Women in Mining
It’s 2020 why have we not done more?

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Microbes, viruses and geological processes

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Geoscientist Employment Improves in Australia

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Geotourism - Help spread the word in the community

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Mine to plant reconciliation
FAST FACTS

THEME
THE CRITICAL ROLE OF MINERALS IN THE CARBON NEUTRAL FUTURE
The meeting will feature presentations on topics related to mineral deposit research, exploration, sustainable development and environmental and social aspects related to mineral deposits.

WHEN
15 – 18 November 2021, plus pre- and post- conference field trips and short courses.

WHERE
Rotorua Energy Events Centre in Rotorua, New Zealand.

WHO SHOULD ATTEND?
delegate representation includes academia, industry, government research organisations, consultants and service providers.

KEY DATES

CALL FOR SUBMISSIONS – DEADLINE 2 NOVEMBER 2020
The Organising Committee are calling for proposal submissions for pre- and post-conference short courses and field trips. Visit the conference website or contact sga2021@confer.co.nz for more information on submitting a proposal for consideration and inclusion in the 2021 programme.

CALL FOR ABSTRACTS – OPENS 2 NOVEMBER 2020

EARLY EARLY-BIRD REGISTRATION – DEADLINE END DECEMBER 2020
Register before the end of December 2020 and receive a further discount on the Early Bird rate. Visit the conference website for more information.

PROGRAMME HIGHLIGHTS

The Technical Programme will consist of four days of oral and poster presentations with themes including:

• Ore forming processes
• New research and exploration developments
• Sustainable mining and environmental issues
• Specific mineral systems
• Geometallurgy
• Social license

FIELD TRIPS: Visit the conference website for more information on the provisional field trip options available, including locations in New Zealand, Australia, Indonesia and New Caledonia.
Inside this AIG News...

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September 2020

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56 AIG Council & AIG News
2020 will be a year remembered for a range of reasons. The COVID-19 pandemic continues to disrupt life to varying extents in different parts of Australia and internationally, making it more difficult to connect with family and friends, and almost without exception, changing the way in which we work.

The advent of electronic communications, particularly video conferencing, using laptops, tablets and smartphones, has certainly made a difference by enabling learned societies, professional institutes, universities and research organisations to maintain contact with members, stakeholder and the public. AIG’s experience, on the whole, has been a positive one with branch committees able to reengage with members across Australia and internationally. This has benefited members living and working in regional areas or outside Australia by enabling them to access technical talks, seminars and short courses that, in past years, have only been offered to attendees able to be present in person. Some branches have been able to resume face to face activities, which is great to see as there is no substitute for being able to meet friends, peers and colleagues, to talk about things of interest in a way that on-line meetings don’t provide. I’m confident, however, that on-line meetings will become a permanent feature of AIG’s events calendar due to their ability to reach out and engage with a greater segment of AIG’s membership and to maximise opportunities to access speakers.

By the time you read this, AIG’s new website should be on-line or be just around the corner. Feedback from members has been used to deliver a new website that provides access to all features with a single login and increases the range of content available exclusively to members.

This issue of AIG News also announces AIG’s first special interest group, championed by Neil Fordyce and focused on geoscientific data management. This is an important field that touches almost every aspect of the work that professional geoscientists undertake, and has rapidly gained additional prominence with the advent of data analytics technologies, designed to draw disparate data together in a way that helps to create new insights. “Big data” has become a catch phrase. Few mention, however, the need for “consistent data” and “quality data” that need to be pursued with equal passion if analytics are to deliver real insight. Again, this initiative is intended to bring members with common interests together, to promote continued professional development through promotion of best practice and innovation and provide learning opportunities for early career geoscientists.

AIG has also partnered with Ok Tedi Mining Limited to produce a volume commemorating the 50th anniversary of Ok Tedi’s discovery through capturing the stories of those involved in early exploration, discovery of the deposit and the subsequent commissioning, operation and contributions to the mine’s resource base through ongoing exploration in the region, with
From your President

contributions spanning multiple disciplines. The book really points out how major discoveries represent the work of teams and the persistence needed to make discoveries, which I’m sure members will both enjoy and find interesting. Mike Erceg and team have done a great job of capturing and preserving the stories included in the book. Copies are now available through the AIG website.

There are two major issues facing our profession at present. The process of updating the JORC Code, last revised in 2012, is about to commence after considerable planning by the JORC Committee comprising representatives of the three JORC parent bodies: AIG, AusIMM and the Minerals Council of Australia. Initial consultation with major external stakeholders and regulators including the Australian Securities Exchange (ASX), Australian Securities and Investment Commission (ASIC) and other industry groups will soon be accompanied by broader consultation in which all workers in our mineral resource industries need to express their opinions on the future direction of the JORC Code and improvements needed to ensure it remains a principles-based standard of best practice for the reporting of exploration results, Mineral Resources and Ore Reserves. JORC needs to keep pace with developments affecting the mineral resources industries on both financial and social fronts. The information included in exploration results, Mineral Resources and Ore Reserves reports need to be accessible to all investors, not just informed investors and analysts as previous versions of the code have stated and, arguably, include realistic assessments of the opportunities and risks presented and faced by projects respectively. Maintaining and further building investor trust is central to being able to access capital necessary to explore for and develop new resources in an efficient and responsible manner. The New South Wales government, in recent weeks, has introduced new competency requirements for exploration managers, required to support applications for, and renewal of exploration and mining licences in that state. We shouldn’t see this sharper focus on competence as being a one-off event. I will be very surprised if it does not emerge as a major theme during
the JORC update process. Be ready to express an informed and considered view when the consultation process commences in the next few weeks.

The other challenge facing geoscience in Australia is the changing focus of some universities, moving away from “traditional” or “core” geology and geoscience education to courses that are more broadly focussed, offering Earth science subjects that offer broader insight into aspects of our planet without providing the necessary knowledge to understand Earth as a complex web of inter-related systems operating on vastly different timescales. I’ve heard some of the new courses described as physical geography rather than geology. This situation creates a risk of some future graduates lacking fundamental geological knowledge required to work effectively in a range of fields, extending beyond exploration and mining to areas including groundwater management and contaminated site remediation. It may be, ultimately, that we need to add a competence and knowledge overlay to AIG’s membership requirements of a relevant degree as membership pre-requisites.

Universities operate as businesses and aren’t avoiding teaching of aspects of geology by choice. Subjects being taught are designed to satisfy the requirements of courses being sought by students. We need to be equally conscious, however, of the fact that many students undertaking undergraduate geology studies gain their first exposure to geology at university and pivot to geology from other science courses in

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**From your President**

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**APEX**

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AIG News Issue 141 September 2020
which they initially enrolled. There are groups working hard to improve geology teaching in Years 11 and 12 at high school where geology remains on the curriculum in all states, but teachers need the confidence to deliver classes.

A competency-based framework for P.Geo accreditation has been in operation in Canada now for a number of years. The experience gained there, where needs are arguably quite similar to Australia’s, we can use to our benefit. The approach has the benefit of making the competencies required to be a geoscientist clear. Where gaps exist micro-accreditation could be used to fill the gaps through education offered by both universities and other providers. Tertiary course accreditation is also an option, but proved to be onerous and difficult to keep current in Canada. I expect that the same issues would prevail here.

An additional benefit to a competency-based framework would be a more transparent means of accepting membership applications from geologists who have studied overseas, especially in countries where English is not the first language and guidance on how courses compare with those offered in Australia offered by government and other sources is incomplete.

There will clearly be a lot to think about in the remainder of 2020 as both the JORC update and consideration of geoscientist competency issues progress. Your thoughts, ideas and suggestions are, as always, especially welcome. Please participate in the discussions which will shape the future of our profession.

Andrew Waltho
President
The Australian Geoscience Council is offering a scholarship to provide financial support of $5000 per annum for a full time student to finish their undergraduate degree. The scholarship is available to those Indigenous students who have completed at least the first year of their university course and intends majoring in a field of Geoscience.

For those who want more, details of the scholarship are listed on our website - www.agc.org.au as well as Aurora’s - www.indigenousscholarships.com.au.

The ADIA have been working to increase the number of online industry courses and are pleased to open their newest: Exploration Drilling for non-drillers course.

This course is ideal for those working in mining or exploration companies or geological consultants who need to broaden their knowledge on the different drilling types and techniques.

This is a self-paced, online course with an open-book assessment at the end.

Course information can be found on our website: https://www.adia.com.au/advocacy/online-industry-training-courses

Mineral Exploration Services
ABN: 28 069 772 384

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“Wearing out boot leather finds mineralisation first step to an orebody.”

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“Wearing out boot leather finds mineralisation first step to an orebody.”
**Webinars support minerals exploration success**

Join us at the latest GSQ and UQ collaborative webinars to learn about new data, techniques and information with the potential to boost minerals exploration success in Queensland.

The free webinars are presented by experts from industry, academia and government, each offering unique insights, interpretation and advice.

**Book your place**

Webinars take place monthly and culminate in a face-to-face workshop in Mt Isa in November.


**Digging Deeper takes a break**

Digging Deeper – the Geological Survey of Queensland’s annual geoscience and exploration conference for industry – will not take place in 2020. The event is most effective as a collaborative, face-to-face gathering of geoscience and industry leaders from across our state and beyond. Covid-19 restrictions make it very challenging to deliver a best-quality event of this type in 2020.

In the meantime, we will be stepping up a range of other knowledge-sharing opportunities, to ensure industry and researchers can easily access the latest Queensland geoscience research (led by GSQ and our university partners), thinking and support.

Some key upcoming opportunities are GSQ and University of Queensland (Sustainable Minerals Institute) collaborative webinars – find out more above.

**A new era for geoscience data discovery and industry reporting**

The new GSQ Open Data Portal and GSQ Lodgement Portal are now available to use.

The GSQ Open Data Portal allows you to search and download the following via a world-class data repository:

- all open-file geoscience data held by GSQ (replaces QDEX Data)
- all open-file statutory reports held by GSQ (replaces the report searching function of QDEX Reports).

No registration is required. View the tutorial video.

The GSQ Lodgement Portal is a streamlined and secure way to lodge statutory reports and notices to DNRME. It replaces the report submission aspect of QDEX Reports.

To use the lodgement portal, you need to have a QGov account.

Recycling the Exploration Cycle

The Exploration Cycle was originally discovered around the turn of the century on a property in northern Victoria, sharing a paddock with the Mad Mare and Dolly the Sheep. It made its way into the pages of a long-forgotten issue of AIG News, then dropped out of sight for a couple of decades. It resurfaced recently in a drawer full of old photos in an apartment in Lima, Peru.

It seems appropriate to take another look at the Exploration Cycle in these fraught times. As the photo shows, its features include:

- Large, sturdy front wheel for negotiating exploration tenement backlogs
- Contemporary ‘downturn’ frame design
- Trainer wheels for re-training out-of-work geologists

Multiple seats are provided for parliamentary steering committees, but it should be noted that the steering wheel is firmly welded to the front wheel and exerts no directional control. If attempts are made to steer the Exploration Cycle it will go round and round in circles until it flies completely apart.

If ridden carefully, the Exploration Cycle will carry us forward to Exciting Exploration Opportunities and Highly Encouraging Drill Intersections. However, the Exploration Cycle has no aquatic capability. If it is used to try and ride the Second Wave or navigate the Shoals of a Recession, it will become lost in Uncharted Waters, capsize in the Wake of a Minerals Boom, or founder under the weight of accumulated clichés.

Dave Shatwell
FAIG
Discoveries in the Tasmanides:2021

A Mines & Wines Event
Orange NSW 8-10 Sept 2021

The Discoveries in the Tasmanides 2021 conference will present an exciting program of exploration and project case histories from the Eastern Australian Tasmanides. This 2021 conference, the eighth in the series will feature exploration and project geoscience presentations with a Tasmanides focus. Presentations are invited from explorationists and project/mine geoscientists. The speaker program is supported by contextual, big picture presentations from invited speakers. Registration is relatively inexpensive and student registration is particularly encouraged. To keep faith with the banner themes of the conference, wine tasting and winery visits are features of the event. The wine theme is supplemented by a mines-related field excursion, short courses, suppliers’ booths, and a stunning set of conference presentations. Mines and Wines is an opportunity for young geologists to share the geoscience challenges of their projects with their peers. It is also a feel-good event which celebrates the profession and engenders exploration networking. The conference will commence with a one day field excursion to some key mineral deposits in the Orange region. There will be the very popular conference dinner on Thursday night and the usual Wine Tour in the Saturday following featuring some of the top wine makers of the terroir.

For more information please visit the Mines and Wines site here https://minesandwines.com.au/
New NCGRT Director

Professor Peter Cook has been appointed interim Director of Flinders University’s National Centre for Groundwater Research and Training, following Professor Craig Simmons’ secondment to the Australian Research Council.

An internationally renowned groundwater scientist, he was the US National Ground Water Association’s Darcy Lecturer for 2009, the first scientist from outside North America to receive this honour. His research covers groundwater flow, estimation of aquifer recharge and discharge, groundwater and land salinisation, groundwater-dependent ecosystems, and water resource assessment and management for irrigation, mining and unconventional gas developments.

He has collaborated with government and industry throughout Australia, and has been acknowledged as Australia’s Field Leader in Hydrology and Water Resources by The Australian.

“The NCGRT has developed an excellent reputation for the quality of its research and has been a groundwater leader within Australia. Craig Simmons has done a fantastic job over more than 10 years to get the Centre where it is today. But we still need to bring research and industry closer together, and this will be my main goal over the next few years.” Professor Cook said.

AIG congratulates Professor Cook on his appointment.
Latest mineral exploration statistics contain positive news

Mineral exploration expenditure, in real terms, rose 11.9% ($72.7m) to $683.3m in the June quarter 2020. Brownfield exploration expenditure rose 17.5% ($67.5m) while greenfield exploration expenditure rose 2.4% ($5.3m) compared to the March quarter. Exploration drilling metres drilled rose 10.8%. Drilling on greenfield targets rose 5.6% and brownfield drilling metres rose 13.7%. Again, the seasonally adjusted figures fell 13.2% in the June quarter.

The real increases in both brownfield and greenfield exploration expenditure and exploration drilling are seen as having positive implications for geoscientist employment in the exploration sector. The June quarter Australian geoscientist employment survey results, released during August, confirmed this with the unemployment rate recorded by the survey improving from 10% and the end of March 2020, to 8.6% at the end of June. More than three-quarters of Australia’s geoscientists work in mineral exploration and mining.

The next Australian geoscientist employment survey will launch 30 September.

Seasonally adjusted expenditure was less positive, falling 6.8% ($48.3m) to $665.0m in the June quarter 2020. The largest contributor to the fall this quarter was Western Australia (down 7.8%, -$33.3m).

ABS mineral exploration expenditure, June 2012-June 2020

This will be the 8th incarnation of this iconic and unique event and will attract about 250 registrants including project geoscientists in the mining and exploration industry, service providers, plus government and academic specialists.

This conference is renowned as a forum for exploration and mine case studies as well as scientific advances in understanding the tectonics and metallogenesis of the Tasmanides.

Mines and Wines is about presentations by geoscientists for geoscientists.

YOU are Invited to this Iconic event!

For Information and updates visit www.minesandwines.com.au
Covid-19 Virus Willing...

**Short Course – Sydney**

**EPITHERMAL Au-Ag and PORPHYRY Cu-Au EXPLORATION**

16 & 17 FEBRUARY  Chatswood Club, 11 Help Chatswood (5 mins walk from Chatswood train station) lunch, morning and afternoon teas provided. Two days of PowerPoint lectures focus upon mineral exploration for epithermal and porphyry ore deposits derived from Dr Corbett’s 40 years field experience, including short courses provided with the late Terry Leach from the early 1990’s. Exploration and mining examples from over 40 countries are used to delineate the characteristics of different epithermal and porphyry ore types, and controls to mineralisation, using tools such as alteration, structure and breccias. A final section considers geological features recognised in exploration marginal to ore bodies. Participants will be provided with exercises to test yourselves and a current draft of the new short course notes. Early drafts of the first few chapters are available at: http://corbettgeology.com/Publications/.

18 FEBRUARY  A practical exercise held at the W B Clarke Geoscience Centre, Londonderry, uses diamond drill core and geological specimens referred to in the lectures (above), to provide hands on training in ore and alteration mineralogy and the use of geological models. Greg is helped by and Stuart Hayward, who has over 30 years experience in epithermal-porphyry ore deposit exploration and mining. Return bus from Chatswood and lunch provided.

Prices include handouts, lunch, morning and afternoon teas and transport to and from Londonderry. Minimum of 20 participants required and limited to a maximum of 40.

**Employed geologists** from $1500 + GST

**Unemployed geologists** from $400 + GST

**Students** $150 + GST but if you need assistance contact greg@corbettgeology.com

**Registration**  www.corbettgeology.com/short-course
Dates & Times

All webinars will be presented over two days, 2 hours per session.

**East Coast Webinar Times** 10-12pm (AEDT)
- Workshop 1 - Introduction: Wed/Thu 18 & 19 Nov
- Core module for Workshops 2,3,4: Tue 24 Nov
- Part 2 of Workshop 2: Wed 25 Nov
- Part 2 of Workshop 3: Thu 26 Nov
- Part 2 of Workshop 4: Fri 27 Nov

**West Coast Webinar Times** 2-4pm (AWDT)
- Workshop 1 - Introduction: Wed/Thu 18 & 19 Nov
- Core module for Workshops 2,3,4: Tue 24 Nov
- Part 2 of Workshop 2: Wed 25 Nov
- Part 2 of Workshop 3: Thu 26 Nov
- Part 2 of Workshop 4: Fri 27 Nov

Registration

Registration is now open at aig.org.au/events/jorc-workshop-web-2020

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The deadline for registration is two days prior to the commencement of each workshop.

Attendees have the option to complete an online assessment to receive a certificate of completion for each workshop. Please see the registration form for details.
Institute News
QLD Branch Report

QLD Branch Report
Peter Caristo
QLD Branch Chair

AIG-ALS Technical Meeting Series

The challenges of 2020 continue with the gift that keeps on giving (COVID-19) wreaking havoc with our plans! While things have generally improved in Queensland, requirements in public venues still make it difficult to hold events with networking, and as such the face-to-face AIG-ALS monthly technical meetings remain to be broadcast across the ether via ZOOM only until we can provide a quality event. On the plus side – our meetings now have a far wider reach, and judging by attendances has been widely appreciated, with many “dialling-in” from interstate and off-shore.

Since the last update we have had presentations from Cam Switzer on gold mineralisation in the Chillagoe district, Scott Halley shared his considerable knowledge on Calculating quantitative alteration mineralogy from assay data (never before presented!), and Thomas Jones updated us on some of his research into microbe – mineral interactions. And by the time you read this Stuart Hayward would have updated us on the geology and mineralisation of the Misima Gold deposit in PNG.

The final two presentations in the AIG-ALS Technical series will be from Craig Feebrey on the Wharekirauponga (WKP) low-sulphidation epithermal gold deposit in the Waihi district (NZ) and Mike Erceg will close off the year with a local QLD talk on the Briggs copper porphyry deposit.

The RPGeo E-forums which are an initiative of the Queensland branch this year have been quite well received. Since the last update we have run E-forums on Geophysics, Mineral Exploration, Geochemistry, Hydrogeology, Information Geoscience and Coal. As mentioned previously, we aim to cover all RPGeo disciplines with Petroleum and Mineral Resource Estimation already planned for this year with more to come. Initially scheduled as a twice-monthly offering, we have dropped them back to monthly as webinar fatigue sets in. These E-forums will continue as on-line only offerings post Covid-19 times! A special thank you to all those who have helped organise these including Mark Berry, Jane Harvey, Mark Pirlo, Chris Dickson, Christine Brown, Kane Maxwell, Kat Gioseffi and Rod Carlson. With more disciplines to organise, help from experts in those fields is always appreciated!

We continue to plan for a time when networking is possible again with investigations into running the QA/QC in Mining and Exploration Seminar for later this year well advanced. And ever hopeful, we are looking into organising and booking the 2020 Christmas Party with the hope of actually holding it in 2020 – because quite frankly we all deserve it!!!

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Due to the concerns over the Covid-19 pandemic, the Tasmanian branch continued to suspended it’s first face to face meetings and events until July.

The branch held it’s first GeoPub in many months on the third Thursday of July. Although the turnout was small, it was good to see geophysicists – including a current honours student, make up half our numbers.

Another small GeoPub was held in August.

The committee have a modest forward program to see out the year – all contingent on no further outbreaks.

For the September GeoPub we have planned a double bill – a lecture by distinguished Professor Ross Large on “History of Atmosphere Oxygen and timing of basin-hosted ore deposits” and a presentation by Dr Jodi Fox “What lies beneath: Volcanoes and the Antarctica Ice Sheet”.

The Tas branch are jointly hosting the annual Tasmanian Geological Symposium in early December. The event will be held in Strahan and comprise a day of lectures and two (hopefully) post conference field trips.
The Victorian Committee has been quiet of late due to statewide limitations on movement and non-essential activities. Some committee members have also been quite busy due an up-tick in gold exploration.

The lack of local face to face events has, to a large degree, been replaced by an array of online talks and webinars from interstate branches, affiliated organisations, and industry. Considering our resources and not wishing to duplicate effort, the Victorian Branch has come up with the following initiatives which it hopes to implement over the coming months.

1. A Geo Quiz. The committee is currently preparing the quiz questions and details will be available in due course. We will also be asking AIG members to contribute to quiz development by completing a survey on Survey Monkey. We’d like to acknowledge the recent IAH /NGC Trivia Quiz. While not the original inspiration for this event they have blazed the trail and we hope to be just one of many to follow.

2. Field Kits for Second Years Geoscience Students. Given the current lack of field trips and conferencing opportunities we have decided to invest our unused travel grant funds into the development of a field kit for second years geoscience students at Victorian Universities. The content of the kits will in part depend on the degree of sponsorship but at a minimum we propose to include among other things a scribe, swing magnet, waterproof notebook, scale rule, hand lens, and clutch pencil.

3. A series of one-hour online presentations on geospatial software developments. Acknowledging that many people don’t have time for full day or half day courses we have asked a number of consultants to prepare one hour webinars primarily focussing on the latest updates and tools for a number of commercial and open sources software packages. Again, this is in early days of development and we hope to have more details in due course.

4. 10-15 minute presentations for the AIG You tube channel. We are seeking brief presentations from Victorian members for posting on the AIG You Tube Channel. These presentations could be a mixture of slides and video and should relate to some aspect of geology in Victoria. We would ultimately aim to present a number of clips in a Zoom session with an opportunity for Q&A.

The Mentoring program continues as a distance program. Face to face meetings may occur when COVID restrictions permit but no group gathering have been planned. This year Victoria only has 2 mentees and one mentor, which is a
significant drop on previous years. This drop in numbers may reflect the lack of face to face events and the relatively small cohort of young geoscience graduate based in Victoria. We hope after 4 years we haven’t exhausted the pool of potential participants and that post COVID we will see a reinvigoration of this key program.

The annual Victorian Minerals Round-up is on hold for the time being. A Victoria Gold Mining and Exploration Forum was held online on 27 August by Informa. A prohibitively priced event, it was probably tailored towards well attired and cashed up investors (no aspersions on geologists’ attire as plaid is back in fashion). As such we feel there is room for a more economical and geology focused Round-up when conditions are safe for large gatherings. What that looks like is uncertain. If it is to be social distanced, with temperature checks, masks, limited speakers, limited numbers, no happy hour, and require recent COVID tests or vaccination records then it may not happen. Still, we live in the hope that one day we will be free to breath on each other once again. Just be sure to suck a mint and chew with your mouth closed.

The annual Victorian Minerals Round-up is on hold for the time being. In the meantime, a Victoria Gold Mining and Exploration Forum was held online on 27 August by Informa. This event was priced for executives rather than the shop floor so we feel there will still be room for a more economical and geology focussed Round-up when conditions are safe for large gatherings. What that looks like is uncertain. If it is to be social distanced, with temperature checks, masks, limited speakers, limited numbers, no happy hour, and require recent COVID tests or vaccination records then it may not happen. Still, we live in the hope that one day we will be free share a beer and breath on each other once again.

- Petrophysical data acquisition and analysis
- Geophysical data acquisition
- Geological review and forward modelling
- Speciality 2D and 3D survey planning
- Supervision and QA/QC of data acquisition
- 2D and 3D modelling and imagery
- Geological integration and interpretation
- Target generation and prioritization
- Drillhole database management

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This year the AIG Bursary Program received applications from 24 geoscience students from 7 universities. The AIG Education Committee is currently in the process of finalising the review of the applications, and this year’s awards will be announced in the November issue of AIG News.

While the number of applications is up on last year, the number of universities represented has dropped. Has the move to online teaching and remote learning reduced student engagement at some universities? Or is this, perhaps, because some universities are reducing the options for degrees with a geoscience major? At the moment the tertiary geoscience sector seems to be unsettled and undergoing some fundamental shifts (while also dealing with the changes imposed by COVID-19). Some universities are restructuring and rebranding degree courses and, of most concern, some are reducing the emphasis on core geoscience subjects or removing them entirely.

The fundamental changes that are occurring in some geology degrees has ramped up the volume of conversation about geoscience education in Australia, and the impact of the changes on graduate knowledge and competencies. Recently, the University of Newcastle announced it will not be offering a geology major from 2021. In response to this announcement, in early September, the Queensland Exploration Council (QEC) hosted an online event about the Future of Geology Studies in Queensland.

The QEC event comprised presentations by senior academics from the three Queensland universities that offer geoscience programs. The academics provided brief updates on the status and future of the programs at their respective universities (Queensland University of Technology, James Cook University, University of Queensland). Although the speakers could only provide brief snapshots of their programs and the external and internal challenges that face their geoscience departments in the time available, it was a valuable exercise that promoted discussion between the universities, employers of graduates, and professional bodies.

I don’t know if similar events have been held in other states, but would appreciate hearing from members if they have, or are being planned. I would also encourage members to urge their relevant state organisations (e.g. chambers of mines, professional bodies, universities) to promote and facilitate ongoing discussion about the future of geoscience education in Australia.
Membership Updates

April 2020

STUDENT
BARTLETT, Ryan • BENSON, Richard John
• DOHERTY, Jason • EDWARDS, Dariarne
• FISHER, Eliza • KABARAN, Eileen Janice
Leyla • KITCHENER, Brett William • MCMAHON, Keely Louise • MACEY, Adrian
• MORAN, Nicholas • PATRIZI, Francesco
• ROM GUSTAFSSON, Sandra • SMITH, Madison • SPEAKMAN, Ben Michael John • WILSON, Olivia

GRADUATE
GRIEVE, Duncan • HIN, Stuart • JOHNSON, Graham • JONES, Harrison • KENWORTHY, Charles • SOMMERFELDT, Schone • VERDUGO-IHL, Max Robert • HIN, Stuart • VIEY-CHEVALIER, Alyzee Emma Marie

MEMBER
ALLEN, William James • AVCI, Serdar Onur • DE JOUX, Andrew James • HUGHES, Adam • LEDWIDGE, Peter Francis Rene • LEES, Christopher Michael • MORAN, Timothy James • MURRAY, Amberly Louise • OVERALL, Dale Keith • QUEEN, Lawrence Dechard • MURRAY, Amberly Louise • RAYSON, William Alexander • SNARE, Andrea Diane

FELLOW
KAMENSKIV, Nikolayb • WATSON, Justin Troy

June 2020

STUDENT
BRENNAN, Heather • HIGGINS, Marissa Catina • LU, Maria Loraine Dela Rosa

GRADUATE
AIAD, Marina Moreira • CAMPBELL, Matthew James • DWIGHT Thomas • GARDNER, Elise Nicole • HIND, Sebastian • LOIDOLT, Christina • OBERLAND, Adrian • OPPELAAR, Jamie • SHAND, Fraser • STEVENSON-VISSERS, Thomas Alexander • WRIGHT, Thomas

MEMBER
ALEHASHER, Seyedsajad • BADOCK, Stuart • BANKS, Andrew • BELL, David Francis • OORSCHOT, Christopher William • WALLIN, Elizabeth

FELLOW
LAWRENCE, Ronald James • REDMAN, Andrew Philip

ASSOCIATE
KING, Alastair

July 2020

STUDENT
IVES, Barbara Ann • SPALDING, Steven Keith • YANG, Analissa

GRADUATE
BOWMAN, Claudia Renee • CARUSO Alicia • DWIGHT Thomas • NAZWAD, Sizah • VILLANUEVA Jose Miguel

MEMBER
ALI, Sader Hassan • CALAIS, Janice • CAMILLE, Ristch • CHESELL, Duncan Charles • CLIFFORD, Neil John • CUMMING, James Robert • DORAN, Daniel • HAYNES, Katherine Estelle • ILA’AVA, Malai • LITTLE, Esther Elisabeth • PATON, Christopher Ian • SLOO, Nicholas Tibyabo • SPARKS, Darren Jamesn • VELEZ, Gustavo Baltazar • WILLIAMS, Gretchen Caroline

FELLOW
BUTERA, Kristin Michael
Microbes have ruled Earth's biosphere since life began. The community of microbes — bacteria, fungi, archaea and protists — also includes viruses. Even though they are not cellular life forms, viruses are considered as microbes because of their microscopic size.

Microbes are jam-packed in sea waters, with bacteria and viruses estimated to comprise nearly 90% of the weight of all marine creatures. They carry out crucial tasks in aquatic ecosystems, recycle nutrients and shape the planet's climate. Although they are seldom friendly to each other, they rarely bother swimmers and surfers.

Bacteria are the oldest known life form. Bacterial remnants have been described in the 3.4 billion year old Strelley Pools formation in WA and in the 3.7 billion year old Isua Greenstone Belt in southwestern Greenland. Although numerous occurrences of bacterial mats and mounds (stromatolites) have been described in Archean and Proterozoic strata, the existence of viruses in these ancient ecosystems has not been determined.

Viruses vastly outnumber other microbes. A survey of all current living organisms would likely demonstrate that viruses outnumber everything else by more than ten to one: just one cup of sea water contains as many as one billion viruses!

They are constantly seeking to parasitise algae and bacteria, which in turn rely on countermeasures for protection.

Both bacteria and viruses play a variety of roles in geological processes.

**Bacterial contributions to ore genesis**

Bacterial influences on ore-forming processes are many and varied. They include:
- bacterial activity in oil and gas reservoirs
- coal seam gas — microbial methane generation may be one of the main processes responsible for the accumulation of methane in some coals
- phosphate deposits — fossilised bacterial remnants represent polyphosphate use by sulfide-oxidising bacteria that precipitate apatite
- polymetallic sea floor nodules and surfaces — bacterial biofilms are important facilitators of deep water manganese deposits
- gold biomineralisation — Cupriavidus metallidurans can extract trace elements from compounds of heavy metals to form tiny secondary gold nuggets.
Bacterial sulfate reduction is an important process in the creation of some large, secondary sulfide deposits, such as the Las Cruces copper deposit in Spain. Here, colonies of sulfate-reducing bacteria assisted copper sulfides to precipitate nanometer-sized crystals of covellite, which became embedded in the polymeric compounds that encapsulate the microbes. These crystals have coalesced to form copper-bearing veins.

Metal-processing bacteria may hold the key to many future mineral discoveries, as well as to more efficient treatment of ores, mine tailings and recycled electronics.

**Virology and paleovirology**

A typical virus is a small piece of genetic material consisting of nucleic acid (RNA or DNA) enveloped by a thin protein cover. Viruses are only 20–400 nanometres in diameter: smaller than the majority of bacteria and most other microbes.

Most theories on virus origin assume that cells existed before viruses, and that viruses evolved in the presence of cells. However, recent studies have indicated that viruses may have been self-sustaining before cells developed. Over time, these ancient forebears may have evolved into cell-like entities.

Viruses are fanatical thieves, taking genetic fabric from multiple cells including bacterial, archaeal and eukaryotic. Because every virus appears to be focused on a fixed pathway of entering a living cell, hijacking its metabolic system and multiplying, they are the most abundant biological entities on earth and have adapted to almost all environments.

Microbiologists are yet to understand how cell-based life came to co-exist with such an astounding range of viruses (known as the virome).

In a recent, far-reaching, five-year study of an off-shore Californian battleground comprising armies of microscopic organisms, researchers at the University of Southern California have found marine virus communities that are relatively stable. Almost 95% of the same virus species were identified in most samples, and these persisted over time and across a variety of locations. Importantly, within each virus species, mutations were constantly occurring — but each new mutant virus strain dominated the population for only a few months. To survive, the viruses continually adapted to keep one step in front of bacterial defenses.

The field of paleovirology has accelerated this century, driven largely by swifter genetic sequencing and the need to understand and control sweeping human viral diseases such as influenza, Ebola, Zika, HIV/AIDS and COVID19. The last decade has witnessed titanic advances in our ability to precisely edit DNA, mostly because of the identification of the Crispr-Cas9 system. This unique technology enables geneticists and medical researchers to edit parts of the genome. Interestingly, some bacteria employ Crispr-Cas9 as an immune system, because it allows them to store pieces of virus DNA, identify similar viruses and then destroy the virus DNA.
Knowledge of virus species and their influences and activities prior to human history are rare, although recent investigations have extended the time range of some known viruses. For example, studies of hepadnavirus — a virus group that includes hepatitis B, and is embedded in the genomes of modern songbirds — have revealed that they have been around for at least 19 million years and possibly as long as 82 million years. This is considerably longer than the several thousand years that researchers had previously estimated, but still hardly a scratch in geological time.

Paleovirology, in particular the influences of virus activities in the formation of rocks and mineral deposits, is an open door for geoscientists eager to make new and far-reaching discoveries: not only for planet Earth, but elsewhere in the universe. Development of effective virus-detection techniques, speedier virus sequencing and closer understanding of virus–bacteria paleoecology are therefore imperative for a clearer understanding of virus contribution to the geological record.

**Viral contribution to geology**

Nobody has yet dug up an ancient virus fossil, and there is no known evidence of viruses in the rock record. In fact, scientists don’t really know how to look for fossilised viruses. Because of their minute size and absence of preservable metabolism, viruses are unlikely to form significant deposits in their own right. However, their actions may have been important to ecosystems and geological processes.

Diatoms (near-surface marine algae) are considered to have contributed as much as 20% of the planet’s oxygen, so virus interactions with these microorganisms could have substantial ecological implications. A study recently reported in Nature Microbiology found widespread virus attacks on diatoms that resulted in considerable changes to marine microbial ecosystems. Accelerated and wide-scale diatom mortality can modify carbon cycling and influence the atmosphere. Under conditions of low ocean silica, diatoms are more likely to be infected and killed by virus blights, which will accelerate the release of their remains and debris into surface processes.
Microbes, viruses and geological processes

Ocean waters. Silica shells (frustules) of dead diatoms sink, making their nutrients, carbon and organic matter unavailable for near-surface recycling. Diatomaceous earth and many other siliceous sediments in the rock record contain frustules, and accelerated virus attacks may have occurred at the time some of these strata formed.

Viruses may be overlooked in many other rock-forming processes, particularly within carbonate sequences. Extensive evaporative flats at the Mesaieed sabkha in Qatar have been described in detail by microbiologists, who have found an intricate link between viruses and carbonate formation. Following saltwater incursions and dry periods, microbial mats in shallow depressions of the sabkha harden, and their surfaces crack and shrink to form saucer-like polygons. In the black sabkha sludge, built by bacteria over thousands of years, top layers flourish in sunlight, whereas older, buried layers lithify into carbonate sediments (microbialite). Researchers suggest that instead of just preying on the bacteria in the mats, viruses are integral to lithification and mineral-forming processes. They are exceptionally abundant in microbial mats, with some sabkhas reported to contain up to 28 billion viruses per gram of mat material.

Although less than 20 cm thick, the modern day stromatolites in the Mesaieed sabkha have taken 6 000 years to grow. The bacteria in the top layers of the mats are photosynthesising. They produce bicarbonate, which reacts with calcium and magnesium to form minute calcite and dolomite crystallites. This bacterial carbonate production is unlikely to occur at a sufficient rate to convert a mat to stone: a catalyst is necessary to nucleate the crystallites. Detailed transmission electron microscope images of sabkha substrata at Mesaieed show threadlike, extracellular polymeric substances encasing bacterium. These tiny nanospheres appear to be viruses coated with calcium or magnesium minerals. Since viruses have a tendency to acquire a slightly negative charge, electrostatic attraction may have drawn these crystallites together to coat virus structures with positively charged calcium or magnesium ions.

Chemical residues, such as lipids, may also help determine the planet’s viral history. Lipids are molecules with extended carbon chains that, in some settings, can persist for millions of years. Furthermore, lipids in lipid-containing viruses are distinct from the lipids in their hosts. Studies seeking virus bio-signatures within silica-coated inclusions from active and ancient geothermal deposits have been progressing for some time, but despite considerable research no fossilised virus remnants have been isolated.
Assessing the variability of estimates produced by expert geoscientists

Rhys S. Davies
Allan Trench
David I. Groves
Michael Dentith
Marianne. J Davies and
John P. Sykes

Despite increased expenditure, the rate of discovery of new mineral deposits has decreased since the beginning of the 21st century. As ore deposits that are exposed at surface or have surficial geochemical footprints are depleted, targeting below deeper, more complex cover is recognised as key to opening up new search-spaces and re-invigorating exploration success. In exploring beneath cover, existing techniques and technologies are reaching maturity, as direct-detection exploration methods are costly and are providing limited success. Future exploration targeting is likely to be conducted in a more predictive manner, requiring the application of concept-based approaches. Predictive exploration targeting requires explorers to estimate the potential of each search space for hosting undiscovered mineral deposits, prior to the application of direct-detection exploration methods, and is seen as critical to successfully taking mineral exploration under cover.

This article discusses findings published in an open-source research paper, in the journal *Ore and Energy Resource Geology*. The paper compares the results of two identical United States Geological Survey’s (USGS) Three-part Undiscovered Mineral Resource Assessments, in which participants were asked to predict undiscovered gold endowment by assessing orogenic gold mineral systems within the Sandstone greenstone belt of the Yilgarn Block, Western Australia (Figure 1). For the initial study, the participants consisted of a group of expert geoscientists, with at least ten years of relevant industry experience. The participants of the second study comprised exclusively non-geoscientists, whom were experts in their own fields, such as engineering and computer science.
It was recognised that the expert group produced estimates covering a significant range of potential outcomes; from the Sandstone greenstone belt being unprospective, through to a world-class goldfield containing several significant undiscovered gold deposits. A common method for exploring the role of expertise in conducting a particular task is to compare experts with non-experts, looking for differences between method, performance and task outcome. This study was conducted to develop a better understanding of which factors led to variation in expert estimates, as this may have applied relevance to the mineral exploration industry.

The aims of the study were as follows: (1) to better understand the differences between experts and non-geoscience experts in conducting an undiscovered mineral resource estimation exercise, and (2) determine the source of variation in the initial expert estimates.

The USGS Three-part Assessment was developed as a framework for estimating undiscovered mineral endowment within a study area. The assessment is conducted by reviewing comprehensive geological map data, geochemical and geophysical surveys, along with deposit-specific grade-tonnage models. Participants use this information to estimate the number of undiscovered deposits, which, combined with an appropriate grade-tonnage model, is used to produce probabilistic estimates for total contained metal within the study area.

The Sandstone greenstone belt presented an ideal natural laboratory case-study. Although the belt had previously received significant exploration attention, these activities were focused on the discovery of shallow deposits within the weathered oxide zone. This narrow focus was driven by the limitations of the local processing facility to extract gold ore from fresh rock. As such, the oxide-zone, extending to a maximum regolith depth of approximately 80 m, represents a mature exploration search space, containing several known gold resources. In contrast, the fresh-rock primary-zone beneath remains virtually untested, representing an early-stage exploration search space.

Where data are limited, such as the primary-zone of the Sandstone greenstone belt, there is greater reliance on the ability of experts to conduct subjective interpretations of geoscientific datasets as part of an assessment (Table 1). The highly variable USGS Three-part Assessment expert estimates were variably correlated with those of non-geoscientists (N = 10). It was recognised that half of the geoscience experts (N = 11) produced statistically similar estimates to those produced.

Figure 1. Interpreted bedrock geological map of the Sandstone greenstone belt, WA, outlining major gold deposits and drill holes exceeding 100 m in depth.
### Datasets Details

<table>
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<th>Datasets</th>
<th>Details</th>
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<td>1:50,000 scale Outcrop/regolith mapping and basement interpretation (including stratigraphy and structural history)</td>
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<tr>
<td>Geological model</td>
<td>Course 3D interpretation of greenstone belt shell and major stratigraphic units</td>
</tr>
<tr>
<td>Drillholes</td>
<td>&gt;18,000 collars 320,000 samples assayed (70% Au-only, 30% multi-element)</td>
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<tr>
<td>Surficial geochemical samples</td>
<td>&gt;50,000 samples 80% soil, 10% rock chip, 8% auger, 1% stream sediment, 1% biogeochemistry</td>
</tr>
<tr>
<td>Petrophysics</td>
<td>&gt;200 samples Magnetic susceptibility, P-wave velocity, grain density, wet and dry bulk density, apparent porosity, and remnant magnetism (samples from 3 EIS diamond drillholes)</td>
</tr>
<tr>
<td>Airborne magnetometry &amp; gamma-ray spectrometry</td>
<td>50 - 200 m line spacing, covering entire belt</td>
</tr>
<tr>
<td>Gravimetric</td>
<td>2 - 4 km (average 2.5) grid spacing, covering entire belt</td>
</tr>
<tr>
<td>Remote sensing</td>
<td>Landsat and ASTER covering the entire belt, full-colour drone photography for select regions within the belt</td>
</tr>
<tr>
<td>Seismic</td>
<td>1 line crossing E-W across the belt, vibrators shooting 2–3 sweeps at spacing of 80 m or 40 m and receiver groups spaced 40 m apart along a 12 km spread.</td>
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<td>Historic mineral occurrences</td>
<td>&gt;300 Predominantly minor shafts and workings</td>
</tr>
<tr>
<td>Exploration history</td>
<td>Detailed review of exploration history, including methods and strategies employed in previous discoveries and failures</td>
</tr>
</tbody>
</table>

Table 1. Datasets utilised is the USGS Three-part Undiscovered Mineral Resource Assessment of the Sandstone greenstone belt.

Exploration targeting is recognised as a low-validity task, owing to its low base-rate of success resulting in limited feedback. Developing expertise in any ask requires a vast amount of training in high-validity environments that provide significant opportunity for feedback and reflective learning. To improve the quality of expert estimates, it is suggested that individual expertise and appropriate assessment strategies can be developed through scenario-based training courses and practice environments, where simulated experiences can provide participants with a form of calibration for their estimates, and that greater skill and experience diversity within exploration teams is desirable, leading to more balanced aggregate estimates.

by the non-geoscience experts (with group estimates for median total gold endowment of 99 t/3.18 Moz and 120 t/3.89 Moz, respectively), whereas the other half of the geoscience experts (N = 11) produced significantly more optimistic estimates (with a group estimate for median total endowment of 350 t/11.25 Moz). Based on this comparison (Figure 2), and the inconsistency recognised within the expert estimates, several factors may explain the variations in estimates. These factors include the application of contrasting strategies, with participants opting to apply either more empirical or more conceptual approaches, and differences in background experience, resulting in distinct skillsets and varying ability to estimate uncertainty.
Assessing the variability of estimates produced by expert geoscientists

Further research is warranted to determine the degree to which the proposed factors account for these disparities. This research could be used to adapt the composition of exploration teams, and develop training programs and practice environments to promote the development of expertise in predictive exploration targeting, in order to promote discovery of future mineral resources.

Figure 2. Individual estimates of total gold endowment for the Sandstone greenstone belt, split into three groups: conservative geoscience experts; optimistic geoscience experts; and non-geoscience experts. The conservative geoscience experts and non-geoscience experts groups are deemed statistically similar enough to not be separated, whereas neither of these groups are statistically similar to the optimistic geoscience experts.

For further information, the original publication can be accessed free of charge from the journal website (https://doi.org/10.1016/j.oreoa.2020.100006) and the authors can be contacted via email (rhyssamuel.davies@research.uwa.edu.au).

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CONTACT:
Geoff Davis
0419198898 or geoffda@bigpond.com
Some background information on Lou, the grant and why we’ve teamed up with M&W

In 2018 Louise Christie, one of Sandfire's young exploration geologists (and a dear friend and co-worker of mine) passed away. Lou had a passion for geology, exploration and a love of mentoring others. To honour her memory, Sandfire together with her parents set up a grant in her name.

The grant was intended to be as far reaching as possible so to that effect Sandfire have this year teamed up with the AIG for the eighth iteration of the “Discoveries of the Tasmanides” conference. Through the Grant program we hope to facilitate greater student attendance at the 2021 conference by providing sponsorship support for eligible tertiary students and 2020 graduates. Sponsorship includes a conference ticket and subsidised travel and accommodation.

Attendance and participation in the conference provides students with an excellent opportunity to garner an appreciation for geology in the context of exploration and mining and also provides students with a fantastic career networking opportunity.
Sandfire Resources has teamed up with the AIG for the eighth iteration of the “Discoveries in the Tasmanides” Conference.

The conference is renowned for providing the latest technical case studies of discoveries and advances in the Tasmanides with presentations by geoscientists for geoscientists.

The event is scheduled to take place in September 2021 in Orange, NSW.

Through the Lou Christie Grant Program we hope to facilitate greater student attendance at the 2021 conference by providing sponsorship support for eligible tertiary students and 2020 graduates.

Attendance and participation in the conference provides students with an excellent opportunity to garner an appreciation for geology in the context of exploration and mining and also provides students with an excellent career networking opportunity.

The sponsorship includes:
- Conference ticket
- Subsidised travel and accommodation

To find out if you are eligible and to apply visit www.sandfire.com.au/site/sustainability/community/community-investment/grant-programs

For any queries please contact Kristyn.Adamczyk@sandfire.com.au

The application period closes April 2021.
Breaking Occam’s Razor

Roger Marjoribanks
FAIG

William of Occam (or Ockham) was a 14th century English Franciscan monk and philosopher who gave his name to the principle now known as Occam’s Razor. This is a well-known philosophical idea that has universal application in all fields of problem solving. It states that, given a range of possible solutions, the simplest solution – that is to say, the one that rests on the fewest assumptions – is always to be preferred. For this reason, the maxim is often referred to as the principle of economy, or even, with more impact, as the KISS principle (Keep It Simple, Stupid). However, Occam’s Razor – conjuring up as it does an image of ruthless slicing away of over complex and uncontrolled ideas – has a certain cachet which the other terms do not quite capture.

All stages of mineral exploration involve making decisions based on inadequate data. To overcome this, assumptions must be made and hypotheses constructed to guide decision making. Applying Occam’s Razor is an important guiding principle for this process, and one that every explorationist should apply. This is especially true when selecting areas for exploration, and in all the processes which entail, such as literature search, regional and semi-regional geological, geochemical and geophysical mapping, and prospecting. However, as the exploration process moves progressively closer to a potential orebody – from region to project to prospect to target drilling – the successful explorationist must be prepared to abandon the principle of economy. The reason for this is that orebodies are inherently unlikely objects that are the result of rare combinations of geological factors. If this were not so, if copper metal (say) were as common as road metal, you and I would be working in some other profession.

When interpreting the geology of a mineral prospect, the aim is to identify positions where orebodies might occur and to target them with a drilling program. Almost always, several different geological interpretations of the available data are possible. Interpretations that provide a target for drilling should always be preferred over interpretations that yield no targets, even although the latter might actually represent a more likely scenario, or better satisfies Occam. This is not a license for interpretation to be driven by mere wish-fulfilment. All interpretations of geology still must be feasible, that is, it they must satisfy...
the rules of geology and explain the available evidence. There still has to be at least some evidence or a logically valid reasoning process behind each assumption in the geological model that is used to define the drill target or targets. If unit A is younger than unit B in one part of an area, it cannot become older in another; beds do not appear or disappear, thicken or thin without some geological explanation; if two faults cross, one must displace the other; faults with varying displacement or orientation cannot be simply invented so as to solve each detail of complexity. And so on. But if these conditions are met, the interpretation which leads to definitions of potential ore-forming sites should be the preferred model. At this point in the exploration process, to give yourself any chance of success, decisions are not necessarily made on the balance of probabilities.

Unless there is serendipitous early success, there comes a point in any exploration program where it is easy to find any number of good reasons why the property might not contain an ore body. Managers worried about budgets, rival explorationists who want your share of the exploration dollar or your own internal self-doubt and lack of confidence can all people this list of fools and Jeremiahs, and the logic of Occam’s Razor may well be on their side. But the skill of the experienced explorationist lies in finding the one good reason why there might still be an ore body to be found.

Even if the model tested turns out to be wrong (and the odds are that it will), an orebody could still be found. Many geological processes are non-linear and unpredictable by processes of inductive reasoning. Great orebodies can represent an unknown unknown in the system – a Black Swan occurrence that is only explicable with hindsight. By drilling the targeted hole, the geologist creates the chance of discovery, even if all or some of the reasoning behind the targeting is wrong. The 1975 discovery of the giant Olympic Dam deposit in South Australia is perhaps the best example of this.

Long odds against discovery are always the nature of the game.
Why do I think this topic is critically important?

The mining industry’s social licence to operate is under a level of scrutiny that is more intense than at any time in its history. It hasn’t always been this way though. Most mining industry veterans would agree that in decades and centuries past, there was widespread acceptance that it was almost inevitable for mining to be:

• Dangerous
• Dirty
• Environmentally damaging
• Damaging to community health
• Prioritised over indigenous land rights all around the world
• Loose with regulatory and compliance management, and
• A men’s club.

This acceptance was held not just by direct industry participants, but also the wider public. It was seen as tough “men’s work”, essential to the rapidly industrialising world. It was also a time when many people had someone in their direct family involved in, or knew someone in, mining. As a result, mining’s social licence to operate was rarely questioned and its pitfalls and externalities were largely accepted. But, oh, how things have changed.

The pressure for mining to change

Today our industry is under pressure from all sides, and a growing proportion of the population has absolutely no connection to it. As a result, our social license to operate is being questioned like never before.

Paul Young, Global Mining and Metals Leader at EY, explains this succinctly in his report, “The Top Ten Business Risks Facing Mining and Metals”

Young makes a number of excellent points; however, it was his powerful description of an alternative future that especially struck me.

“We need to talk about the future of mining,” he said.

“Trusted, transparent and brand-savvy. Imagine a global miner superseding Apple for brand value.
"Imagine miners are trusted in the same way as leading consumer goods companies. In this future, miners have done what it takes to build trust by being transparent, listening to stakeholder concerns and acting on them. And they maintain that trust through open and continuous disclosure, supported by advanced technology that minimizes environmental footprints and accelerates rehabilitation.

“For example, sensors monitor production processes and keep an eye on environmental impact, rehabilitation activities, and safety practices. Outputs are streamed to the web so any stakeholder or investor can see what’s happening live. There are no secrets anymore.

“As a result of increased transparency and consumer awareness, miners are far more brand-savvy. Close attention is paid to the ‘look’ of mining operations, as well as the aesthetic impact.

“Just as agricultural companies now think about ‘paddock to plate’, miners consider branding across their entire operation, from exploration to the point of sale. Origin sourcing becomes a critical part of this branding. “And along with better branding comes premium pricing.”

What has this got to do with women in mining?

I agree with the developing view that resetting some of the entrenched views of our industry held by the wider public is going to require a diversified response. We need fresh ideas, including from non-mining industry players, technologists, car companies buying mines and the like. But while I agree, I also fear it just might be too slow at a time when social licenses are continually being torn up.

Let’s be open to all these external interventions, for sure. But the lowest-hanging fruit for injecting more diversification (and subsequently innovation) into the mining industry today is within our control right now. The answer, surely, is to get more technically trained women into senior leadership ranks.

Mining needs to do more to attract women

Let’s go back to the AusIMM report for a moment, for some insights into how the industry is going with this. In short: not well enough, according to the views of 700 women in mining.

While the report found that progress has been made, there is still inadequate support for women in FIFO, DIDO and onsite roles. These are the roles critical to ensuring access to the technical experience and knowledge necessary to advance to senior leadership positions.

I accept there are more women on company boards, but most of them have come through business support functions: lawyers, accountants, human resources and the like. That is good but it is not enough.

Let’s add to that with more technically trained women

Supporting women in remote mining locations

The AusIMM report summarises clearly some of the things the industry as a whole is still not doing well enough to support women on remote resources sites. Some of the items mentioned include:

- Flexible work arrangements
- More extensive access to childcare
- Much improved site facilities.

As we emerge from our grand, enforced experiment in flexible working, I appeal to all senior mining leaders to consider policies that directly increase the number of women in senior site roles, paving the way to many more of them becoming board members in five to 10 years.

The difference it could make to our industry in terms of accelerating progress towards the alternative future described above could be immense. Isn’t that a future we can all get behind?
Following the highly successful symposia Structural Geology and Resources in both 2002 and 2012, the Australian Institute of Geoscientists (AIG) will be running a three-day symposium in Kalgoorlie. The Kalgoorlie symposium will be accompanied with field trips, mine visits and short courses (in Perth and Kalgoorlie).

WHO SHOULD ATTEND
The symposium, short courses and field trips are aimed at anyone with a graduate degree in geology interested in structure and ore deposits. Past meetings have attracted Company Directors, Senior Managers, Exploration and Mine Geologists, Academics and Students. We hold the meeting in Kalgoorlie with the specific aim of being accessible to local mine geologists in the early stage of their careers.

KEYNOTE SPEAKERS
We are currently talking to six potential overseas keynote speakers (Europe, North America and New Zealand) and colleagues in Western Australia. Details of Keynotes will be in the January 2021 update.

CALL FOR PAPERS
We welcome an early indication of speaker name and talk title.

Contact sgrkal2022@aig.org.au

The meeting will include an AIG published extended abstract volume with contributions from all speakers. As with previous events, we invite speakers to also submit a full paper for publication in an after-event peer-review journal (details pending).

EARLY CALL FOR SPONSORS
At this early stage we are seeking sponsors. Sponsors will have on-going exposure with name and logo on symposium materials, a trade booth, guaranteed lecture slot and two delegates. We are pleased to talk to you about your detailed requirements including the bulk booking of delegates. Contact sgrkal2022@aig.org.au

We are offering Trade Exhibitors a trade booth and one delegate registration. Again, talk to us about your needs.

TIMETABLE

<table>
<thead>
<tr>
<th>Date</th>
<th>Event</th>
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<tbody>
<tr>
<td>July 2020</td>
<td>First announcement</td>
</tr>
<tr>
<td>January 2021</td>
<td>Confirmation venue, short courses, field trips, charges and discounts</td>
</tr>
<tr>
<td>March 2022</td>
<td>Final expressions of interest regarding presentations</td>
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<tr>
<td>April 2022</td>
<td>Submission of draft extended abstracts</td>
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<td>August 2022</td>
<td>PDF version of abstract volume</td>
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<tr>
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<td>Field trips, short courses</td>
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<tr>
<td>27 to 29 Sep 2022</td>
<td>Symposium</td>
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<tr>
<td>After 29 Sep 2022</td>
<td>Field trips, short courses</td>
</tr>
<tr>
<td>November 2022</td>
<td>Submission manuscripts for publication in special issue peer-review journal</td>
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About the South Australian Exploration and Mining Conference

The South Australian Exploration and Mining Conference (SAEMC) has been held annually near the end of the year since 2004. It is preferably held on Saint Barbara’s Day – St Barbara being the patron saint of miners – on the first Friday in December.

It is designed to provide an opportunity for active mineral explorers and miners to present succinct technical updates to their peers of activities on their flagship mines and exploration projects. Participants will gain a comprehensive appreciation of the diverse activities in South Australia and gain ideas from each other which will collectively improve our chances of mineral discovery and improved mining developments.

The conference is organised by a voluntary committee representing four local branches of professional associations:

- Australian Institute of Geoscientists (AIG)
- Australian Society of Exploration Geophysicists (ASEG)
- Australasian Institute of Mining and Metallurgy (AusIMM)
- Geological Society of Australia (GSA)

Representatives from the South Australian Department for Energy and Mining (DEM) and University of Adelaide have also joined the committee.

Conference registration fees are kept low to encourage a broad attendance and the modest profits are intended to be invested in student-related activities by the local professional associations.

Friday 27 November, 2020
Adelaide Convention Centre
Register online: www.saemc.com.au

Registrations: $220  Student: $50
Full refunds available to registrations prior to: 13 November, 2020
Registrations close: 26 November, 2020

Sponsor / exhibit / presenter enquiries
Nicole Galloway Warland
+61 (0)417 006 431
info@saemc.com.au

* Conference format may change subject to the uncertainties of the COVID-19 pandemic and associated travel and social gathering restrictions.
Geoscientist Employment Improves in Australia Despite Coronavirus Pandemic

Australian Geoscientist Employment Survey

“The level of improvement observed in the survey results was small but defied the increase in unemployment observed in the Australian community as a whole, and the sharp downturn in economic activity affecting Australia’s economy”

Andrew Waltho

Geoscientist employment in Australia improved in the second quarter of 2020. Nationally, unemployment decreased to 8.6% from 10% in the March quarter, while underemployment also fell to 17.4% from 18.1% for the period.

AIG President, Andrew Waltho, described the improvement as most welcome. “The level of improvement observed in the survey results was small but defied the increase in unemployment observed in the Australian community as a whole, and the sharp downturn in economic activity affecting Australia’s economy” Mr Waltho said. “With more than three-quarters of Australia’s geoscientists working in exploration and mining, the results point to the absolute importance of our mineral resource industries in helping to maintain economic activity in Australia, even while in recession” Mr Waltho said. “This quarter is also the first time since the 2011 minerals boom that geoscientist unemployment has fallen below the unemployment rate for the Australian economy.”
as a whole, pointing to the success of efforts being made to ensure business continuity and resilience during the pandemic” Mr Waltho said. “It is extremely encouraging to see mining and exploration activity continuing across Australia under very difficult conditions” Mr Waltho said.

Employment impacts varied between states. Unemployment amongst geoscientists fell in Western Australia, but increased slightly in Queensland, New South Wales and the ACT, and Victoria. Underemployment fell in Western Australia, New South Wales and ACT, and Victoria, and remained little changed in Queensland from the previous quarter.

A high proportion of self-employed geoscientists, however, continued to experience difficulty securing more than a quarter of their desired workload. Long term unemployment remained stubbornly high, with almost 34% of unemployed geoscientists reporting having been out of work for more than 12 months, including 22% who have been out of work for more than two years. Some 40% of unemployed geoscientists were not confident of returning to work within the next 12 months.

“Long-term unemployment continues to be of serious concern” Mr Waltho said. “AIG, other professional associations and industry groups including CSIRO have responded positively to the challenges posed by the pandemic and the need to suppress the coronavirus through limiting gatherings of people by moving quickly to delivering professional development talks, seminars and short-courses on-line”, allowing members to participate from home” Mr Waltho said. “These have included many talks and seminars delivered at no cost to participants in an effort to provide members with accessible and valuable professional development opportunities, essential to maintain members’ skills and motivation” Mr Waltho said. “In many ways, access to continued professional development opportunities has improved significantly, with events previously available only in particular cities or states accessible nationally, and by members overseas” Mr Waltho said.

An excellent response to the survey was received nationally, with 508 geoscientists completing the survey. Responses from geoscientists in South Australia fell, however, preventing state employment and underemployment results from being reported. The next survey will be conducted at the end of September. All contributors, especially AIG members, are thanked for their ongoing support.
Geotourism

Help spread the word in the community through input into AESC2021

Mike Freeman
GSSC

There is huge potential for geotourism developments across Australia, but how many currently exist? Are there any sites within cooee of where you live or work or visit that you might be able to help stimulate or create? Then, what geo-aspects can be covered and developed? What support can be obtained from others in the community – State tourist departments, national park operators, local Government authorities?

In recent years, we have been embarking on endeavours to improve the penetration of geology into modern tourism. The geology has always been there, but nobody to deliver the message, until the recent few years. Mind you, the story of ecotourism has been there for many years, and so now geology is playing a catch-up.

The development of the World Geopark concept under the auspices of UNESCO

Do you have any ideas or thoughts on the promotion of geotourism? Perhaps some embryonic thoughts that need hatching and growing? Think! Then promote your thoughts to the Australian Earth Science Convention for 2020-2021 (AESC2021) virtual conference. Coordinators say “As you may know, the Geological Society of Australia has defined geotourism as ‘tourism which focuses on an area’s geology and landscape as the basis for providing visitor engagement, learning and enjoyment’.

Geotourism adds considerable value to the content of traditional nature-based tourism as well as cultural tourism, thus completing the holistic embrace of ‘A’ (abiotic – landscape and geology) plus ‘B’ (biotic – flora and fauna) plus ‘C’ (culture, both indigenous and post European settlement) aspects. The Australian Geoscience Council is currently working on a draft national geotourism strategy, and there is a session to be included in the ASEC2021 on this subject.

The AESC invites presentations on all aspects of geotourism, including the development and function of geosites, geotrails and geoparks around Australia, with particular reference to the following strategic themes.

Geotourism as a means of celebrating geodiversity through identification of new digital technologies (e.g. smartphones, 3D visualisation, AR & VR) and GIS technologies.

Examples of new geotrail development – local, regional and national engagement with existing walking, biking and rail trail interest groups and operators.
Examples for collaboration with providers of other areas of natural (bioregion) and cultural heritage content, inclusive of mining heritage.

Identification of professional development opportunities for geoscientists, including tour guiding, interpretation and natural area management.

There is Theme 5 entitled “Geoscience in society, education and environment” within which there is “Geotourism. Enriching the visitor experience: a spectrum of solutions in response to a changing world.” Screaming out for your thoughts on how and where!!

How about thinking of what you’ve liked about features or sites you are familiar with and how it could be promoted? Who could help or, better, promote your ideas? What support might be available to support such promotion. And now, what digital promotional facilities or platforms might be available. Then develop your ideas to share with colleagues with a presentation at the AEGC.

The AESC2021 is seeking abstract submissions and has extended the deadline until 28th September. So, please support the dissemination of your ideas of how our science can be spread to the rest of society.

Follow online at https://www.aesconvention.com.au/

John Forrest National Park heritage railway
Mine to plant reconciliation: a new approach to magnetite banded iron formation deposits, an example from Ferrexpo

Introduction
The Ferrexpo Group is Ukraine’s largest iron pellet producer, and is among the top ten global suppliers of seaborne pellets. The ore is produced from two active pits: the larger GPL pit and the smaller Yerystivske pit, served by a centralised FPM processing plant and pelletising facilities. All are located in Poltava region, Central Ukraine. The deposits are hosted in the Kryviy Righ Group, within which three banded iron formations (BIFs) are being economically mined. Each BIF consists of several sub-formations and the difference between them is mostly in mineralogical composition; predominantly variations of magnetite, magnetite-cummingtonite and magnetite-hematite-cummingtonite.

A significant issue in mines in general, and in magnetite BIF hosting deposits in particular, is the discrepancy between the mine estimate of production and the actual processing plant estimates after beneficiation. Normally, plant operators apply an experience-based discount factor to particular ores to predict plant recovery.

Approach
The mining operation relies on kriged grade models based upon RC and blast hole samples in order to determine dig-lines by processing ore type. In heterogeneous structured environments the reconciliation error is introduced firstly in the blast hole sampling itself because of smearing and smoothing of grades in reverse circulation holes. The blast holes are designed to break the hard rock by explosives, not to provide adequate material for assaying while the sampling support is based on the consideration of mining and geotechnical factors only. As a result, the mines predict lower tonnages but higher head grades than the plant reports. This type of error is reduced by considering the particle size distribution to determine the representative sampling weights for different lithologies. The problem however remains and as such, the grade control model is an estimate and thus is subject to estimation issues.

Despite the plant not being immune to its own sampling errors this article is based on the assumption that the plant values are considered to be the most accurate values for reconciliation. The processing plant balancing method is to compute tonnes and grades by using linear equations as a minimum-error fit to simulate the production flowsheet. Similarly, the grade control model should be adjusted to the linear relationship between iron-magnetic grades of in-situ ore and iron content in magnetic concentrate.

There is a weak (if any) linear relationship between ore values and concentrate grades. The problem is solved by introducing an independent variable which should be linearly dependent on in-situ ore grades and with concentrate...
grades. This independent variable, termed the ‘processing efficiency factor’ or ‘PEF’ is calculated from a formula as follows:

$$PEF = \frac{fe\_con - fe\_mag}{72.4 - fe\_con} \times 100\%, \quad (1)$$

where $fe\_con$ – is iron total content in concentrate, $fe\_mag$ – is iron magnetic content in-situ ore, and 72.4 – is the theoretical iron total content in 100% pure magnetite.

Because the iron content in pure magnetitic concentrate cannot exceed 72.4 %, the PEF can be defined as the probability of achieving this goal from a particular sample under consideration. Similarly, the 95% probability indicates that theoretically the iron content in concentrate produced by magnetic separation would not be higher than 68%. On the other hand, mining testifies that there are multiple probabilities to achieve a concentrate of the desired quality on the local level. In this respect, iron magnetic content of in-situ ore is circumstantial to the prediction of the iron content in magnetic concentrate and the efficiency to process low-grade ore is generally higher.

Results

In Figure 1 ‘PEF’ values achieved during a processing test at FPM plant facilities are shown along with those calculated by grade control and the resource models. Despite some discrepancies, a linear relationship between ‘PEF’ and $fe\_con$ grades is apparent in both cases.

Figure 1: Correlation between ‘PEF’ and iron content in concentrate

The observed phenomenon can be explained by limiting grade population to the grade confidence interval where the Sturgis formula and histogram of the population guide the choice of the confidence limits. With this simple manipulation, a relation between ‘PEF’ and $fe\_con$ grades transform to a strong linear regression, as shown on Figure 2. To be even more accurate, a further adjustment to $fe\_con$ grades can be applied by assuming 98% magnetite content in concentrate. Thus, $fe\_con$ is predictable but within a relatively narrow $fe\_mag$ confidence limits, which is not often the case when the mining block is considered.
Figure 2: fe_mag vs fe_con grades vs ‘PEF’ relationship: original drill hole data

Implementation of this method is practical when the size of a block being mined is reduced to a selective mining unit (SMU) with the condition that the SMU is located within the limits of a particular BIF lithological domain and the standard deviation of fe_con grades is taken into account (subtracted from the linear regression equation). Hence the equation (1) for a particular fe_mag confidence interval can be transformed to one as follows:

\[ fe_{con} = a + b \times PEF - \sigma, \quad (2) \]

where a and b are linear regression coefficients determined experimentally and \( \sigma \) is a standard deviation.

The equation (2) was then used in a number of mining trials to predict a plant grade for a SMU. SMU sizes of different support were considered. The results are given in Table 1 showing fe_con grades estimated by linear regression are closer fit to plant reported grades, thus proving the validity of the described approach.

Two other outcomes were achieved with modification of grade control model by linear regression. Firstly, as testified by the graph on Figure 3, the relation between reconciliation error and tonnage feed is lognormal. This suggests that application of lognormal or indicator kriging to grade control mapping could be more effective. Since both methods are sensitive to the presence of low-grade boundaries, which is not unusual in the mines, the current grade control practice could be further advanced.

Secondly, both Table 1 and Figure 3 suggest that the relative reconciliation error can be also used to determine the size of SMU, which is another issue in the mines. In practice, the choice of SMU size is guided not only by the lithology and grade distribution pattern but also by a size of equipment, geotechnical considerations and other mining factors.

The graph in Figure 3 shows general decrease of relative reconciliation error derived from linear regression method along with an increase of the block size. This is in line with general tendency of averaging for longer mining periods. It is also

<table>
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<th>'SMU' size, '000 tonnes</th>
<th>Plant reported grade, fe_con, % (P)</th>
<th>Mine reported grade, fe_con % (SA)</th>
<th>Relative reconciliation error, (P - SA) %</th>
<th>Estimated by linear regression, fe_con % (RE)</th>
<th>Relative reconciliation error, (P - RE) %</th>
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apparent that by reaching in this case the SMU of 500 thousand tonnes the reconciliation error decays to zero. In contrast, the reconciliation error provided by the “normal” grade control model increases with the size of a block, is significantly higher, and its distribution has a powerlike shape.

**Figure 3. Relative reconciliation error vs plant feed**

It has been recognised in the iron ore mining industry that the SMU for the recoverable mineralisation should be of size (or divisible to one) for which the variability of the ore body and the selectivity of mining are in agreement: for example, variation is minimised while tonnage is sufficient to feed the plant for a certain number of shifts. In this regard, the graph on Figure 3 should not be read in a way that larger size SMU is preferable to a smaller one. In fact, using the reconciliation error as a guide both Table 1 and Figure 3 suggest that the SMU size between 30 to 40 thousand tonnes would be an optimum. At these volumes the reconciliation error derived from a “normal” kriged grade control model and from an adjusted one by a linear regression are closer.

Current Ferrexpo practice employs SMU size of 40 thousand tonnes, which is approximate to two plants’ shifts or one day of production. It also correlates with the resource block model parent cell size. The bigger support is used in a long-time planning.
Conclusion

The main advantage of the described approach is in its relative simplicity and transparency. It also presents important arguments to choose the appropriate method of estimation and the likely size of the selective mining unit during grade control. In a rapidly changing marketing environment, the block models are dynamic and there is no single and uniform approach to ore body modelling. The methods of estimation can and should change in time from simple to sophisticated and return just to make a case the modelling approach needed.

The procedure to calculate a predicted plant grade involves several steps briefly described below. As a prerequisite to estimation, the required confidence intervals should be determined and linear regressions calculated for each confidence interval from grade control data. Lithological and structural domaining is essential before estimation to avoid unnecessary mixture of grades.

Step 1. Assays for a domain (mining block) are tabulated and ‘PEF’ is calculated for each assay and for a block average.

Step 2. Simple average values are obtained for fe_mag and for fe_con.

Step 3. Standard deviation is calculated for fe_con for the block.

Step 4. Following results of Step 2 an appropriated regression equation is chosen.

Step 5. Plant grade is then calculated using results of steps 1 through 4.
Australasian Exploration Geoscience Conference (AEGC) 2021

CO-HOSTED BY:
15-20 September 2021    Brisbane Convention and Exhibition Centre

SHORT ABSTRACT SUBMISSION NOW OPEN!

KEY DATES
Short abstract submission NOW OPEN
Short abstract submission deadline 30 OCTOBER 2020
Extended abstract submission open 21 DECEMBER 2020
Extended abstract submission deadline 5 MARCH 2021
Early bird registration open 5 FEBRUARY 2021

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Introduction to the AIG Data Management Special Interest Group

Neil Fordyce
MAIG, MAusIMM

It has been over a year since I talked to Andrew Waltho about starting up a data management special interest group within the AIG. The idea for the group has come about as I continually see a similar range of data issues at a variety of sites, irrespective of country. The problems are not always complex and don’t require technologically intricate solutions to identify them but they appear to persist.

The aim of the group is to share knowledge about data in our industry.

I see the principle reason for data management as making better geological and business decisions based on your data.

If you don’t use your data to make decisions then you don’t need to manage it.

I hope the group will provide easy to understand solutions and examples to allow members to produce better quality data for better quality decision making.

I propose to start the data discussion with short articles outlining a problem and discussing solutions. More detailed articles, including coding examples, may be generated for those wishing to apply direct technological solutions. Articles will be collated thematically, or tagged with key words, and placed on the AIG web site for access. At some point in the future salient points from articles could be combined into a comprehensive document for reference.

AIG members are encouraged to contribute short articles on ways to identify and fix data problems or illustrate interesting methods of analysis that may help people find structure in their data. The articles should concentrate on generic data problems inherent in geological data rather than technical issues specific to a particular software package.

This special interest group is proposed to provide opportunities for transfer of technical expertise, experience and awareness of data management issues across all levels of membership.

There are a vast array of data issues found in geological data and we cannot hope to solve them all in a heartbeat but let’s start.

About Neil

I have worked in mineral exploration for just on 30 years and had a prior career in Forestry before studying Geology at University. My numerical career started in a summer job in 1979 in Forest Mensuration. Six years was spent in Forest Research where, in 1984, I was introduced to programming, data analysis and data management on a VAX mainframe. From 1991 to 2007 I worked for Placer Dome in data management and Geographical Information Systems (GIS). Since 2007 I have consulted in GIS and databases specialising in data management, compilations, validation and analysis.
Downhole surveys are a critical component for placing your assays and geology in three dimensions for analysis and modelling and as such need to be reviewed for their quality. Boreholes can deviate due to geological and technical factors and the downhole surveys measure the drill hole path from the planned setup.

As well as the confusion between magnetic, grid, true and, potentially, local north readings there are procedural and instrument issues to consider.

Sections and plans are an aid to identifying where data may be erroneous but do not always illuminate the problem. In this article I will illustrate some ways to identify problem surveys using simple graphs and textural reporting.

I see downhole survey errors as just one component of the potential errors in a drill hole.

Hole errors = Positional errors + sampling errors + assaying errors + logging errors.

Positional errors = surveying errors + coordinate errors.

Surveying errors = instrument errors + human errors.

Evidence of survey problems

What are some of the signs that there are downhole survey or survey data problems?

Some or all of the following are relevant indicators you may have a problem:

- Drillers and Geologists arguing where the hole is going during the morning meeting.
- The underground orebody is not there when you have put a drive in to it.
- Drill traces are not parallel to the drilling grid.
- Visual kinks in the drill traces.
- Dip and azimuth deviations plot outside of valid ranges.
- No hole deviation.

One can argue that for short holes a degree or two of error in a survey does not matter and I agree. The change in location at the bottom of hole is minimal in some circumstances and will not probably materially affect the nature of the work being carried out with the data. But how do you know the errors are insignificant unless you have analysed them?

If you are drilling for a resource and to generate a block model and a hole shift materially affects a block result then is that not destroying your optimisation and costing you money?

The density of modern downhole survey data and the smoothing methods used to create the drill trace can hide potential survey errors when running a visual check using sections or plans.

Some sort of other metric is needed in order to flag surveys for further review in order to exclude erroneous surveys from use and for this we can use azimuth and dip deviations in degrees per metre for a definitive result.
"Both sets of data are very peaked, centred around zero, and have a similar shape. All the downhole survey data sets I have analysed, greater than 500,000 downhole surveys, have shown a similar distribution."

Survey Deviations in Degrees per Metre

Analysing your downhole survey for changes in dip and azimuth in degrees per metre is a good metric for identifying problems with your surveys. Simply looking at the absolute difference between two surveys does not tell the story. Degrees per metre deviations adjusts for differences in the distance between surveys.

There are limits on how much drill rods can flex and your downhole surveys do not have unlimited variation in non-vertical holes. This includes wedge points which still can only deviate at the rate of the rod flex. The deviations should follow some sort of numerical distribution which you can visualise in order to assess the data. Shown below are the dip and azimuth deviations from ~6,000 downhole surveys from QDEX data (Figures 1 and 2).

Both sets of data are very peaked, centred around zero, and have a similar shape. All the downhole survey data sets I have analysed, greater than 500,000 downhole surveys, have shown a similar distribution.

If we treat the data like geochemical data and look for where a smoothed frequency distribution descent cuts the x-axis we can see that it would occur at about 0.2 degrees per metre (Figure 3).

This is the approximate cut-off that I use to flag erroneous dip data for my projects.

Similarly azimuth deviations have been reviewed with this method and I have chosen +/-0.3 degrees per metre to flag erroneous azimuth values.

Values outside of these ranges need to be reviewed.

The downhole deviations are calculated using

\[
\text{Azimuth Deviation} = \frac{\text{AzimuthTo} - \text{AzimuthFrom}}{\text{DepthTo} - \text{DepthFrom}}
\]

\[
\text{Dip Deviation} = \frac{\text{DipTo} - \text{DipFrom}}{\text{DepthTo} - \text{DepthFrom}}
\]

"Both sets of data are very peaked, centred around zero, and have a similar shape. All the downhole survey data sets I have analysed, greater than 500,000 downhole surveys, have shown a similar distribution."
With the azimuth calculations you have to be careful where that calculation crosses 0/360 e.g. the difference between 358.8º and 1.2º is 2.4º not 357.6º.

Discussions with drillers, who were drilling wedge holes, indicated a flex of 1 degree in azimuth in a rod of 3m was the maximum that could occur. This supports the +/- ~0.3 degrees per metre calculated from data.

The azimuth deviations are greater than the dip deviations as holes swing more than they lift or drop. One feature that needs to be taken into account is that azimuth deviations become greater as the hole approaches vertical. At some point you need to remove the “vertical” surveys from your analysis of azimuth deviations.

Plotting azimuth deviations against dip may illustrate to you where the survey instrument is starting to vary because of the vertical nature of the hole. Figure 4 below shows the trumpet shape created by the larger azimuth swings as the hole nears vertical.

The point at which data is deemed vertical, and excessive swings can be ignored, is a decision made by the person doing the analysis. With the erroneous data removed from the data in Figure 4 the cut-off for defining a vertical hole is about -88 degrees. Azimuth deviations for dips value of less than -88 degrees in this data can be ignored.

The drill holes in Figure 5. have swung north off the drill lines due to an incorrect azimuth being stored with the data. The magnitude of the swing north is close to the regional magnetic declination which may have been applied incorrectly to the data.
Dodgy Downhole Surveys

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Table 1. SQL Server generated report table. azimuths.

Textural Reporting

The functions to calculate azimuth and dip deviations can easily be embedded in a database so that a report for users can be generated to allow assessment of their own surveys as part of best practises.

Note that the two errors in table 1 have been generated by the one erroneous survey of azimuth 90 degrees and dip -80 degrees at 185m. The NOTE field text is generated in the code.

This data has been created by joining the downhole surveys table intervals against the previous interval in Microsoft SQL Server using the row_number() and over() functions.

Simple down hole plots of dip and azimuth against depth created in Excel, or a statistics package, highlight the problem survey and would allow staff to flag it as an error (Figures 6 & 7).

Which azimuth?

There are potentially four different azimuth readings that can be stored in the database.

- Grid (AMG 84, GDA 94, GDA 2020 etc.) azimuth.
- Magnetic azimuth.
- True azimuth.
- Local grid azimuth for old data.

Figure 8 illustrates the relationship between a local grid and the other azimuth readings for the data shown in Figure 5.

- Grid readings align to map grid lines of the projection you are using (black arrow).
- Magnetic readings point at the magnetic north pole (blue arrow).
- True readings point at the north pole (red arrow).
- Local Grid readings align to the established local grid (magenta arrow).
The grid is located in the western portion of an AMG zone and dated to 1995. Measurements are shown in decimal degrees.

It is important to store the magnetic reading in the database as this is the primary azimuth that all the others can be calculated from. There is often confusion between these different readings and this is often a source of error. Ideally the differences between all the azimuth readings should be documented for a drill project to avoid confusion. Where a local grid exists then it needs to be documented and proof of the coordinate relationships needs to be confirmed. This includes the numerical relationship between the common coordinate points.

With respect to the above diagram the numerical values are

- Magnetic declination: the difference between true north and magnetic north (blue text).
- Grid declination: the difference between AMG grid north and magnetic north (black text).
- Grid convergence: the difference between grid north and true north (red text).

The magnetic declination changes over time and varies across the globe. It is important to note the date of surveying and/or the date of drilling in order to establish the magnetic declination correctly if magnetic azimuths need adjusting in your data.

For completeness I store the annual magnetic declination for a project in the database alongside other survey data. There are several on-line magnetic calculators with which to calculate historic magnetic declinations for historical data and to get your current magnetic and grid declinations.

### Grid Convergence

The grid convergence is zero at the central meridian of an AMG/GDA or UTM zone and diverges with increasing distance from the central meridian i.e. as you approach the zone boundaries the magnitude of the values increases. Negative values occur to the west and positive values occur to the east of the central meridian.

The grid convergence also increases with increasing distance from the equator. In north Queensland at the latitude of Burketown the values close to the zone boundaries are in the order of +/- 0.8 degrees whilst in northwest Tasmania and near Geelong the readings are in the order of ~ -1.4 degrees and ~-1.6 degrees respectively.

These grid convergence values can create a significant coordinate shift at the bottom of a deep drillhole especially at mid and higher latitudes.

### What are the primary causes of the survey data issues?

Primary causes of the downhole survey problems I observe are

- Using a compass or planned azimuth for the hole collar survey
- Using the incorrect azimuth type for the surveys
- The effects of multiple downhole survey passes
- Mixing survey types e.g. gyro with single shot
- Using and not flagging different types of survey instruments downhole
- Wedge junctions and the application of different survey runs on the wedge surveys
- Instrument problems
- Human error (including putting the camera in upside down!)

Note that I do not include magnetic rocks as a “data” issue affecting surveys but highly magnetic rocks are a cause for large deviations and need to be taken into account. When the data is stored in a database you may wish to attach the logged lithology at the survey point depth to the deviation table to allow assessment of the magnetic effect of the lithology.
Some solutions

• Ensure staff understand which primary azimuth is to be used with the data.
• Have a survey instrument calibration stand to ensure consistency and repetition.
• Ignore the collar, compass and planned survey values if there is a close downhole survey.
• Ensure that the magnetic azimuth is stored as the primary data.
• Calculate the other azimuths required from the magnetic azimuth.
• Allocate the first downhole survey values to the collar location.
• Analyse multiple surveys at the same points down hole and use an average or median of the values.
• Flag different survey methods and filter the data to retain only the best method.
• Treat multiple survey passes as different “samples” and check adjust for consistency (level the data) between passes.

In Summary

• Accurate downhole surveys are essential to accurately track drill hole path and become more critical with increasing depth.
• One method for highlighting erroneous drill hole deviations is to calculate dip and azimuth deviations and compare to cut off limits of 0.2 and 0.3 degrees per metre.
• Inspect dip and azimuth graphically and also the drill hole trace in plan and section.
• Azimuth readings vary and drill projects should clearly define the different types and what is stored in the database.
• Grids need to be documented.

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**Dodgy Downhole Surveys**

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<td>15-18 September 2020</td>
<td>Whistler Conference Centre, Whistler BC, CANADA</td>
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<tr>
<td>Principles of Structural Data Collection</td>
<td>20 October 2020</td>
<td>Perth WA</td>
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<td>A Better Understanding of Exploration Geochemistry</td>
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