration funding.

"The RER proposal appears to be based on a very shallow understanding of the exploration industry," Mr. Waltho said. "Companies are simplistically presumed to either make a discovery, that becomes a new mine, in which case the RER provides a benefit, or to fail – but this is not how the exploration sector works."

"Successful exploration requires geoscience professionals to interpret and test the natural systems responsible for mineral and energy accumulations, and these rank amongst the most complex natural systems on Earth," Mr. Waltho said.

"Major resource discoveries are characteristically made by companies that are the third, fourth or later holders of exploration tenure over the deposit, but rarely the first."

"Companies which fail to make a discovery, still tangibly contribute to future discoveries reporting and open access to past exploration information that exists in all Australian states. The RER proposal does not acknowledge this important contribution but more appropriate investment incentives do."

Mr. Waltho explained that "the return on capital from a project must compensate for all the related 'failed' exploration expenditure (at the scale of a company or of a sector), not simply the capital investment in the project of concern. This is a key issue that appears to be completely ignored in the Government's analysis."

The other important factor affecting exploration is the likely negative impact of the so-called Resources Super Profit Tax (RSPT). Mr. Waltho said, "the Resources Super Profit Tax removes much of the fundamental incentive for high risk investment in mineral exploration, making it more difficult for exploration companies to raise funds for greenfields exploration".

"This dramatic reduction in incentive for investment will not be compensated for by any exploration tax rebate scheme."

A particularly unfortunate aspect of all of this is that, purely unintentionally, the greatest negative impact is likely to be felt by Australia's base metal and gold industries, rather than the major bulk

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From Your President

WELL, A THIRD OF 2010 has passed, and in terms of economic outlook, what a difference today is from January; not to mention compared to this time last year! And while the Federal government celebrates the success of its economic stimulus package as the key to Australia's resurging economy, that fact that the improvement has been almost entirely on the back of demand in the mineral resources industry (in particular from China) seems to have quietly slipped by in the wake.

Or has it? When I first started penning this report I made the comment "With the implementation of the Carbon Emissions Trading Scheme having been extended to 2013 or beyond and expectations of surging demand in the resources sector, one can't help wondering how quickly the government's attention will swing towards a Resources Rent Tax as an opportunity to ease the burden on an over-stretched budget." Well, recent events have overtaken me and the answer to my own questions has turned out to be, "very quickly indeed".

Yet the rationale behind the planned "Super Tax", as it's now being called, is confusing. Certainly mining companies made profits through the boom. They also took a thorough beating during the recession – far more so than most other parts of the economy. The latter point notwithstanding, one can't help asking the question, why mining companies? After all, if the intention is to target "super profits", surely there are other companies in other sectors of the Australian economy that would qualify equally well, if not better? I can think of at least one sector which, over the past year or so, has made profits which could be described as verging on obscene.

The Super Tax also begs the question, what, or better still, who are the mining companies? Unsurprisingly, the bulk of the mining industry comprises companies listed on the Australian Stock Exchange. In other words the true owners of the mining companies – the true beneficiaries of the profits (and indeed the losses) generated by the mining companies – are, to a large extent, ordinary Australians, like you and me, who own shares in mining companies either directly, or indirectly through superannuation investments; hence it is the owners of the mining companies who would bear the brunt of the Super Tax, though reduced dividends and depressed share prices. Indeed, only two days after the government's announcement of the Super Tax and $14 billion dollars worth of value has been wiped from mining stock owners' share portfolios. I suppose it could be a complete coincidence that the slump in share prices happened immediately after the government's announcement of its Super Tax, but somehow I doubt it. Moreover I'm almost prepared to bet that the shareholders who are expressing their sentiments about the Super Tax by selling their mining industry shares and driving share prices down are the professional investors; which leaves mum and dad investors carrying the losses.

The two questions of, why the mining industry, and who will bear the burden of the Super Tax, would seem to beggar the government's slogan, 'A Fairer, Simpler, Tax System', which it has adopted to sell its tax reform package.

On the positive side, however, although the government has chosen not to fulfil its election promise of a flow through share scheme as a means of incentivizing mineral exploration, at least some tax incentives will be provided to exploration companies – albeit that at first glance it appears the current scheme will favour larger, well-established organisations.

It's early days yet, and we are still in the process of reviewing and understanding the implications to our members of the Henry Review. Nevertheless, we will continue to keep you informed as we develop our responses. We also encourage you to provide your feedback on the Henry Review so that we can incorporate your comments and views in our evaluation and in any submissions we make to government (please e-mail your comments to The Secretary, at www.aig.org.au).

I have previously written about the strong growth in membership numbers through the period of the mining boom, but it is pleasing to see that our growth rate remained high through the recession and continues to be strong in the early stages of emergence from the slump. Indeed, at the Council Meeting in April, over fifty new members were endorsed. This translates into a long-term growth rate of about 16% per year, which is very pleasing. Our rapid growth has, however, also had some downsides; in particular a dramatic increase in workloads faced by Council, State Branches and our Secretariat.

Our rapid growth rate also precipitated a review of the strategic direction of the Institute and in relation to this, Council met on the back of the IAGOD Giant Ore Deposits Down Under Symposium held in Adelaide in April. This face-to-face meeting was pretty-much a first for Council and it was good to finally meet the human beings behind the e-mails and teleconferences that are the standard means of managing Council affairs. Saturday morning commenced with an ordinary Council Meeting and this was followed by a strategic planning workshop that took up most of the rest of the weekend. The aims of the workshop were to (i) establish a vision for where the AIG would be in 2015, (ii) identify broad goals which would be consistent with that vision and with our Memorandum of Association, and (iii) identify actions that Council would undertake over the next five years to achieve our vision. The following four broad goals were identified (not in order of priority):

- Promoting interaction between geoscientists
- Promoting the good standing of geoscience and geoscientists
- Promoting the professionalism of geoscientists
- Representing geoscientists

For each goal a number of actions were defined and these will be the focus of our activities over the next five years. Some of the actions we will be implementing include:

- Enhancing our website as a key means of communication between Council and members and for better delivering services to members, for example the live-streaming of AIG

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commodity industries (iron ore, bauxite and coal) that the RSPT appears to primarily target.

"Our analysis is that Australia's base metal and gold industries will suffer major "collateral damage" if the Resources Super Tax goes ahead in its current form" Mr. Waltho said.

"The reasons for this include:

- Base metals, and to a lesser extent gold, are commodities with significantly more volatile pricing than iron ore or coal. Therefore, the return on investment in these industries is much more strongly tied to a "few good years". WA's nickel industry is a particularly good example of this dynamic. Historically these mines spend a significant part of their life as either unprofitable or very marginal operations.
- Unlike the bulk commodities (where the location of many of the significant, yet to be developed deposits are known), a significant and sustained investment of risk capital in exploration is required to sustain the base metals and gold sectors with the discovery of new world class deposits.
- As demonstrated in the report recently released by the AIG, the base metal and gold industries in Australia are already showing significant signs of decline in both production rates and truly economic resource inventory, despite recent high metal prices. They are clearly in a fragile state for the long term if resources are not replenished by exploration, illustrating the concept of an "exploration pipeline". The removal of incentive for exploration for these commodities will inevitably accelerate this decline."

"The Henry Review's comment that 'there are no strong grounds to believe that exploration generates unusually large positive spillovers that would justify a subsidy' are demonstrably ill-informed and based on a shallow understanding of the sector."

Mr. Waltho said, "detailed economic modeling has shown that effective investment incentives for exploration have significant economic benefits in the short term, many of which are delivered to regional and remote Australia, as well as the major contribution new deposits bring to the economy as a whole. It looks like these impacts are currently being overlooked in the resource-related tax debate and changes".

"Quite simply, the Government needs to implement effective measures to promote resource exploration investment in Australia. The exploration rebate, as proposed, appears unlikely to be able to achieve this critical outcome for Australia's resource sector."

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AIG's web site www.aig.org.au provides information regarding institute activities, including reports examining market failure affecting the ability of junior explorers to raise capital for exploration and the economic benefits of a flow through shares scheme for Australia. ▲▲

From Your President

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workshops, seminars and presentations to make them more widely available. In recognising the broadening technical base of our membership we are also considering enhancing the website to include technical specialist groups.

- Upgrading the presentation quality and broadening the technical content of the AIG News to better reflect our membership, as well as initiating an e-mail newsletter that would provide more frequent communications with members.
- Increasing advocacy activities to government on issues that affect our members. In this respect we plan to engage, through our Secretariat, someone who will provide dedicated and professional assistance in the development of policy initiatives, promoting the Institute and assisting with enquiries and requests from members on professional issues.
- Promoting the value and increasing local and international awareness of our RPGeo scheme and strengthening reciprocity with overseas professional organisations to facilitate the ready movement and employment of our members across international boundaries.
- Providing high quality training on aspects of geoscience, including targeted handbooks on practical issues such as health and safety, mapping, logging and drilling supervision.
- Boosting our support for education at both secondary and tertiary levels to ensure that geoscience remains an attractive career opportunity for students.

These are just some of the long list of actions that were identified at the workshop. Once finalised, the strategic plan will be loaded onto the website.

We are also currently undertaking a number of independent activities that also have strategic implications, including reviews of our Procedure Manual, Articles of Association, Memorandum of Association and Code of Ethics, to ensure consistency and relevance. Additionally, we are considering the pros and cons of replacing our current Rules with a modern Constitution, if this would be better suited to our future needs.

All these activities take time and it is pertinent to reiterate that, with the exception of our Secretariat, Council is run entirely by volunteer members, all of whom have permanent jobs and who contribute their time, energy and enthusiasm to the management of the AIG, for no personal gain. Indeed, our Rules prohibit us from employing anyone directly, hence our reliance on an external Secretariat. It is also apparent that to achieve our 2015 goals we will need to rely more on our Secretariat than we have in the past. Obviously this will have a cost impost on us. For this reason Council recently endorsed a small increase in annual membership fees of $20 on all membership categories. This increase will go towards engaging the dedicated person mentioned above to assist in policy and promotion issues. It will also cover the creeping running costs that we have experienced since the last membership fee increase more than four years ago, and it will cover the recent increase in fees to our Secretariat which, while it has taken on a significant additional workload since it was first engaged in 2001, has had little more than annual CIP increments since that time. While it is Council's approach has always been, and continues to be, to maintain membership fees as low as possible, we believe that the benefits to members from implementing the 2015 strategic plan will far outweigh the fee increase.

Hopefully you will have noticed that over the past three months Council has been increasingly active through public submissions and media releases on issues such as the emissions trading scheme, flow though shares scheme and economic demonstrated resources. We have also been active in presenting updates of our ongoing and highly successful employment survey, the results of which have drawn considerable public attention and have been quoted in submissions to government by both AIG and kindred organisations. For current developments in any of these areas, please see the "Policy and Advocacy" section of our website.

While on the subject of the website, we are increasing our efforts to keep the information on our site up-to-date and I encourage you to visit the site regularly to stay informed of the most recent AIG developments. I also encourage you to log into the members' area, where you will have access to additional information that is unavailable to general site users (to access this part of the website, use the same login and password as you use to pay your on-line membership subscriptions). Needless to say, if you experience problems, please contact the Secretariat (www.aig.org.au).

Martin Robinson

CSIRO Focus On Drilling Research

THE MARCH/APRIL EDITION of CSIRO Earth Science and Resource Engineering's (CESRE) Earthmatters magazine details how CSIRO researchers are working to improve understanding of drilling mechanics and dynamics.

"Our research impacts the most critical component of resource exploration and production,"says CESRE Chief, Dr Mike McWilliams. "Drilling is a major expense in the resources industry. Our scientists and engineers are comprehensively redesigning and improving drilling equipment and techniques precisely when global commodity needs are on the upswing. This is good news for Australian resource companies."

Stories in this 'smarter drilling' edition include:

Keep on drilling: Science and industry are collaborating to re-design the future of drilling.

A meeting of minds: How the recent merger between CSIRO Exploration & Mining and CSIRO Petroleum Resources to form CESRE now offers a wealth of new collaboration and opportunity for Australia.

"Our research impacts the most critical component of resource exploration and production." CESRE Chief, Dr Mike McWilliams

The upside of deep stress: A CSIRO research team has developed a new method for estimating in-situ rock stress in deep holes that will aid geothermal energy extraction. A good understanding of the stress regime is essential to help determine the position and shape of the fracture 'cloud' created by hydraulic fracturing in hot rock.

Moving in the right direction: CSIRO scientists have invented and patented a new drilling method and assembly that improves operators' abilities to avoid deviation from the drilling line.

Leading a drive to excellence: CESRE's new Science Leader, Dr Michael Glinsky, discusses how Australia's minerals and petroleum science is the "best in the world" and his role in helping to guide that science.

Face-to-face with the drillers: Listening to drillers and seeking their input on all issues of their profession is helping CSIRO scientists design smarter and safer systems.

Exploration's future is deep: A new Cooperative Research Centre (CRC) has been launched to tackle the growing technical and economic challenges of deep exploration. Much of CESRE's geoscience capability will be deployed through the Deep Exploration Technologies CRC.

At the cutting edge: Developing an improved understanding of exactly what happens at the bit-rock interface. ▲▲

WA Branch Report

THE WA BRANCH HAD a very busy and successful 2009 under the guidance of Gerry Fahey as Chairperson and the committee: Dale Annison, Jonathan Bell, Chris Cairns, Ben Hames, Marcus Harris, Bill Hewitt, Louis Hissink, Jill Irvin, Graham Jeffress, Sandy Moyle, Michele Pigott, Rick Rogerson, Ian Ruddock, Somealy Sheppard, Wayne Spilsbury, Steve Sugden, Roger Thompson, Jocelyn Thomson, Suzy Urbaniak. There have been several retirements from the committee due to work changes, ill health or retirement.

MEGWA

The monthly MEGWA talks have continued to be popular and we started the year with two excellent talks (Steve Beresford and Nick Hayward) being videoed and placed on the AIG web.

One Day Workshops/Seminars

With the industry on a down swing a one day workshop Surviving the Downturn was held in March for people un- or under employed. This workshop was heavily subsidized by the WA Branch and a first, it was also videoed and placed on the AIG Website.

In June in conjunction with ioGlobal, 128 delegates attended a one day seminar Maximising the Value of Geochemical Data.

In August we held the 3rd in a series of government legislation updates – Cut the Red Tape on Exploration Approvals Processes in WA. 127 delegates attended this one day seminar.

The Mineral Asset Reporting and Valuation Seminar, attended by 171 delegates was held in October. This was by far the largest attendance at a one day seminar since the WA Branch started these events. This event was also videoed and placed on the web.

Gemcom supported the industry and the AIG by offering their 2 day Surpac Foundation Course at a very heavily discounted price for un-employed AIG Members. This course was run twice.

Climate Change Debate

By far the biggest surprise for the Committee was the overwhelming success of our free evening debate on Climate Change between Ian Plimer and Gary Warden, mediated by Thomas Murrell. We were hoping for about 100 people but were overwhelmed with approx 660 attendees. This debate was videoed and placed on the web for eastern state's members to view.

Student Sponsorship

Once again the WA Branch sponsored the:

Kent Street School Geology Course excursions and Top Student awards; AIG Bursary Awards; Student Career evening; Curtin Medal; AIG/Curtin Medal board with a list of the winners since this award was instigated.; Years 11/12 Australian Student Mineral Venture (ASMV); Curtin University geology student body; UWA Geology student body; and 3 university students to attend Gemcom Course

Xmas Cruise

Once again this very popular event was fully attended.

The WA Committee thanks all members, non members and the various companies that sponsored and/or participated in these functions, for their continuing support. ▲▲

Australian Geoscientists Condemn Government's "Mining Super Profits"Tax Proposal

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"AIG members are not intractably opposed to a review of taxation arrangements for the mining industry, but insist that proposals must be developed in a considered manner, following a consultative process to ensure that the requirements of both the industry and the Australian community are satisfied".

"We are, however, opposed to the current proposal that clearly fails on this front" Mr Waltho said. "The Institute believes that the current proposal is seriously flawed and call on the Prime Minister and Treasurer to work with companies in a consultative, transparent and constructive manner to address the proposal's shortcomings". ▲▲

Upcoming Conferences and Events

CIM 2010 Vancouver Conference and Exhibition
When: Sunday, May 09, 2010 - Wednesday, May 12, 2010
08:00AM - 05:00PM (America - Vancouver)
Where: Vancouver Canada

Brownfields Exploration Short Course
When: Monday, June 07, 2010 - Friday, June 18, 2010
08:00AM - 05:00PM (Australia - Hobart)
Where: University of Tasmania

Australian Earth Sciences Convention 2010
When: Sunday, July 04, 2010 - Thursday, July 08, 2010
08:00AM - 05:00PM (Australia - Sydney)
Where: Canberra ACT

5th International Archean Symposium - Evolving Early Earth
When: Sunday, September 05, 2010 - Thursday, September 09, 2010
08:00AM - 05:00PM (Australia - Perth)
Where: Burswood Entertainment Complex Perth, Western Australia

FOSS4G (Free & Open Source Software for Geospatial)
When: Monday, September 06, 2010 - Thursday, September 09, 2010
08:00AM - 05:00PM (Europe - Madrid)
Where: Barcelona Spain

Mines and Wines 2010 (AIG Event)
When: Thursday, September 23, 2010 - Friday, September 24, 2010
08:00AM - 05:00PM (Australia - Sydney)
Where: Mudgee NSW

Geo-Computing 2010 Uses and Abuses (AIG Event)
When: Wednesday, September 29, 2010 - Friday, October 01, 2010
08:30AM - 05:30PM (Australia - Brisbane)
Where: Rydges Hotel Southbank, Brisbane

Bowen Basin Symposium 2010
When: Wednesday, October 06, 2010 - Friday, October 08, 2010
08:00AM - 05:00PM (Australia - Brisbane)
Where: Mackay Qld

34th International Geological Congress (AIG Event)
When: Thursday, August 02, 2012 - Friday, August 10, 2012
08:00AM - 05:00PM (Australia - Brisbane)
Where: Brisbane Qld

Volcanic Carbon Dioxide: Guesswork, Politics and Intemperate Volcanoes

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Consulting Geologist

Acknowledgment: Many thanks to Liberata Luciani for assisting me with the streamlining and editing of this article.

Abstract

A brief survey of the literature concerning volcanogenic carbon dioxide emission finds that estimates of subaerial emission totals fail to account for the diversity of volcanic emissions and are unprepared for individual outliers that dominate known volcanic emissions. Deepening the apparent mystery of total volcanogenic CO_2 emission, there is no magic fingerprint with which to identify industrially produced CO_2 as volcanic CO_2 is isotopically identical. Molar ratios of O_2 consumed to CO_2 produced are, moreover, of little use due to the abundance of processes (eg. weathering, corrosion, etc) other than volcanic CO_2 emission and fossil fuel consumption that are, to date, unquantified. Furthermore, the discovery of a surprising number of submarine volcanoes highlights the underestimation of global volcanism and provides a loose basis for an estimate that may partly explain ocean acidification and rising atmospheric carbon dioxide levels observed last century, as well as shedding much needed light on intensified polar spring melts. Based on this brief literature survey, we may conclude that volcanic CO_2 emissions are much higher than previously estimated, and as volcanic CO_2 is isotopically identical to industrially emitted CO_2, we cannot glibly assume that the increase of atmospheric CO_2 is exclusively anthropogenic.

1.0 Introduction: How Volcanoes make the Carbon Budget Holier than Thou

If we neglect to ask how the greenhouse effect of various gases is quantified in terms of real, measurable thermodynamic properties, the idea of anthropogenic global warming may well survive long enough for us to ask how the carbon budget establishes that observed increases in CO_2 (Keeling et al., 2005) could not be caused by anything other than human activity. Plimer (2001), Wishart (2009), and Plimer (2009) point out that an enormous and unmeasured amount of CO_2 degases from volcanoes. This is not such a silly idea given that the source chemistry for lavas contains a surprising amount of carbon dioxide. Along with H_2O, CO_2 is one of the lightest volatiles (materials of relatively low melting point), found in the mantle (Wilson, 1989). The fluid nature of the aesthenosphere, or upper mantle of the earth, ensures that lighter volatiles are fractionated, buoyed towards the surface, and either extruded or outgassed into the atmosphere via volcanoes and faults. The "solid earth", a term popular amongst climatologists, is a deceptive misnomer as the aesthenosphere is a deeply convecting fluid upon which flexible sheets of crust (i.e. plates) float. This deeply convecting fluid tears these delicate plates apart at rift zones and crushes them together like the bonnet of a wrecked car at convergence zones. Mountains rise out of fold belts resulting from the crumpling of plates, and where differences in plate buoyancy allow, one plate rides over another, forcing the other plate to follow the convection current into the aesthenosphere. Furthermore, this liquid aesthenosphere, which continues to create new crust at rifting zones such as the mid oceanic ridges, melts down subducting crust as the residue of this crust is drawn deeper into the mantle. While volatiles trapped in the remaining crustal residue are ultimately assimilated into the mantle, lighter volatiles from the crustal melt are fractionated and float up towards the surface to feed plate margin volcanoes. Volatiles, such as CO_2, are more prone to outgassing at the surface via tectonic and volcanic activity because of the fluid nature of the earth.

1.1 The Importance of CO_2 in Volcanic Emissions

The importance of juvenile (erupted and passively emitted) volcanic CO_2 is due to the fact that carbon, and particularly carbon dioxide has a strong presence in mantle fluids, so much so that it is a more abundant volcanic gas than SO_2 (Wilson, p. 181; Perfit et al., 1980). According to Symonds et al. (1994) CO_2 is the second most abundantly emitted volcanic gas next to steam. Although you might imagine that there is no air in the mantle, the chemical conditions favour oxidation, and shortages of oxygen ions are rare enough to ensure a strong presence of CO_2 (Schneider & Eggler, 1986). Oxidation of subducted carbon sources such as kerogen, coal, petroleum, oil shales, carbonaceous shales, carbonates, etc. into CO_2 and H_2O makes volcanic CO_2 quite variable in back arc and continental margin volcanoes, where these volatile gases can be surprisingly abundant (eg. Vulcano & Mount Etna). Subduction isn't the only way CO_2 enters magma. At continental rift zones, where an entire continent is being pulled apart by divergent mantle convection, magma rising to fill the rift is enriched in CO_2 from deep mantle sources (Wilson, 1989, p. 333). Oldoinyo Lengai is an example of a continental rift zone volcano, which has above average CO_2 outgassing at 2.64 megatons of CO_2 or 720 KtC per annum (Koepenick et al., 1996).

If volcanoes produce more CO_2 than industry when they are not erupting, then variations in volcanic activity may go a long way towards explaining the present rise in CO_2.

1.2 The Location of CO_2 Monitoring Station in regions enriched by volcanic CO_2

Volcanic CO_2 emission raises some serious doubts concerning the anthropogenic origins of the rising atmospheric CO_2 trend. In fact, the location of key CO_2 measuring stations (Keeling et al., 2005; Monroe, 2007) in the vicinity of volcanoes and other CO_2 sources may well result in the measurement of magmatic CO_2 rather than a representative sample of the Troposphere. For example, Cape Kumukahi is located in a volcanically active province in Eastern Hawaii, while Mauna Loa Observatory is on Mauna Loa, an active volcano - both observatories within 50km of the highly active Kilauea and its permanent 3.2 $MtCO_2pa$ plume. Samoa is within 50 km of the active volcanoes Savai'i and/or Upolo, while Kermandec Island observatory is located within 10 km of the active Raoul Island volcano.

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From The Editor

THIS IS THE 100TH ISSUE of AIG News and were it not for the proposed resource rent, or super profits tax, by the commonwealth government via the Henry Taxation Report, I would have scoured the archives for past articles to publish in this issue; this is not to be, so this issue of AIG News focuses on the ramifications of the Super Profits Tax, as well as further refutation of the climate change. But first the impending economic disaster proposed by government.

Put simply, the ideas of a resource rent tax were originally proposed by David Ricardo and others, and a super profits tax by Karl Marx in his book Das Kapital, two centuries ago. Resource rent is an idea that someone, somewhere, is receiving unearned income while a super profit is deemed to be one greater than the social average, and in Australia's case, benchmarked at the Commonwealth Bond rate currently set at 6%. Both ideas are based on economic fallacies.

Resource rent, or more correctly economic rent, "is a differential that is determined by the appearance of "no-rent" land, or what we today would call marginal land, land that it just pays to bring into production. According to Ricardo a community farms the most fertile land first. Eventually the pressure of population growth forces the cultivation of "no-rent" land. This development now means that the most fertile land now earns rent. According to Ricardo if land A (the most fertile land) produces 100 units and land B (the second most fertile land) produces 90 units then land A now receives 10 units in rent. When land C is brought into cultivation at 80 units land A now receives 20 units in rent and land B receives 10 units1. (David Ricardo, The Principles of Political Economy and Taxation, Penguin Books, 1971, chapter II.)"

The idea was dealt a fatal blow in 1831 by the Rev. Richard Jones who noted that economic rent is due to the productivity of land and not to any differential.

And then the idea of super profits deemed to be greater than an arbitrary social average have to be balanced by the existence of super losses, or those greater than the average social losses, and which logically leads to a theoretical nonsense. If super profits ought to be taxed, then to balance the books, super losses, whose existence depends entirely on the existence of their profitable opposites, ought to be also compensated. Karl Marx never understood economics, nor, it seems, his modern day successors.

This issue of AIG News pub lishes AIG's position statements on the Super Profits tax and the Exploration Rebate Scheme, as well as a thought provoking article on volcanic caarbon dioxide.

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Observatories located within active volcanic provinces are not the only problem. There is also the problem of pressure systems carrying volcanic plumes several hundred kilometers to station locations. For example, the observatory in New Zealand, located somewhere along the 41st parallel, is within 250 km of Tanaki and the entire North Island active volcanic province. Low pressure system centres approaching and high pressure system centres departing the Cook Strait will displace volcanic plumes from the North island to the South Island.

Another class of problem for monitoring stations plagues "Christmas Island", which is actually Kiribati Island (02º00'N, 157º20'W) where the Clipperton Fracture Zone (Taylor, 2006) crosses the Christmas Ridge and is nowhere near Christmas Island (10º29'S, 105º38'E; located on the other side of Australia, 10,000 km due west of Kiribati). Christmas Ridge is formed in a concentration of Pacific Seamounts. Extraordinary numbers of seamounts are volcanically active (Hillier & Watts, 2007). Moreover, active fracture zones also offer a preferred escape route for magmatic CO_2, as this CO_2 also finds its way into aquifers (eg. Giggenbach et al., 1991), which can be cut by fracture zones that consequently provide a path to the surface (Morner & Etiope, 2002). This may raise doubts concerning measurements taken at the La Jolla observatory, which is located near the focal point of a radial fault zone extending seaward from the San Andreas Fault (see imagery sourced to SIO, NOAA, USN, NGA, & GEBCO by Europa Technologies & Inegi, for Google Earth).

Amundsen Scott South Pole Station appears to be well separated by 1300 km from the volcanic lineation extending along Antarctica's Pacific Coast (From the Ross Shelf to the Antarctic Peninsula), However, Antarctic volcanoes are not nearly as well mapped as those in more populated regions, such as Japan. In any case, the strong circumpolar winds that delay mixing will inevitably concentrate Antarctica's volcanic CO_2 emissions over the Antarctic continent, including Amundsen Station. The same potential problem exists with the observatory at Alert in Northern Canada, because it is located inside the circumpolar wind zone along with the Arctic Rift and thousands of venting seamounts along key parts of the Northwest Passage.

That leaves us with Point Barrow, arguably the only CO_2 monitoring station whose CO_2 measurements are unlikely to be influenced by magmatic gas plumes. However, the Canada Basin, extending seaward from Point Barrow, is also referred to as "the Hidden Ocean" because of poor access, which consequently leaves us with very little information about the sea floor in this region. The high probability of active seamounts in the vicinity of Point Barrow has not been ruled out, and in view of the fact that the other observatories probably experience significant skew due to magmatic CO_2, it would not be unreasonable to remain skeptical until this possibility has been ruled out.

This question of volcanic skew in CO_2 measurements has been raised a number of times, in addition to other more serious allegations (Bacastow, 1981; Jaworowski et al., 1992; Segalstad, 1996).

2.0 Calculated Estimates: Glorified Guesswork

Gerlach (1991) estimates volcanic CO_2 emissions total 55 MtCpa globally and evenly distributed between subaerial and submarine volcanism. Kerrick (2001) takes a grand total of 19 subaerial volcanoes, which on p. 568 is described as only 10% of "more than 100 subaerial volcanoes". It is interesting to observe that Kerrick (2001) leaves out some of the more notable volcanoes (eg. Tambora, Krakatoa, Mauna Loa, Pinatubo, El Chichon, Katmai, Vesuvius, Agung, Toba, etc.). Nevertheless, despite these omissions Kerrick calculates 2.0-2.5 x 1012 mol of annual CO_2 emissions from all subaerial volcanoes, which is understated on the assumption that the sample is from the most active volcanic demographic. This is in spite of the fact that eight of the world's ten most active volcanoes are omitted from Kerrick's study (Klyuchevskoy Karymsky, Shishaldin, Colima, Soufriere Hills, Pacaya, Santa Maria, Guagua Pichincha, & Mount Mayon).

At 44.01g/mol, 2.0-2.5 x 1012 mol of CO_2 amounts to a total of 24-30 MtCpa - less than 0.05% of total industrial emissions (7.8 GtCpa according to IPCC, 2007). My main criticism of Kerrick's guess is that it putatively covers only 10% of a highly variable phenomenon on land, and with the cursory dismissal of mid oceanic ridge emissions, ignores all other forms of submarine volcanism altogether. If we take the Smithsonian Institute's list of more than 1000 potentially active subaerial volcanoes worldwide, Kerrick's 10% is reduced to 1-3%.

According to Batiza (1982), Pacific mid-plate seamounts number between 22,000 and 55,000, of which 2,000 are active volcanoes. However, none of the more than 2,000 active submarine volcanoes have been discussed in Kerrick (2001). Furthermore, Kerrick (2001) justifies the omission of mid oceanic ridge emissions by claiming that mid oceanic ridges discharge less CO_2 than is consumed by mid oceanic ridge hydrothermal carbonate systems. In point of fact, CO_2 escapes carbonate formation in these hydrothermal vent systems in such quantities that, under special conditions, it accumulates in submarine lakes of liquid CO_2 (Sakai, 1990; Lupton et al., 2006; Inagaki et al., 2006). Although these lakes are prevented from escaping directly to the surface or into solution in the ocean, there is nothing to prevent superheated CO_2 that fails to condense from dissolving into the seawater or otherwise making its way to the surface. It is a fact that a significant amount of mid oceanic ridge emissions are not sequestered by hydrothermal processes; a fact which is neglected by Kerrick (2001), who contends that mid oceanic ridges may be a net sink for CO_2. This may well sound reasonable except for the rather small detail that seawater in the vicinity of hydrothermal vent systems is saturated with CO_2 (Sakai, 1990) and as seawater elsewhere is not saturated with CO_2, it stands to reason that this saturation is sourced to the hydrothermal vent system. If the vent system consumed more CO_2 than it emitted, the seawater in the vicinity of hydrothermal vent systems would be CO_2 depleted.

Morner & Etiope (2002) published a somewhat more representative estimate of subaerial volcanogenic CO_2 output based on a more comprehensive selection and found as a bare minimum that subaerial volcanogenic CO_2 emission is on the order of 163MtCpa. Morner & Etiope (2002) also provide a much better explanation of how CO_2 is cycled through the mantle and the lithosphere. However, this still does not account for active volcanic emissions and remains vulnerable to eruptive variability. Based on data reproduced in Shinohara (2008), there were on average about five subaerial volcanic eruptions every year producing an average of 300KtSpa (kilotons of sulphur per year) from 1979-1989. Shinohara (2008) also presents molar ratios of CO_2, SO2, & H2S from which, via the same academic daring as Gerlach (1991) and Kerrick (2001), we might derive an average ratio of 3.673 mol carbon for every mol of sulphur in gaseous volcanic emissions. That would loosely translate to 1.376KtC for every 1.000KtS. This gives us a figure of around 2MtCpa for minor volcanic activity based on SO_2 emission events reported in Shinohara (2008). However, applying the same statistical assumption to some of the more notable eruptions of recent history, contrasted with one or two slightly older examples, gives us the following estimates:

Year	Volcano	Mean Sulphurous Output	Source	Est. Carbon output during year(s) of eruption
1883AD	Krakatoa	38 $MtSO_2pa$	Shinohara (2008)	26.14 MtCpa
1815AD	Tambora	70 $MtSO_2pa$	Shinohara (2008)	48.16 MtCpa
1783AD	Laki	130 $MtSO_2pa$	Shinohara (2008)	89.44 MtCpa
1600AD	Huaynaputina	48 $MtSO_2pa$	Shinohara (2008)	33.02 MtCpa
1452AD	Kuwae	150 MtH_2SO_4pa	Witter & Self (2007)	67.40 MtCpa
934AD	Eldja	110 $MtSO_2$	Shinohara (2008)	75.68 MtCpa
1645BC	Minoa	125 $MtSO_2pa$	Shinohara (2008)	86.00 MtCpa
circa 71,000BP	Toba	1100 MtH_2SO_4pa	Zielenski et al. (1996)	494.24 MtCpa

Notice how all but one of the individual annual volcanogenic carbon outputs, estimated above, dwarf the global subaerial volcanogenic carbon outputs estimated by both Gerlach (1991) & Kerrick (2001). Even the Morner & Etiope (2002) subaerial estimate (163 MtCpa) is shaken by most of these figures and dwarfed by one. If this is not enough evidence of just how unreliable volcanic emission estimates can be, let us take a closer look at my 89 MtCpa estimate for the 1783AD Laki eruption. Consider the difference it makes if, instead of using the average ratio by weight for carbon and sulphur emissions I derived from Shinohara (2008), we take the ratio we use for the Laki estimate from more direct observations. Agustsdottir & Brantley (1994) studied emissions from Grimsvotn, from which Laki extends as a fissure, and found that Grimsvotn outgasses 53 KtCpa for 5.3 KtSpa. In other words, the weight of carbon emitted at Grimsvotn is ten times that of the sulphur emitted there. This would extend to Laki, which shares the same source, and is described by Agustsdottir & Brantley (1994) as a fairly stable ratio. By this ratio, Laki's 130 Mt of sulphur dioxide in 1783AD translates to an emission of 650 MtCpa that year. This demonstrates just how much uncertainty is involved when trying to audit the volcanic contribution to the "carbon budget".

As you can see, volcanic systems are diverse and unpredictable. They cannot be statistically second-guessed for the same reason that lottery

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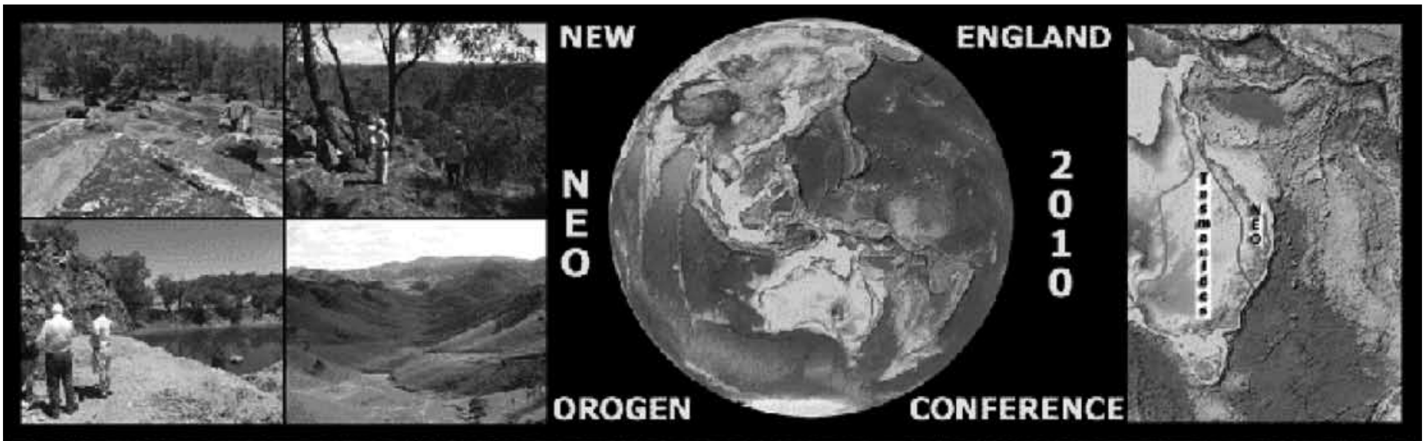

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numbers cannot be statistically second-guessed. This in itself raises serious doubt concerning the reliability of volcanic carbon dioxide emission estimates. This is especially problematic when significant elements of the estimates, such as passive submarine volcanic emission, all active volcanic emission, and at least 96% of passive subaerial emissions, are based on statistical assumptions rather than on any actual measurement.

3.0 Abusing Doctor Suess: Pulling the Cat out of the Hat

So far, the evidence presents the rather tantalizing implication that volcanogenic CO_2 emission is a significant if not dominant contributor to atmospheric CO_2 levels. The next logical step for those trying to prove that the CO_2 rise is anthropogenic is to find a signature to fingerprint anthropogenic CO_2 as separate from all other sources of CO_2. The research of one Harmon Craig, first submitted for publication on ISO:1953-Apr-20, found that ^{13}C & ^{14}C are enriched in carbonates. Harmon Craig discusses the carbon dating errors that can be introduced by natural isotopic fractionation, along with other processes (Craig, 1954). While Rankama (1954), suggests that ^{13}C depletion is characteristic of biogenic sources, Craig (1954) goes so far as to suggest the use of 13C as a tracer for ^{14}C. This becomes the subject of research by Hans E. Suess into the contamination of ^{14}C dates by variations in normal atmospheric ^{14}C, which quantified the effect of processes discussed by Craig (1954). Part of Suess' explanation of his own results was seized upon as a way to fingerprint fossil fuel CO_2 because fossil fuels, being too old to contain measurable amounts of this cosmogenic isotope, will deplete atmospheric concentrations of ^{14}C when burned. In Cleveland & Morris (2006, p. 427) Hans Suess and the Suess Effect, used to account for contamination of radiocarbon dates by various phenomena, are given the following entries:

Suess, Hans 1909-1993, U.S Chemist who developed an improved method of carbon-14 dating and used it to document that the burning of fossil fuels had a profound influence on the earth's stocks and flows of carbon. (Fossil fuels are so ancient that they contain no C-14.)

Suess Effect *Climate Change*. a relative change in the ratio of C-14/C or C- 13/C for a carbon pool reservoir; this indicates the addition of fossil fuel CO_2 to the atmosphere.

However, this is only half of the explanation offered by Suess. In Suess (1955, p. 415) we read:

The decrease can be attributed to the introduction of a certain amount of C^{14}-free CO_2 into the atmosphere by artificial coal and oil combustion and to the rate of isotopic exchange between atmospheric CO_2 and the bicarbonate dissolved in the oceans.

As you can see, Suess himself puts the Suess Effect down to more than just fossil fuel consumption. Yet, the exclusion of other processes, such as isotopic exchange and volcanic input, are hardly surprising given the assumption that fossil fuels are the only cause of ^{14}C depletion. This assumption has quite some history in the literature. According to Tans et al (1979):

THE dilution of the atmospheric $^{14}CO_2$ concentration by large amounts of fossil-fuel derived CO_2 which do not contain any ^{14}C is commonly called the Suess effect. Its magnitude can be calculated with the same geochemical models as the global carbon cycle that also predict the future rise of atmospheric CO_2 to be caused by the combustion of fossil fuels.

Keeling (1979) concurs with a bizarre emphasis on "formulating models rather than surveying and interpreting data". This reflects the rather general attitude, amongst anthropogenic global warming proponents, that the Suess Effect fingerprints the rising atmospheric carbon dioxide as the exclusive product of fossil fuel combustion. Does such a narrow interpretation concur with the original author's idea? Suess (1955), who first proposes the idea that fossil fuels may contaminate the carbon isotope reservoir with adverse effects on carbon dating methods, estimates that fossil fuel CO_2 accounted for less than 1% of carbon isotope reservoir contamination.

The smaller effects noted in the other three trees indicate relatively large local variations of CO_2 in the atmosphere derived from industrial coal combustion, and that the worldwide contamination of the earth's atmosphere with artificial CO_2 probably amounts to less than 1 percent.

While, superficially, this may be interpreted as either 1% of contamination or 1% of total atmospheric carbon, the apparently "smaller effects" of "large local variations" in atmospheric CO_2 due to industry shows that something other than industrial CO_2 accounts for the bulk of the effect. Suess' next statement further clarifies this point:

Hence the rate by which this CO_2 exchanges and is absorbed by the oceans must be greater than previously assumed.

It does not necessarily follow from a 1% contamination of total atmospheric carbon that other processes are at work. Only if industrial CO_2 provides 1% of the 14C contamination does it necessarily follow that, hence, another process must play a greater role. In other words,

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Suess acknowledged that other sources of contamination played a much larger role (Suess, 1955, p.416), but authors, such as Fergussen (1958), Keeling (1979), Tans (1979), Cleveland & Morris (2006), ignored this rather important point. Moreover, insistent on correcting the "misleading" arguments of Durkin (2007) in their 2007 glossy handout, Climate Change Controversies: a simple guide, the Royal Society gets its name plastered to this evident faux pas:

In contrast to this natural process, we know that the recent steep increase in the level of carbon dioxide – some 30 per cent in the last 100 years – is not the result of natural factors. This is because, by chemical analysis, we can tell that the majority of this carbon dioxide has come from the burning of fossil fuels.

Aside from the fact that isotopic analysis is not chemical analysis, I would go so far as to suggest that the same basin sediment kerogen (the carbon source for oil) in addition, no doubt, to some petroleum reservoirs have been subducted and are a major source for volcanic CO_2 emissions at continental margins. Due to the fact that the subduction zone is where crustal material enters the mantle, subducted carbon reservoirs would represent the youngest magmatic source of CO_2. Given the confirmed presence of carbon and particularly CO_2 enriched fluids in magma and lava (Wilson, 1989), one may well ask if it would not be so irrational to suppose that volcanogenic carbon released at continental margins (closest to the subduction zone) is very old; far too old in fact to contain any measurable amount of 14C. Moreover, mantle carbon and CO_2 is vastly older still, as only longer lived cosmogenic isotopes such as 10Be can be used to confirm the speed of mantle convection. In fact, Clark & Fritz (1997) document that there is no volcanic emission of ^{14}C.

The misuse of the *Suess Effect* as a fossil fuel fingerprint instead of an empirical standard for the correction of carbon dating contamination, lead to an initially idiosyncratic expansion of this concept by Keeling (1979), who sought to include 13C depletion of vegetation and its effect on the atmosphere. The atmosphere is enriched in $^{13}CO_2$ by the process of photosynthesis, which favours the assimilation of 12C into plant tissue during growth (Furquhar et al., 1989). This is used to differentiate between terrestrial and oceanic CO_2 sources (Keeling et al., 2005), and the concept, proposed by Craig (1954), is actually older than Suess' original research. Moreover, plant based fossil fuel derivatives are therefore considered to be ^{13}C depleted. Following this line of logic, fossil fuel emissions, being derived from plants, should be $^{13}CO_2$ depleted as well. However, when the Keeling (1979) article expanded its internal definition of the *Suess Effect* to include this observation, it was once again to the exclusion of volcanic influence.

In point of fact, magmatic carbon is, for the most part, ^{13}C depleted. This is solidly confirmed by numerous studies of deep mantle rocks (Deines et al., 1987; Pineau & Mathez, 1990; Cartigny et al., 1997; Zheng et al., 1998; Puustinen & Karhu, 1999; Ishikawa & Marayuma, 2001; Schultz et al., 2004; Cartigny et al., 2009; Statchel & Harris, 2009). Moreover, ^{13}C depletion of volcanic emissions is so well known that Korte and Kozur (2010) explore volcanism, amongst other possible causes, in search of an explanation for atmospheric depletion of ^{13}C across the Permian-Triassic boundary. Although many significant carbonates are not ^{13}C depleted, they are eventually subducted along with organic carbon sources depleted in ^{13}C. Nevertheless, the emissions of continental margin and back arc volcanoes that source a significant proportion of their carbon from subducted volatiles, remain ^{13}C depleted (eg. Giggenbach et al., 1991; Sano et al., 1995). Thus, as plants continue to enrich the atmosphere in ^{13}C while supplying the ^{13}C depleted kerogen that is subducted into the mantle, volatiles failing to return to the surface may cause the mantle to become increasingly ^{13}C depleted over time.

Both tectonic and volcanic CO_2 are magmatic and depleted in both ^{13}C & ^{14}C. This makes CO_2 emissions of volcanic origin isotopically identical to those of fossil fuel emissions. It is therefore unsurprising to find that Segalstad (1998) points out that 96% of atmospheric CO_2 is isotopically indistinguishable from volcanic degassing. So much for the Royal Society's unexplained "chemical analysis". If you believe that we know enough about volcanic gas compositions to distinguish them chemically from fossil fuel combustion, you have indeed been mislead. As we shall see, the number of active volcanoes is unknown, never mind a tally of gas signatures belonging to every active volcano. We have barely scratched the surface and as such, there is no magic fingerprint that can distinguish between anthropogenic and volcanogenic sources of CO_2.

4.0 The Rise and Fall of Oxygen

Manning et al. (1999) find, as an average at La Jolla, that 1.3 mol of O_2 are consumed for every mol of CO_2 produced. They point out that if all atmospheric CO_2 was produced by the combustion of fossil fuels, this result would be 1.44 mol of O_2 consumed for every mol of CO_2 produced. Cellular respiration as a simplified reaction is as follows:

$$C_6H_{12}O_6\ (aq) + 6\ O_2\ (g) \rightarrow 6\ CO_2\ (g) + 6\ H_2O$$

Photosynthesis does not throw out the balance of cellular respiration following the same molar ratios of CO_2 and O_2 in play:

$$6\ CO_2\ (g) + 6\ H_2O \rightarrow C_6H_{12}O_6\ (aq) + 6\ O_2\ (g)$$

As you can see, the net effect of respiration is to lower the number of mols of O_2 consumed for every mol of CO_2 produced with no skew introduced by photosynthetic consumption of CO_2. Volcanoes, once again ignored by Manning et al (1999), produce CO_2 freely without any directly observed O_2 consumption, although it remains possible that volcanic activity may well consume significant amounts of O_2. This could explain the mystery of the loss of half the atmosphere's oxygen 250 million years ago; a mystery that remains unsolved (see Berner et al, 2003). As we can't clearly identify exactly what amount of atmospheric O_2 is consumed by volcanic processes (eg. oxidation of H_2S to H_2O, SO_2, H2$_2$SO4) for every mol of volcanogenic CO_2 released to the atmosphere, we can only guess that volcanogenic emissions reduce this ratio towards a figure substantially less than unity. The argument is therefore made that because we don't see a significantly lower ratio, volcanogenic CO_2 cannot possibly be very much. This however, is a deduction from a guess, and clearly neglects common oxidation reactions that consume O_2 without producing any CO_2, such as some forms of corrosion, combustion of certain volcanic volatiles, and weathering. For example:

$$4\ Fe + 3\ O_2 \rightarrow 2\ Fe_2O_3$$

$$H_2S + 2\ O_2 \rightarrow H_2SO_4$$

$$2\ H_2S + 3\ O_2 \rightarrow 2\ H_2O + 2\ SO_2$$

$$4\ FeSiO_3 + 2\ O_2 + 2\ H_2O \rightarrow 4\ FeO(OH) + 4\ SiO_2$$

Weathering and the successive oxidation of elements like iron from minerals such as pyroxenes present a major example of how oxygen is consumed without producing carbon dioxide, because carbon is **not** the only element on the planet that preferentially combines with oxygen. Such reactions drive the number of mol of O_2 consumed per mol of CO_2 produced higher. As you can see, it is not only fossil fuels that drive this ratio in this direction, and it is a simpler matter to more comprehensively measure volcanic CO_2 output to determine whether volcanoes are indeed a significant CO_2 contributor.

5.0 Plimer Strikes Again: 139,000 Intraplate Volcanoes Leaking CO_2 into the Ocean

Until reading Hillier & Watts (2007), I would have estimated that the oceans, occupying twice the surface area of land, would have twice the number of volcanoes. In fact the number of submarine volcanoes is very much higher than twice the number of subaerial volcanoes. Given the update of Werner & Brantley (2003), which raises the estimate of subaerial volcanogenic CO_2 from 27±3 MtCpa to 78±6 MtCpa, this would seem to imply roughly 200 MtCpa from submarine volcanogenic CO_2 and brings the total estimate of volcanic CO_2 in line with the bare minimum determined by Morner & Etiope (2002). Plimer (2001; 2009) & Wishart (2009) maintain that the amount of CO_2 from volcanoes is enormous, and without estimating an amount suggests that it dwarfs anthropogenic contributions. If we take the updated estimate, correct the conservative bias, and extend to submarine environments we still wind up with a figure around 1.5 GtCpa for total passive volcanic emissions (excluding imponderables such as mid oceanic ridge emissions) and that is still only 20% of the 7.8 GtCpa attributed to anthropogenic CO_2 emissions by the IPCC. As it turns out, there is a lot more to the distribution of volcanoes across different tectonic settings, and Plimer (2009) omits the rather small detail of a 2007 paper presenting primary evidence that underpins his claim in spectacular fashion.

Hillier & Watts (2007) surveyed 201,055 submarine volcanoes estimating that a total of 3,477,403 submarine volcanoes exist worldwide. According to the observations of Batiza (1982), we may infer that at least 4% of seamounts are active volcanoes. We can expect a higher percentage in the case of the count taken by Hillier & Watts (2007) because it includes smaller, younger seamounts; a higher proportion of which will be active. Nevertheless, in the spirit of caution and based on our minimum inference of 4% seamount activity from Batiza's observations, I estimate 139,096 active submarine volcanoes worldwide. If we are to assume, in the absence of other emission figures for mid oceanic plate volcanoes, that Kilauea is a typical mid oceanic plate volcano with a typical mid oceanic emission

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of 870 KtCpa (Kerrick, 2001), then we might estimate a total submarine volcanogenic CO_2 output of 121 GtCpa. Even if we assume, as Kerrick (2001) and Gerlach (1991) did, that we've only noticed the most significant outgassing and curb our estimate accordingly, we still have 24.2 GtCpa of submarine volcanic origin.

If guesses of this order are anywhere near the ballpark, then we can take it that either what has been absorbing all this extra CO_2 is not absorbing as much or there has been some variation to volcanic output over the past 500 years or so. Both are normal assumptions given the variable state of the natural environment, and considering that vegetation consumed something on the order of 38GtCpa more in 1850 than today (see my Deforestation article for the quick and dirty calculation), it is hardly surprising that we were missing a large natural CO_2 source in the carbon budget. The other possibility is that both Werner et al (2000: approx. 38 KtCpa) and Werner & Brantley (2003: approx. 4000 KtCpa) are correct, which could imply that volcanogenic CO_2 emissions are increasing. This certainly would explain steadily rising CO_2 observed at stations in regions most affected by volcanic emissions, it could partly explain the recent increase in ocean acidification discussed by Archer (2009, pp. 114-124), and further it would explain the more intense Spring melting centred on the Pacific Coast of Antarctica and along the Gakkel Ridge under the Arctic ice cap.

6.0 Conclusion: Three Million Volcanoes "Can't be Wrong

Irrespective that other authors may neglect to allow for volcanogenic CO_2, volcanoes represent an enormous CO_2 source that is mostly submarine. Furthermore, volcanic activity beneath both ice caps and localized to the regions of most intense melting has demonstrated an obvious cause of stronger Spring melts at the Poles. It is evident from the observations of Sohn et al. (2008) & Reves-Sohn et al. (2008) that the Northwest Passage was opened up by powerful volcanic activity under the Arctic Ice along the Gakkel Ridge, while West Antarctic melting (as opposed to thickening of ice throughout the rest of Antarctica) can be explained by recent volcanic activity beneath the ice (Corr & Vaughan, 2008). Moreover, there are simply too many volcanoes to deny that the atmospheric concentration of the most erupted gas next to water is predominantly controlled by the balance or lack thereof between volcanic activity and photosynthesis. Furthermore, there is no fingerprint by which we may distinguish fossil fuel CO_2 from volcanic CO_2. This leaves us with no empirical method by which we may attribute the 20th century rise in CO_2 to human energy consumption. ▲▲

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Electric Volcanic Ash

Abstract — Volcanic Plumes Generate Lightning from the Electrification of Plume Particles.

VOLCANIC PLUME charging at over 1200 km from its source was observed from in situ balloon sampling of the April 2010 Eyjafjallajökull plume over Scotland.

Whilst upper and lower edge charging of a horizontal plume is expected from fair weather atmospheric electricity, the plume over Scotland showed sustained positive charge well beneath the upper plume edge. At these distances from the source, the charging cannot be a remnant of the eruption itself because of charge relaxation in the finite conductivity of atmospheric air. (Source Environmental Research Letters, Vol. 5 No. 2).

New Scientist further notes that "the balloon entered the 800-metre-thick ash-laden layer of the atmosphere, they noted a rapid increase in particle concentration and a positive electrical charge that they say could not be attributed to local weather conditions or other sources. "We think that particle collisions must be creating the charge," says Harrison.

The charge increased with particle concentration, reaching a maximum of around 0.5 picocoulombs per cubic metre in areas where there were 50 particles per cubic centimetre of air.

That's around 1/20th of the concentration beyond which the UK Civil Aviation Authority (CAA) has said aircraft are not allowed to fly. "Combined with other measurements, a simple charge detector on an aircraft should be able to alert pilots to dangerous levels of ash," says Harrison.

Whether such a system would be of practical use in busy airspace is another question. "UK airspace is very congested, so any detection system has to be able to warn of the ash far in advance, to give time to manoeuvre safely," says a spokesperson for the CAA., (New Scientist, 27 May 2010) ▲▲

Risk and Uncertainty in Mineral Exploration: Implications For Valuing Mineral Exploration Properties

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Abstract

Most of the methods commonly applied to valuing mineral exploration properties are deterministic and tend to ignore the risky nature of our business, a situation that is at odds with the probability of mineral exploration success and omnipresent uncertainty. This article briefly (a) discusses the main sources of risk and uncertainty in mineral exploration, (b) reviews the common methods for valuing mineral exploration properties, and (c) describes a probabilistic method to project evaluation. Our principal aim is to stimulate discussion and more widespread uptake of probabilistic methods in our industry, in particular for the purpose of valuing mineral exploration properties. We argue that probabilistic methods are not black box approaches. Rather, they are proven analytical tools that combine the principles of probability and statistics with sources of data and expert opinion to try and quantify the uncertainty and risk associated with an investment opportunity. As such, these tools are well suited to meet the challenges of our industry and help to increase the effectiveness of our exploration investments and decisions, and valuations of mineral exploration properties.

Introduction

Valuing mineral assets can be a complex and highly subjective task that requires the valuer to take into account a wide range of input parameters (Bell et al., 2008). The valuation of a mineral exploration property must include all parameters that are relevant for determining the overall exploration and economic potential of the asset, such as geological setting, style of mineralisation, grade-tonnage potential and regional endowment, commodity prices, metallurgy and mineability, infrastructure and access, and security of tenure and sovereign risk.

Given the inherent uncertainty surrounding most of these input parameters, it is rather surprising that none of the methods commonly applied to valuing mineral exploration properties employ a probabilistic approach to incorporate and account for this high level of uncertainty. The argument against the use of probabilistic methods in mineral asset valuation is their apparent lack of transparency (Lawrence, 1994; Thompson, 2001). However, this statement is at odds with the petroleum industry example where the adoption of systematic risk analysis in the early 1990s has brought objectivity, consistency and greater transparency to asset valuation (Rose, 1999, 2007).

This article briefly reviews (a) main sources of risk and uncertainty in mineral exploration, (b) common deterministic methods used to value mineral exploration properties, and (c) use, benefits and limitations of risk-based valuation methods in an attempt to encourage mineral asset valuers, and exploration geoscientists in general, to (d) be more explicit about uncertainty, and (e) adopt probabilistic methods as standard practice as has been done in the petroleum industry. Much of the material presented here was collated from previous publications and presentations by Etheridge et al. (2006), Kreuzer (2007a), Kreuzer et al. (2008), Etheridge and Kreuzer (2010).

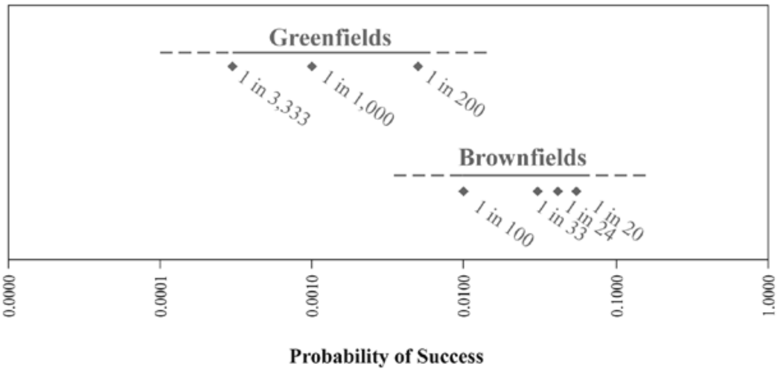

Figure 1. Typical ranges of industry success rates in brownfields and greenfields environments based on figures by Lord et al. (2001), McMahon (Maureen McMahon, pers. comm., 2004), Schodde (Richard Schodde, pers. comm., 2006), Rio Tinto (2007) and Kennecott Exploration (2007: website information no longer available).

Definitions

In its broadest sense, risk is defined as the likelihood of an event occurring, multiplied by the consequences of that event should it take place. This relationship is commonly presented as matrix of likelihood versus consequences (e.g., Clemens and Pfizer, 2000). In the context of mineral exploration, the term risk refers to the probability of a project delivering an undesirable financial outcome. In mathematical terms, this risk can be expressed as the probability of failure and is equal to one minus the probability of success (Singer and Kouda, 1999; Murtha, 2000). The main implications of this definition are that risk can be quantified, or at least estimated, and that it can be reduced if probability of success can be improved.

Uncertainty is a measure of our inability to assign a single value to a possible event and defined as the variability of possible outcomes (e.g., gains or losses) around their mean (expected) value. The quantification of uncertainty is the difference between the true value of a natural outcome and an estimate of its value. Bias occurs when values are systematically over- or underestimated. Despite the uncertainty surrounding geoscience models and interpretations, uncertainty is rarely stated or quantified (Bárdossy and Fodor, 2001).

A mineral exploration property is defined here as a tenement or group of tenements that are at the early to intermediate stages of mineral exploration (i.e., prior to pre-feasibility) and without the prospect of any reasonably certain future mine production and cash flows. Hence, the common techniques of ore resource calculation and discounted cash flow analysis are not applicable to such properties.

Sources of risk and uncertainty in mineral exploration

Mineral exploration is a business activity, and as such it is expected to provide an acceptable return to those who invest in it (Singer and Kouda, 1999; Hall and Redwood, 2006). However, the average probability of success in mineral exploration is so low, and the attendant geological uncertainty so high that it has often been difficult for investors, managers and exploration geoscientists to actively manage for financial success. This has been demonstrated by:

- Ball and Brown (1979) and Ord (1998) whose work indicates that the real rate of return to investors in resources stocks over the two decades from 1970 to 1990 was -1.2%.
- Eggert (1993) whose review of the literature on exploration management illustrates that few mineral companies find exploration profitable. For most companies it is, at best, a marginal economic activity.
- Schodde (2003, 2004) who measured the return from 109 major Australian gold projects in the period 1985 to 2003. The total NPV value of these projects was $4.74 billion, whilst exploration and delineation costs amounted to $4.64 billion, indicating an average return of $1.02 for every $1.00 spent on exploration.
- Leveille and Doggett (2006) who measured the costs of and returns from 65 Chilean copper projects in the period 1950 to 2004. Only 14 projects (22%) generated sufficient returns to offset their exploration costs. The overall return of the Chilean copper industry in the period 1950 to 2004 was below breakeven.

One of the main reasons for the poor overall performance of the exploration industry outlined above and single biggest risk factors in mineral exploration is the low base rate situation or low rate of occurrence of mineral deposits in individual targets (Hronsky, 2004). This situation has profound impact on the success rate of our industry.

Published figures of the proportion of exploration targets that eventually become profitable mines (Fig. 1) range between 1 in 24 (c. 4%) for brownfields exploration (Lord et al., 2001) in a well-endowed gold district, and from 1 in 1,000 (0.01%) to 1 in 3,333 (0.03%) for

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greenfields exploration targeting world-class deposits (Kennecott Exploration, 2007: website information no longer available; Rio Tinto, 2007). A study by Kreuzer et al. (2007b) of 179 Australian junior exploration companies that listed at the Australian Securities Exchange between July 2001 and June 2006 established similarly low success rates. Of the 970 projects controlled by these companies only 10 had advanced to the mining stage, suggesting a junior exploration success rate of 1 in 97 (c. 1%) over a period of six years and taking into account mine acquisitions. However, a recent study by Guj and Fallon (2009) and Fallon et al. (2010a, b) of a very successful exploration campaign in the Plutonic-Marymia Greenstone Belt of Western Australia demonstrates that sometimes greenfields success rates can be much higher (i.e., 1 in 5.5 or 18%). Unpublished data for brownfields exploration by McMahon (Maureen McMahon, pers. comm., 2004) fall within a range of 1 in 100 (1%) to 1 in 33 (3%) while unpublished figures by Schodde (Richard Schodde, pers. comm., 2006) range from 1 in 20 (5%) for brownfields to 1 in 200 (0.5%) for greenfields exploration.

What these figures indicate is that, on average, we need to test at least 20 to 100 skilfully selected targets in brownfields and between 200 and greater 3,000 targets in greenfields exploration to make a discovery that eventually becomes a profitable mine. As a rule of thumb, approximately 30 km (or 200 holes) of geochemical and exploratory drilling are required for a minor greenfields discovery with an in-situ value of ≥US$30 million, 300 km (or 2,000 holes) for a moderate one with an in-situ value ≥US$200 million, and 3,000 km (or 20,000 holes) for a major discovery with an in-situ value ≥US$1,000 million (Schodde, 2003). The clear implication of the low base rate situation is that, despite superior geoscience and skilful exploration, most projects are destined to fail.

Virtually all geological data contain some degree of uncertainty (Bárdossy and Fodor, 2001). Most decisions in mineral exploration are based on geological statements, measurements and calculations and ignorance to or over- / underestimation of the underlying geological uncertainties can augment the overall risky nature of the business. The key uncertainties (Bárdossy and Fodor, 2001) affecting mineral exploration are:

- The inherent natural variability of geological objects and processes, which is a property of nature and exists independent of our geological investigations (e.g., uncertainty about the controls on the location of ore deposits, origin of mineralising fluids, timing of deformation events, nature of the tectonic setting).
- Conceptual and model uncertainty (McCuaig, 2007), which is linked to our incomplete knowledge and subjective interpretation of geological objects and processes. This type of uncertainty is almost impossible to quantify and subject to a well understood set

of heuristics (metal short cuts) and biases (systematic errors) (Tversky and Kahneman, 1974) that can cause severe and systematic errors of judgment (Welsh et al., 2005).

- Errors that occur when we sample, observe, measure or mathematically evaluate geological data, and the propagation of these errors.

Common methods for valuing mineral exploration properties

The Geoscience Factor Method (Kilburn, 1990) is a subjective, matrix-based valuation methodology for mineral exploration properties that do not contain exploitable resources. It requires the valuer to systematically justify the key geological parameters that determine the technical value of an exploration property: Presence and type of valuable mineralization, presence of geological targets, presence of geophysical and / or geochemical targets, and proximity to known valuable mineralisation. Collectively, these parameters provide a measure of prospectivity that is multiplied by the basic acquisition cost of the property to determine the overall technical value. This value is then adjusted for market factors (e.g., commodity prices, exchange rates and country risk) to determine the market value (Thompson, 2000; Lilford and Minnitt, 2005).

In the Market Approach or Comparable Transaction Method (Thompson, 2000) a value is placed on a mineral exploration property based on the value of recent (cash- or share-based) transactions that are similar in terms of scope, time, place and commodity. The main weakness of this method is the shortage of truly comparative transactions. Mineral exploration properties can be also valued on the earn-in or joint venture approach, based on actual deals and commitments, or by analogy with deals on adjacent properties within a particular district, or properties of similar type elsewhere (Thompson, 2000).

The Appraised Value or Multiple of Previous Expenditure Method (Roscoe, 1986, 1988, 2000; Baxter and Chisholm, 1990; Lilford and Minnitt, 2005) is based on the premise that a mineral exploration property is worth meaningful past exploration expenditure (in dollars of the day) plus warranted future costs (i.e., expenditure base). In this method, the estimated property value is derived by a factor known as prospectivity enhancement multiplier (on a scale from 0.0 to 5.0). This factor is directly linked to judgement of the valuer of the success (or failure) of exploration completed to date and an assessment of the future prospects within a property.

A more detailed discussion of the valuation methodologies commonly used in Australia is outside the scope of this study. Readers are referred to Thompson (2000), Schodde (2002), Lilford and Minnitt (2005) and Etheridge and Kreuzer (2009) for more comprehensive and / or critical assessments of these methods.

The case for probabilistic methods

A mineral exploration property is highly conditional asset and a certain liability (Phillip Uttley, pers. comm., 2003). The high conditionality of the asset reflects the very low probability that a discovery of realisable value will occur on a given property, whilst the certain liability is because a property comes with a commitment to spend money. These principles are at odds with the rationale of the traditional valuing methods outlined above that tend to ignore the very low base rate situation of exploration success. Moreover, the traditional methods of valuing mineral exploration projects also always produce positive values, thereby ignoring the fact that mineral exploration as a whole is at best a marginal economic activity (Eggert, 1993; Schodde, 2003, 2004; Leveille and Doggett, 2006). This is particularly unrealistic for greenfields properties given that value will only emerge from the unlikely event of a discovery. Given the situation outlined above, we argue that valuers need to be more explicit about the uncertainty of input parameters used in the valuation of mineral exploration properties, and use of stochastic techniques (e.g., Monte Carlo simulation) to incorporate uncertainty should be standard.

The following is an example of probabilistic framework for estimating the value of mineral exploration properties developed by Kreuzer et al. (2008), which has been successfully trialled by Geoinformatics Exploration Inc (Darren Holden, pers. comm., 2005) and Auzex Resources Ltd (2008a, b). The probabilistic framework of Kreuzer et al. (2008) (Fig. 2) integrates the critical processes of mineral deposit formation and scale and intensity of metal deposition with basic concepts of probability theory and financial and decision analysis,

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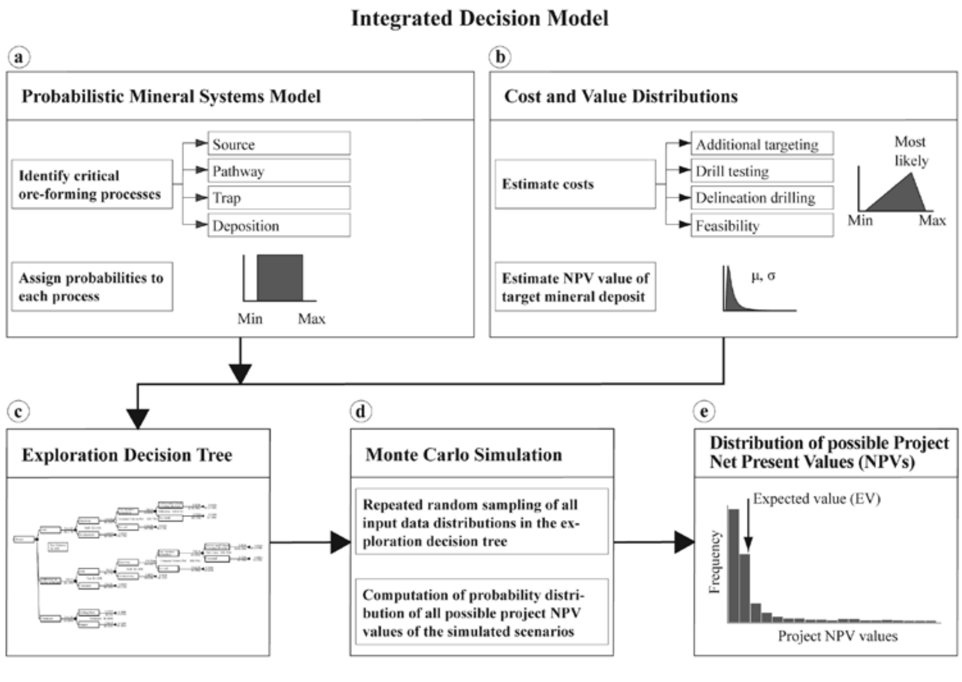

Figure 2. Schematic overview of the modeling process after Kreuzer et al. (2008). NPV = net present value. A subjective (expert) measure of the probability of ore occurrence computed in the probabilistic mineral systems model for a particular project area or target (a) and estimates of the costs of mineral exploration and feasibility and the possible value of the targeted mineral deposit style (b) serve as inputs for (c), an exploration decision tree that offers possible decision alternatives. (d) A Monte Carlo simulation of the exploration decision tree produces (e), the expected value (EV) of a particular exploration project and the probability distribution of all possible NPVs within a minimum and maximum range.

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thereby generating a link between the geologic potential of an exploration project and its probability adjusted financial value. This value is derived from a decision tree model that incorporates Monte Carlo simulation capability.

The four key components of the methodology introduced by Kreuzer et al. (2008) are:

1. Geological assessment: This component requires the valuer to systematically determine and justify the probability of occurrence of potentially economic mineralisation ($P_{Mineralization}$) within a particular exploration property based on the mappable evidence for the critical processes of mineral deposit formation (P_1 to P_4) having occurred within the target area (Fig. 3): P_1 = extraction of ore components such as fluids, metals, and ligands from crustal or mantle sources; P_2 = fluid- or melt-assisted transport of ore components from source regions to trap zones (i.e., effective melt, fluid, or vapour channels); P_3 = formation of trap zones that are sufficiently wide to accommodate large amounts of metal but narrow enough to efficiently focus melt or fluid migration during protracted or brief and repetitive events of energy and mass flux; and P_4 = operation of the physicochemical processes that promote and sustain the deposition of metal from melts, fluids, or vapour passing through a trap zone (Wyborn et al., 1994; Knox-Robinson and Wyborn, 1997). The overall value of $P_{Mineralization}$ is obtained by multiplying the individual probabilities, or probability ranges, assigned to P_1 to P_4 according to the multiplication rule of probability theory (e.g., Megill, 1988) and approach of Lord et al. (2001) (i.e., $P_{Mineralization} = P_1 \times P_2 \times P_3 \times P_4$). In this approach, a $P_{Mineralization}$ value of 1.0 indicates that a mineral deposit is present within the target area given that the valuer would have to have unambiguous evidence for P_1 to P_4 having occurred. If, on the other hand, a probability of 0.0 is assigned to one or more of the critical processes, the chance of ore occurrence within the target area becomes zero.
2. Cost and value distributions: All monetary values in this probabilistic decision model are linked to cost and value inputs or their probability distribution functions (Fig. 2) that were either estimated or fitted to historic datasets using risk analysis software. The possible costs of exploration (i.e., surveying, drill testing, and resource delineation) and project feasibility are defined by the parameters of triangular distributions (minimum, most likely, maximum) that are user inputs and adjustable to suit particular company estimates or cost structures. Three databases of the value of mineral deposits are available for use in the probabilistic decision model (Table 1). These are fitted well by the lognormal distribution, which is consistent with the common lognormal distribution of mineral deposit grade and tonnage data (Folinsbee, 1977; Singer, 1993; Rose, 1999). A good fit was confirmed by goodness-of-fit tests such as Chi-Square, Anderson-Darling, and Kolmogorov- Smirnov, using risk analysis software.
3. Decision tree: Decision trees are widely used for structuring, analysing, and quantifying investment decisions in sequential chronological order and calculating their expected values (EVs) in terms of the probability of occurrence and monetary reward of all possible outcomes (e.g., Newendorp and Schuyler, 2000; Clemen and Reilly, 2001). The tree presented by Kreuzer et al. (2008) is intended to calculate the EV of early stage exploration projects

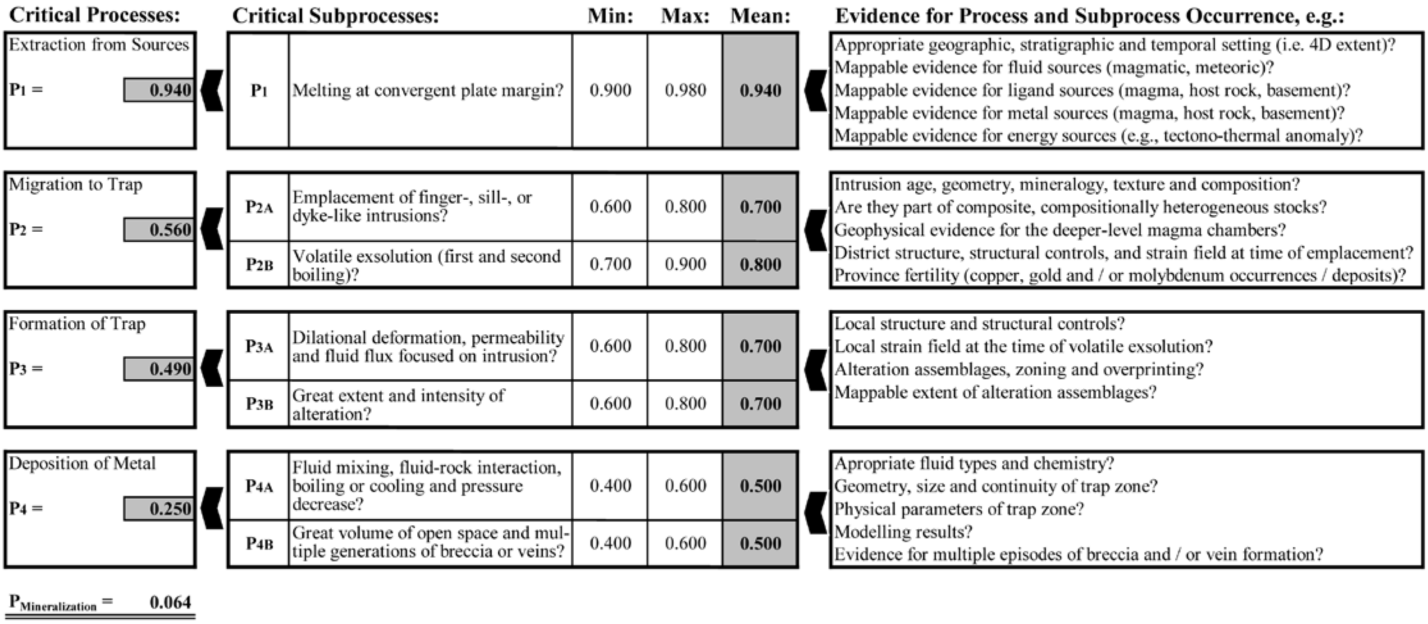

Figure 3. Example of a probabilistic mineral systems model for a porphyry copper (± gold, ± molybdenum) deposit after Kreuzer et al. (2008). Discrete probabilistic values on a scale from 0.0 to 1.0, or ranges of likely values as illustrated in this example, are assigned to each subprocess. Each assignment must be based on geologic evidence for the particular subprocess having operated at the location of interest. The probability of occurrence of a critical process is the product of the probabilities assigned to the each critical subprocess. By multiplying P_1, P_2, P_3, and P_4, a probability of occurrence of potentially economic mineralization ($P_{Mineralization}$) can be obtained for a particular area of interest (cf. Lord et al., 2001). Where a range of probabilities is assigned, the values are assigned a uniform distribution that is characterized by the minimum and maximum of the range and constant probability.

and offers three main decision paths: (a) drill, (b) apply additional targeting technique, or (c) terminate. Decision path 1 (Fig. 4) is based on the scenario where a company has identified a target with a $P_{Mineralization}$ value that is at a level justifying immediate drill testing. Decision path 2 (Fig. 4) is tailored to the situation where the $P_{Mineralization}$ of a target is below the level required to justify immediate drilling, but where the application of an additional geochemical or geophysical targeting method is expected to result in a revised and improved $P_{Mineralization}$that would warrant drill testing. This posterior or updated $P_{Mineralization}$ is calculated using Bayes' rule of conditional probability. Decision path 3 (Fig. 4) reflects the scenario where, despite skilful exploration, no drillable targets are defined, and where the application of further targeting techniques is perceived as futile. Pay-off values, computed for each decision path in the decision tree, represent the EVs of the three exploration strategies outlined above. A positive EV indicates that the corresponding exploration strategy is likely to be successful, whereas a negative EV justifies

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Table 1. Databases of the value of mineral deposits after Kreuzer et al. (2008)

Database	Period	Entries	Source	Characteristics	Valuation Method	Currency	Parameters	
							μ	σ
Gold and Base Metals Acquisitions	1993–2003	343	Metals Economics Group	Large global dataset Broad spectrum of deposit styles Broad range of commodity types Broad spectrum of pre-mining projects at various stages of exploration	Project transaction prices in dollars of the day	2004 A$[1]	121.09	303.95
Australian Gold Discoveries	1985–2002	59	Schodde (2003)	Small Australian dataset Norrow range of gold deposit syles Restricted commodity spectrum (gold ± copper) Restricted to projects that were actually mined Coherent data based on a single study Robust methodology of compilation	NPV calculations based at the time of decision to mine, using constant A$550/oz and the tax rules of today	2003 A$	85.85	193.12
Global Copper Projects	1992–2004	65	Leveille and Doggett (2006)	Small global dataset Various copper deposit syles Restricted commodity spectrum (copper, gold, silver, molybdenum, zinc, cobalt) Restricted to projects that were actually mined Coherent data based on a single study Robust methodology of compilation	IRR and NPV calculations at discount rates of 8%, based on an effective tax rate of 30% and average metal prices over the period 1992-2004	2004 US$	285.51	1748.80

[1] For the purpose of this study all transactions were grossed up to full project value and converted to Australian dollars of 2004

***Key to abbreviations:** NPV = net present value; IRR = internal rate of return*

Risk and Uncertainty in Mineral Exploration: Implications For Valuing Mineral Exploration Properties

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rejecting the underlying decision alternative.

4. Monte Carlo simulation: Monte Carlo simulation of the probability distributions that are built into the decision tree (Fig. 5) and describe the model inputs are sampled at random up to several tens of thousands of times. Each simulation step represents an individual outcome in terms of possible expected NPVs of the analysed project. Collectively, these individual outcomes define a distribution of all possible expected NPVs of the project and provide its statistical parameters (e.g., mean EV, maximum and minimum EV, and standard deviation).

In summary, the probabilistic mineral systems approach of Kreuzer et al. (2008) integrates the critical processes of mineral deposit formation with concepts of probability theory, decision analysis and financial modelling. The principal objective of this approach is to make mineral deposit models amenable to financial risk and value analysis and suitable for communication of value-creating geologic concepts to financial stakeholders in economic terms.

The main limitation of the above method is the subjective nature of assigning probabilities to the critical process parameters and uncertainty in estimating cost and value distributions. However, the inherent uncertainty in valuing mineral exploration properties can be addressed by using ranges of values for the uncertain parameters and applying stochastic modelling techniques. Proven software tools that are widely accepted and applied in other industries are available to help with these tasks. We are confident that the current limitations can be overcome by more widespread use of probabilistic frameworks, and by repeated benchmarking against market transaction values.

Summary and conclusions

One of the greatest impediments to mineral exploration success is the low rate of occurrence of mineral deposits in individual targets. The significance of this low base rate situation is clear: (a) Exploration is a long odds game that commonly requires a large number of targets to be effectively tested and turned over before success can be realised, and (b) most exploration projects are destined to fail. The methods commonly applied to valuing mineral exploration properties ignore these principles and, therefore, are at odds with the odds. They rarely yield a zero value, consistently overvalue greenfields properties whilst often undervaluing well designed exploration portfolios and / or programs.

Probabilistic techniques are available for simulating potential outcomes and evaluing investment decisions under conditions of uncertainty. These methods are widely accepted in the petroleum business but commonly rejected by the mineral resources industry. Why is it that as a profession we are happy to make subjective judgements implicitly whilst being resistant to explicit quantification of our judgement? How to make better probability / value decisions in the face of uncertainty is arguably the most important commercial skill that mineral explorers, especially those who act as Independent Experts and valuers, can learn.

Probabilistic methods are not black box approaches. They are proven analytical tools that in the words of Murtha (2000) “combine the principles of probability and statistics with sources of data and expert opinion to try and quantify the uncertainty and risk associated with an investment opportunity [...] Informed decisions require analysis of the ranges of possible outcomes and their implications” rather than a single deterministic number. As such, probabilistic methods are well suited to meet the challenges of our industry and help to increase the effectiveness of our exploration investments and decisions, and of valuations of mineral exploration properties. ▲▲

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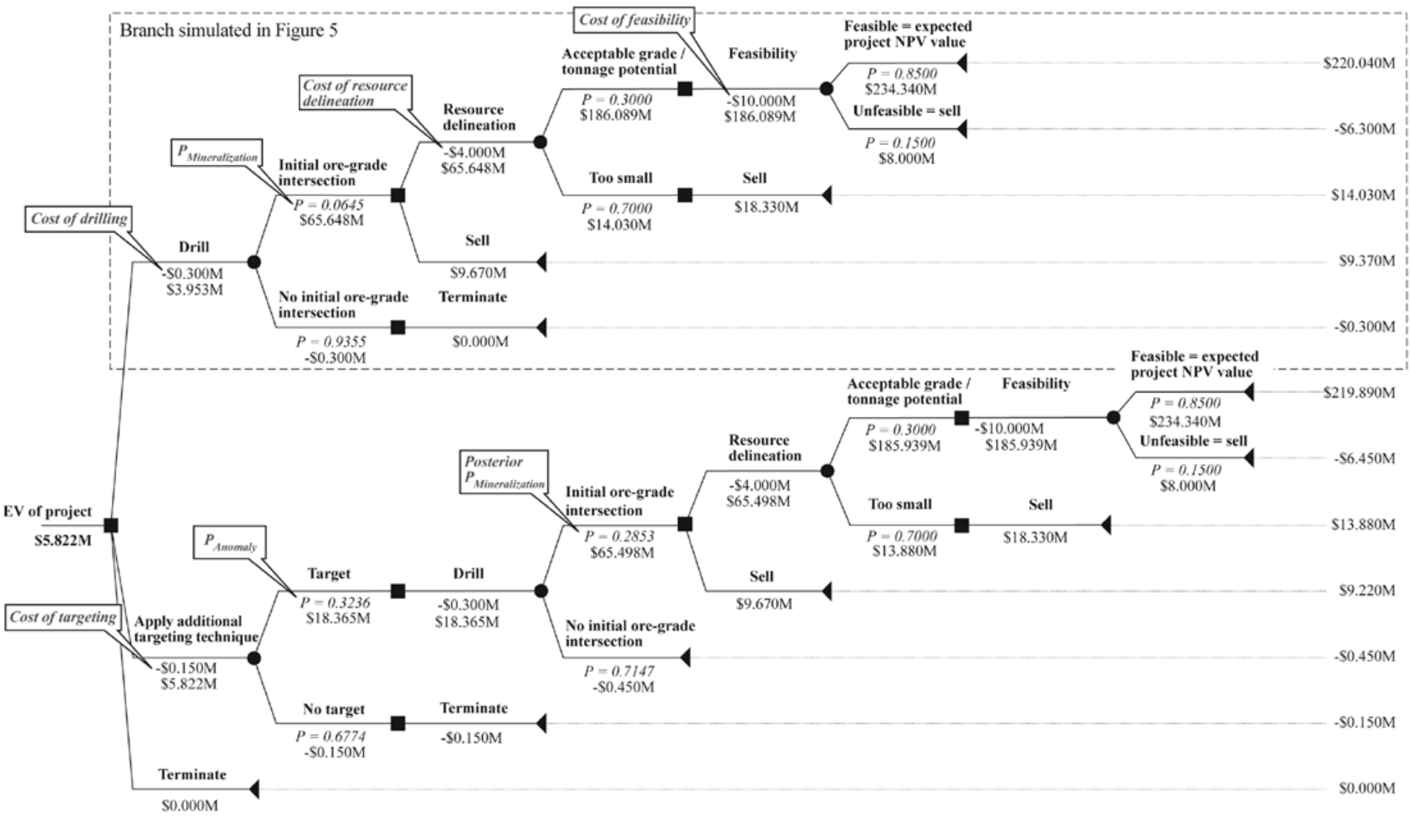

Figure 4. Example of an exploration decision tree offering three main decision paths after Kreuzer et al. (2008): (a) drill, (b) apply additional targeting technique, and (c) terminate. The tree can be used in either a deterministic or probabilistic manner. The deterministic tree (illustrated in this figure) is intended to calculate the “base case” expected value (EV) of a project for which drillable targets have been or are being identified (i.e., exploration stage B of Lord et al., 2001) and as a function of expected (mean) values of inputs. The probabilistic tree integrates the probabilistic distributions of the inputs outlined in Figure 1a and b with a Monte Carlo simulation tool for computing not only the EV of a project but also the probability distribution of all possible NPVs within a minimum and maximum range. $M = million dollars.

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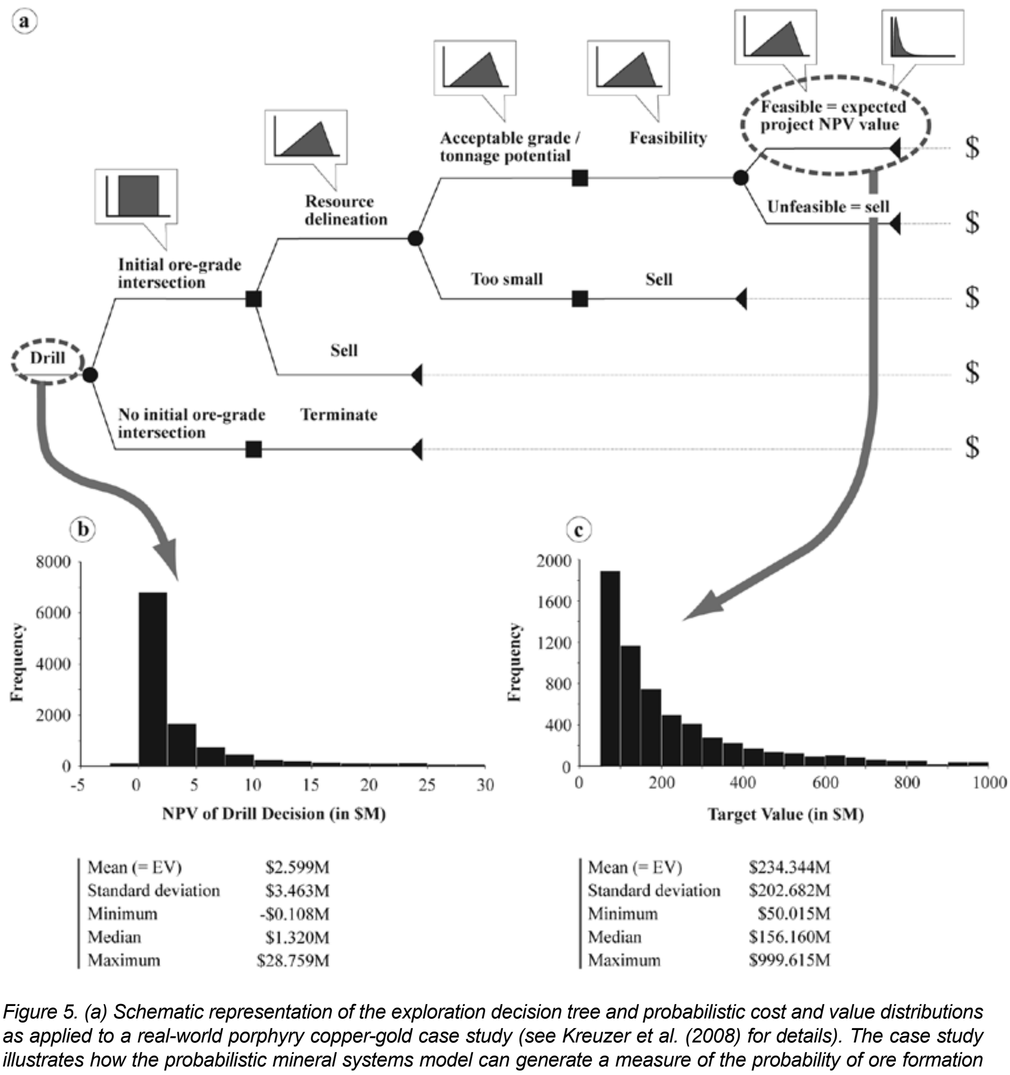


Figure 5. (a) Schematic representation of the exploration decision tree and probabilistic cost and value distributions as applied to a real-world porphyry copper-gold case study (see Kreuzer et al. (2008) for details). The case study illustrates how the probabilistic mineral systems model can generate a measure of the probability of ore formation and how this probability can be used in an exploration decision tree that incorporates Monte Carlo simulation capability. (b) Results of the simulation of the distribution of all possible (expected) net present values (NPVs) of the drill decision. (c) Results of the simulation of the distribution of all possible values of the porphyry copper target sampled in the range from $50M to $1B. $M = million dollars. Figure taken from Kreuzer et al. (2008).

Geoscientist Employment Survey Update

THE AUSTRALIAN INSTITUTE OF GEOSCIENTISTS (AIG) today (21 May 2010) launched the second quarter 2010 update of its series of its geoscientist employment surveys.

The surveys were commenced in early 2009 to help measure the impact of the global economic on geoscientist employment in all sectors of business activity throughout Australia. Data collected by these surveys has charted the impact on geoscientist employment of rapidly changing economic conditions since their inception.

The latest survey follows the Commonwealth government's proposal to impose a Resources "Super Profits" tax on Australia's mining industry which has been widely condemned by mining companies and professional groups involved in the exploration and mining industries.

Professional were shocked by the Commonwealth Government's proposal that will have a profound negative impact on resources industries, the geoscience profession and the Australian community more generally and have called on the Prime Minister and Treasurer to work with companies in a consultative, transparent and constructive manner to address the proposal's shortcomings.

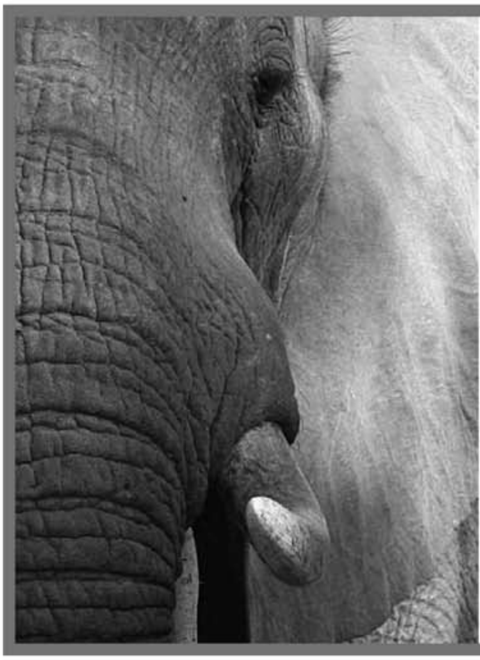
First quarter 2010 survey results showed a dramatic turnaround in employment prospects for Australian geoscientists with the level of geoscientist unemployment and underemployment in Australia falling from 18.7% in December 2009 to 11.9% in March 2010. Unemployment and underemployment in the mineral exploration sector fell from 21.1% to 10.6% in the corresponding period. This was the first survey in which exploration sector unemployment and underemployment was lower than for the profession as a whole.

The survey is open to all geoscientists, both AIG members and non-members. Contributions may be made until June 30, 2010 by following the link on the AIG web site www.aig.org.au. Previous surveys have received great support.

The survey only takes a minute or two to complete and provides valuable data regarding the state of employment in the geoscience professions throughout Australia.

Further information:
Andrew Waltho, Brisbane 0412426764
Graham Jeffress, Perth 0438 044 959

AIG's web site www.aig.org.au provides information regarding institute activities, including seminars, conferences, and the benefits AIG membership.



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Geoscientist Assistance Program

Government of South Australia
Primary Industries and Resources SA

The Geoscientist Assistance Program (GAP) is a collaboration between PIRSA through The Plan for Accelerating Exploration (PACE) and The South Australian Chamber of Mines and Energy (SACOME) in response to the effect of the GFC on the South Australian Resources and Energy industries.

The success of these industries is a crucial component to securing South Australia's economic future. Skills retention is a critical aspect of ensuring that the sectors achieve the very best outcomes for South Australia.

During the current GFC and also the natural lows of the exploration cycle the GAP will provide graduates and experienced geoscientists with a level of certainty regarding their career prospects, ensuring that we do not lose them interstate, overseas and to other sectors.

The GAP will place skilled and graduate Geoscientists into work placements facilitating the retention of these skills in SA. The Program will provide skills and professional development opportunities for participants, ensuring that their skills meet the future needs of industry.

The Program aims to

- Prevent the loss of experienced and highly trained geoscientists from the South Australian exploration, mining, petroleum and energy industries
- Maintain, develop and diversify the skills of geoscience graduates and experienced professionals affected by the GFC

The key functions of the GAP will be to

- Provide subsidies for the employment of GAP approved candidates. Candidates may be either graduates or experienced geoscientists
- Provide up to $1000 contribution towards site readiness training e.g. First Aid
- Assist industry with program application processes
- Source and match suitably qualified candidates for GAP approved projects
- Provide additional opportunities for training and development of skills
- Provide mentoring opportunities for geoscience graduates

For more details about industry sectors and job titles covered by the funding please refer to SACOME's website : www.sacome.org.au

For more information regarding the program please talk to us today

Lisa Jeffery - Manager, Geoscientist Assistance Program

Antonia Mertiris - Director, Skills & Education

Project application forms are available online at:

Phone **08 8202 9999**

Email ljeffery@sacome.org.au

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Education Report

Kaylene Camuti
(Chair, AIG Education Committee)

THE 2010 BURSARY APPLICATION FORM will be sent to universities and students in May, and will also be available on the AIG web site. This year we again invite applications from Third Year, Honours and Postgraduate geoscience students. The closing date for applications is 5 August, 2010.

In this issue of AIG News we include abstracts from two students who were awarded AIG Honours bursaries in 2009. The students are:

David Nettle, from the University of Adelaide, who has completed his project *"The Ediacaran Antaq Basin, Saudi Arabia"*. David was awarded an AIG Honours Bursary in 2009, and this year is working as a graduate geologist with Santos.

Ben Hames, who completed his project *"Geology of a Paleozoic Subduction Complex: Cockburn Formation, New England Fold Belt, NSW"* at the University of Western Australia. Ben was awarded a Digirock–AIG Honours Bursary in 2009, and this year is involved in field trips to Indonesia and Western Turkey, and then may go on to postgraduate study.

In late February the AIG NSW Branch and SMEDG held a student awards night in Sydney, where several bursary winners from 2009 were presented with their bursary certificates. The night included presentations by Laura Klingberg, winner of the 2009 SMEDG–AIG Bursary, and Angela Marshall, winner of a 2009 Digirock–AIG bursary. Laura Klingberg's abstract on the Tomahawk Au-in-calcrete anomaly is available at the SMEDG web site at http://smedg.org.au/Klingberg.pdf, and presentations by Laura and by Angela (on the Wonmunna Marra Mamba Iron Ore deposits) are available at http://www.smedg.org.au/past.html. ▲▲

Pictured Above: AIG bursary winners at the AIG–SMEDG bursary award presentation in Sydney in February. From left to right: Wendy Corbet (AIG Councillor, NSW), Robert McCarroll (AIG 3rd Year Bursary, UNSW), Laura Klingberg (AIG–SMEDG Honours Bursary, Adelaide), Angela Marshall (Digirock–AIG Honours Bursary, Wollongong), and Kim Stanton-Cook (SMEDG).

Photo courtesy of Roger Smyth-King.

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The AIG wishes to thank the following individuals and organisations for their support of the
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HONOURS ABSTRACT — 2009 Digirock–AIG Honours Bursary Winner:

Geology of a Paleozoic Subduction Complex: Cockburn Formation, New England Fold Belt, NSW

The Cockburn Formation is part of the subduction complex assemblage located to the east of the Peel Fault within the New England Fold Belt in eastern Australia. Two major and two minor field areas were mapped and sampled from within the Cockburn Formation. Stratigraphy within the formation comprises a simple succession of westwardly younging basalt, ocean-basin chert and siliceous argillite, and trench-fill sandstones. This succession is repeated across a NNE-SSW striking bedding and foliation by west-dipping thrust faults. Thrust imbrication was associated with basal accretion (underplating) at a convergent plate margin. Deformation represents layer-parallel extension (D_1) and broad zones of mélange formation (D_2). This mélange, or an intense shearing fabric, is often present on the faulted eastern contacts of the basalts and locally the basalts are enveloped within the shear zone. Steeply plunging folds (D_3) may be related to the early Permian Hunter–Bowen orogeny.

SHRIMP U/Pb dating of detrital zircons from trench-fill sandstones at two locations suggest trench deposition occurred between 361.3 ± 2.8 and 364.8 ± 2.9 Ma. These ages extend the previously determined U/Pb ages for onset of accretion within the subduction complex by approximately 10 Ma.

Basalt chemistry, determined by XRF analysis, indicates a generally mid-ocean ridge basalt (MORB) character; however, there is a variation in enrichment classification from N-MORB to E-MORB. One sample has similarities to the modern within-plate South Pacific Superswell, and others show indications of similarly enriched plume input. Major variations in MORB enrichment occur over several kilometres and are likely due to temporal and spatial mid-ocean ridge variation, such as proximity to transform faults, or lateral mantle heterogeneity. ▲▲

Ben Hames,
University of Western Australiia

HONOURS ABSTRACT — 2009 AIG Honours Bursary Winner:

The Ediacaran Antaq Basin, Saudi Arabia

The Antaq Basin is one of a number of late Neoproterozoic volcano-sedimentary basins that overlie the amalgamated arc terranes of the Arabian–Nubian Shield. It is part of the Ediacaran aged Jibalah Group, a series of volcano-sedimentary successions that infill small fault-bound basins formed by phases of intracontinental extension related to Najd faulting. The Antaq Basin was deposited during the late Neoproterozoic, a period that involved the final amalgamation of Gondwana, a rapidly changing environment and the first appearance of multicellular life. Previously it has been unclear whether the Antaq Basin is of marine or lacustrine origin. This study shows that the Antaq Basin succession was deposited in a marginal marine setting. This is supported by sequence stratigraphy, the presence of Ediacaran fossils and microbial mats, and the correlation of Antaq Basin carbonates with the $\delta^{13}C$ record of Neoproterozoic oceans. Chemostratigraphy of the Antaq Basin records a positive shift in $\delta^{13}C_{carb}$ from -6‰ to 0‰, interpreted to represent the end of the Shuram-Wonoka negative $\delta^{13}C$ anomaly. U-Pb zircon geochronology has placed a maximum depositional age of 570 Ma on the basin, confirming its Ediacaran age, and placing an upper constraint on the termination of the Shuram-Wonoka anomaly. A number of authors have proposed correlation between the Jibalah Group and the Nafun Group (Huqf Supergroup, Oman). However, this study provides no reason to correlate the environmentally distinct Nafun and Jibalah Groups. A preferred model is that the Nafun Group lies on a passive continental margin of India and the Jibalah Group lies on a coeval, ~570 Ma, active margin of the Saharan Craton. The study also presents two Ediacaran body fossils, some of the first discovered from the Arabian Shield. ▲▲

David Nettle,
The University of Adelaide

Geosciences at Work — 2010 Photographic Competition

THE AUSTRALIAN INSTITUTE OF GEOSCIENTISTS (AIG) is pleased to announce a photographic competition to highlight the role and contribution of geosciences in the community. The competition is open to all AIG members, including student members.

Geosciences at Work Photographic Competition

Entries to the competition may be contributed in three categories:

1. Geosciences at Work – photographs in this category should depict any activity related to the broad and varied contributions of geology and geosciences to the community, either in Australia or overseas. Subjects may be as diverse as aspects of resource development and mining to geotechnical engineering for infrastructure projects, working safely, environmental and groundwater management, geoscientists in exotic locations, time out from work, or promotion of geological features for tourism purposes, as examples. Use your imagination to come up with an interesting subject. Photographs depicting any aspect of the diverse and innovative applications of geosciences are encouraged.
2. Students in the Classroom, Laboratory and Field – entries in this category are sought from high school and university (undergraduate or postgraduate) students, illustrating any aspect of geoscience education in the classroom, laboratory or field. Separate prizes will be awarded for entries by high school and university students.

Submitting Entries

Digital photographs only in JPEG format, able to be reproduced as a 300 dpi image with a minimum of 600 pixels or more on the longest side of the photograph will be considered eligible.

Entries may be submitted by email to aig@aig.org.au, or on CD or DVD to the AIG Perth Secretariat office :

Geosciences at Work Photographic Competition
Australian Institute of Geoscientists
PO Box 8463
Perth Business Centre, WA 6849

Prizes and Judging

Entries will be judged by a committee comprising AIG Council and State Branch representatives. Winners will be announced on 30 September 2010.

The prizes for each category are:

- Geosciences at Work: Two prizes of one dozen premium red, white or mixed red and white Australian wines, selected and delivered to prize winners by Wine Selectors.
- Students in the Classroom, Laboratory and Field:
  - The winning university student will receive one dozen premium red, white or mixed red and white Australian wines, selected and delivered to prize winners by Wine Selectors.
  - The winning high school student will receive general geoscience books, selected by the AIG Education Sub-committee, and copies of the same books for the winner's school library, to a combined value of $300.

The Fine Print

Copyright for all entries will remain the property of the photographer who agrees that The Australian Institute of Geoscientists may non-exclusively and at no cost use entries on its web site and other publications, including its member newsletter "AIG News", on posters and other promotional material.

All entries must be the original work of the photographer.

Entries must be accompanied by the photographer's name, photograph title, a brief description of the photograph and the photographer's contact email. Students must also include the name of the school or university at which they are studying, class or course and year of study for Tertiary students.

Multiple entries are welcome. Digital manipulation of images is permissible, however these are to be kept to those features that "enhance" the existing content of an image ie USM, levels, exposure and tonal adjustments (localised or otherwise). Digitally "modified" images that display excessive enhancement or that owe their "content", total or in part, to post photographic processes* of subject duplication, combining of images of differing content or the creation of new image elements by any other process, may not be entered. Visual effects created by the external application of filters and/or other photographic accessories at the time of capture are not considered to be digital manipulation.

Images considered offensive will be rejected.

AIG will not be responsible for any images lost or damaged during submission.

The decision of the competition judges will be final and no correspondence will be entered into.

Prizes will only be delivered to Australian addresses.

All entries are accepted on the understanding that the photographer agrees to these terms. ▲▲

CSA Global success with Innov-X and new XRF range

INTERNATIONAL GEOLOGICAL and mining consultancy group CSA Global has been successfully using Field Portable XRF (FPXRF) analysers for over 10 years.

The XRF analysers provide rapid in-situ analysis of mineral samples. The FPXRF's reduce testing times, while also providing real time 'Instant Geochemistry" to allow decisions to be made on the go.

Continuing to build on a decade of FPXRF success, CSA Global are now distribution agents for the Innov-X range of XRF Analysers, directly serving the exploration, mining and environmental sectors in Australia and New Zealand.

FPXRF's have the capability to analyse up to 30 elements in a single pass in less than one minute. They can be used in various applications including prospecting, regional exploration, drilling programs, grade control and environmental monitoring.

If used correctly, FPXRF's can increase efficiency at exploration and mining projects by reducing assay costs, allowing rapid refinement of field programs and providing the ability to collect greater amounts of data than with traditional sampling and analytical techniques alone.

The Smarter, Stronger, Faster DELTA XRF

We are delighted to announce the arrival of the new Innov-X DELTA line to our shores.

The improved high-precision DELTA is to some extent based on suggestions and feedback from CSA's experience with past Innov-X models in the field. The improved product includes features such as redesigned geometry to achieve lower detection limits, a second heat sink to allow operation in hotter environments and improved software and electronics to allow faster and easier operation. See the CSA Global web site at www.csaglobal.com for further details – visit the XRF Services page to learn about the new DELTA features.

CSA Global's DELTA expert is Andrew Margereson, and he has first hand experience on how this technology can be used to add value to field campaigns. Andrew is presently working closely with exploration and mining companies to train project managers and geologists in the most effective use of the new technology. Already this approach is leading to successful outcomes for sampling programmes and is assisting greatly with grade control in open pit and underground mines.

For a demonstration of the Innov-X FP-XRF range of equipment or assistance with XRF use in mining and exploration please contact: andrew.margereson@csaglobal.com or call + 61 (0) 406 175 645

Registered Professional Geoscientist Approvals & Applications

CANDIDATES APPROVED BY AIG COUNCIL IN APRIL 2010

Mr. Chris Dickinson of Redland Bay, Queensland, in the field of Hydrogeology

Mr. Steven Flynn of Indooroopilly, Queensland, in the field of Geotechnical and Engineering

Mr. Ian (Joe) Potter of Le Vesinet, France, in the field of Mineral Exploration

NEW CANDIDATES PUBLISHED FOR PEER REVIEW BY THE MEMBERS OF THE AIG

Mr. Martin Brownlee of Malvern, Victoria, is applying in the field of Hydrogeology

Mr. Richard Bray of Parkerville, WA, is applying in the field of Mining

Mr. Andrew Moser, of Maleny, Queensland, is applying in the field of Hydrogeology

For the latest in Geoscientist news, views, codes, events, employment and education visit the AIG website:
www.aig.org.au

Results of the 2010 Annual General Meeting held in Perth, 19th May 2010

- Mike Erceg NSW
- Gerry Fahey WA
- Jill Irvin WA
- Stephen Sugden WA
- Graham Teale SA
- Doug Young QLD

Membership Update

New Members and Upgrades at the April Council Meeting 2010

FELLOWS			
CRANNEY	Paul	Joseph	Mr
MEYERS	John	Bennett	Dr
MUKHIN	Pavel		Dr
WILDE	Andrew	Robert	Dr
MEMBERS			
ANDREWS	Jeffrey	David	Mr
ASARE	Francis	Yaw	Mr
BUBNER	Graham	John	Mr
BUSHELL	David	John	Mr
DUBIKOVA	Maria		Dr
GRIEVE	Andrew	James	Mr
HOOPER	Garry	John	Mr
JONES	Andrew	Thomas	Mr
KNIGHT	Joseph	Templeton	Dr
LEEDEN	Cherie	Louise	Ms
LITTLE	Glen	Anthony	Mr
MASOTTI	Fabio	Sampaio	Mr
MATUSALEM	Randolph		
MONAZAMI	Alireza		Mr
MONTI	Richard		Mr
SAINTY	Rodney	Alan	Mr
SEREDKIN	Maxim		
SMITH	Peter	Craig	Mr
SMITH	Huw	Douglas	Mr
TURNBULL	Catherine	Watson	Ms
TURNOCK	Kerry		
YOUNG	Simon	Hardy	Mr
ZHARNIKOV	Alexey		
STUDENTS			
ARCHER	Michael	Alexander	Mr
GIANFRIDDO	Charles		Mr
HARBOUR	Andrew	John	Mr
HONOR	Paige	Courtney	Miss
LUDEKENS	Stephanie		Miss
MANTON	Ryan	John	Mr
MARTIN	Zoe		Miss
MILLER	Julia	Rose	Mrs
NGUYEN	Natalie	Jayne	Ms
PIACENTINI	Thiago		Mr
REID	Joanna		Miss
ROBERTSON	Matthew		Mr
WAITE	Rebecca	Maree	Miss

We welcome all new members to the AIG.

AIG FEDERAL COUNCIL FOR 2010-11

PRESIDENT		
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AIG NEWS

CONTRIBUTION DEADLINES

AIG News is published quarterly as per the following table. Avoid disappointment by contacting the Editor at least several days beforehand to advise submission of items for the newsletter.

ISSUE DATE	CONTRIBUTION DEADLINE
February	January 31st
May	April 30th
August	July 31st
November	October 31st

The BUSINESS ADDRESS of AIG News is:

PO Box 8463, Perth Business Centre, Perth WA 6849
Tel: (08) 9427 0820 Fax: (08) 9427 0821
Email: aignews@fgservices.biz Web: http://www.aig.org.au

Please use these contacts for all matters relating to advertising accounts, changes of address, AIG News distribution, or membership.

The EDITORIAL ADDRESS is:

Editor: Louis Hissink
Email: aignews@fgservices.biz
Tel: (08) 9427 0820

Please submit all articles, letters and advertisements to the above email address.

SUBMISSION FORMATS

Text: Word Files (Please DO NOT EMBED pictures in Word, supply as separate files.)

Pictures, Logos, Maps, Diagrams: Resolution 300dpi. Photoshop EPS, Tiff, Jpeg or press-optimized PDF files in Grayscale/Bitmap. Please provide images of all pictures separate to text. Please EMBED ALL FONTS in EPS and PDF files.

ADVERTISEMENTS

AIG News provides an ideal opportunity to advertise your company and services to the AIG membership throughout Australia (and some overseas). There are about 1,300 members who receive the newsletter four times per year. Please contact the Editor for further details or to book advertising.

Prices are inclusive of GST

Size (Dimensions – w x h)	**Per Issue**
Full page (188 x 264 mm)	$545
Three quarter page (188 x 200 mm)	$458
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Third page (188 x 90 mm)	$273
Quarter page (188 x 75 mm or 90 x 130 mm)	$198
Business card - Members (90 x 55 mm)	$25
Business card - Non Members (90 x 55 mm)	$125
Inserts	
Pre-printed (1 page)	$453
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Pre-printed (3 or more pages)	By negotiation and weight
Including printing	By negotiation

Note: All advertisements are mono, no bleed.

The **AIG Website** in currently undergoing a major update. Comments on content suggestions or new features should be directed to Andrew Waltho (andrew.waltho@bigpond.com

AUSTRALIAN INSTITUTE OF GEOSCIENTISTS
Supporting Geoscientists