

AUSTRALIAN
INSTITUTE OF
GEOSCIENTISTS

Supporting Geoscientists

AIG News

Issue 135

March 2019

Does carbon dioxide drive climate change?

36

South American
Lithium Brines:
How and where
did it come from?

47

Geology: quo
vadis? Walking
where angels
fear to tread

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Geotrail: A
Blow-Up Pub
Selling Ground-
Shaking Beer

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The AIG
Mentoring
Program 2019



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RESOURCES NL

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students & graduates!**

LOUISE CHRISTIE GRANT PROGRAM

To honour the memory of our late geologist, Louise Christie, Sandfire Resources has established a grant program in her name. Tertiary students and 2019 graduates pursuing careers in geology may apply for sponsorship to attend work experience or geology-related events for upskilling and networking.

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Please send application forms to
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The application period closes on 30 April 2019 and successful applicants will be notified by Monday 13 May 2019.

*Sponsorship payment must be used within the 2019/20 financial year. Tax receipts or invoices must be provided for all activities.



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March 2019

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**AUSTRALIAN
INSTITUTE OF
GEOSCIENTISTS**

Supporting Geoscientists

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From your President Mike Erceg

Engineers, like Geoscientists self-regulate through a number of State-based organisations, with the exception of Queensland where registration by the Board of Professional Engineers Queensland is mandatory. It looks like NSW may join Queensland following the release of the final report from the independent investigation into Opal Tower structural failure (see link below).

<https://www.planning.nsw.gov.au/News/2019/Final-Report-on-Opal-Tower-Released>

“The biggest recommendation in today’s report is about registering engineers– and we’ve already committed to that.”

- Minister for Better Regulation
Matt Kean

From the Report:

*“1. Creation of a Registry of Engineers. Registered engineers should have a high level of competency including recognised qualifications benchmarked to international education standards, minimum level of professional practice and currency of continuing technical professional development (particularly important in an evolving field such as building design and construction). **The Registry should be managed by government in partnership with an appropriate professional body.**”*

Could government regulation be forced onto Geoscientists? It’s not too hard to imagine say, a tailings dam failure in Australia due to a faulty hydrogeological model and/or poor geotechnical test work. In British Columbia the provincial government has introduced legislation to govern the practice of Engineers and Geoscientists in part as a response to the Mount Polley Mine tailings dam failure (refer link below).



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PETROLOGICAL (CONSULTING) SERVICES

Roger G Taylor (PhD, DIC, MAIG)

Descriptive and overview interpretation of:-

- Ore Textures
- Breccias
- Alteration
- Paragenetic sequencing
- Gossans-leached outcrops/supergene enrichment

*Porphyry copper, IOCG, Skarn, Carbonate replacement, Tin-Tungsten
Epithermal and Granite related gold systems*

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<https://www.leg.bc.ca/parliamentary-business/legislation-debates-proceedings/41st-parliament/3rd-session/bills/first-reading/gov49-1>

Is regulation of our profession by government in the interest of professional geoscientists? My personal opinion is no, but its a debate I suspect we will be called on to have. By providing inexpensive professional development the AIG strives to improve the competency of its members. Members in turn are encouraged to keep abreast of best practice in their fields of expertise, and to keep a record of their CPD. Incompetence appears to have been the root cause of the Opal Tower and Mount Polley incidents.

In April we will be calling on nominations for seven of the positions on Federal Council. Under the Constitution, each year half of Councillors step down (but may re-nominate). A Nominations Committee has recently been formed to ensure a more competitive process for seeking nominations for the vacated positions. State branches have been contacted to put forward recommended individuals whom the Nominations Committee will approach, encouraging them to nominate. The Committee will soon roll out a communications campaign to encourage more members to put themselves forward. So, if you have an interest please contact your State Branch, the Nominations Committee Chair, Brendan Howard at brendan.howard@aig.org.au or the AIG President at president@aig.org.au.

And finally, activity in the mineral exploration industry appears to be increasing. Have you tried to get a drill rig in Australia this year?

This increased activity is supported by AIG's latest employment survey results which continues to show a downward trend in unemployed geoscientists. Recent improvements in the prices of commodity and announcements of potential mergers between the major gold miners suggests to me we are headed for another boom! 🍀



Mike Erceg

MAIG RPGeo, President

REVISED EDITION!



Mineral Resources Bulletin 25

GEMSTONES OF WESTERN AUSTRALIA

SECOND EDITION

by J Michael Fetherston, Susan M Stocklmayer, and Vernon C Stocklmayer



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 GAA
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 Geological Survey of Western Australia

Institute News

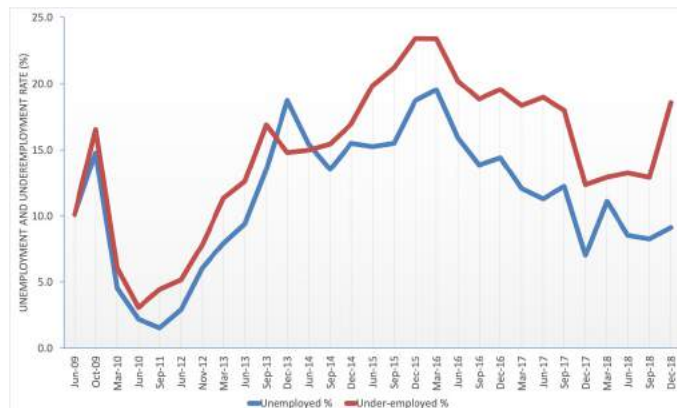
Snippets

Employment survey snapshot

The latest AIG Australian Geoscientist Employment Survey for the final quarter of 2018, conducted during January 2019, revealed a slight increase in overall unemployment amongst Australian geoscientists and a spike in underemployment amongst self-employed geoscience professionals.

Geoscientist unemployment and underemployment in Australia June 2009 to December 2018

The unemployment rate rose slightly from 8.3% at the end of September to 9.1% at the end of December 2018, while



underemployment for the same period increased significantly from 12.9% to 18.5%.

The unemployment rate was the lowest recorded since March 2013 but points to the geoscientist employment situation in Australia remaining somewhat fragile.

Analysis of the survey results is available later in this issue and from the AIG website.



Professor Ross Large awarded Order of Australia in this year's Australia Day Honours

AIG extends sincere congratulations to Professor Ross Large AO, recognised for his distinguished service to education, and to scientific research, in the field of economic geology, and to professional societies on this year's Australia Day Honours.

Professor Large is Distinguished Professor and Professor of Economic Geology at the University of Tasmania.

Professor Large has shaped economic geology teaching and research at University of Tasmania, through a number of roles including:

- Distinguished Professor Emeritus, Economic Geology, since 2016.
- Director, National Key Centre for Ore Deposit and Exploration Studies (CODES), 1989-2012.
- Member, Professorial Board and Academic Senate, 15 years.
- Member, University Research Committee and Research College Board.
- Member, University Promotions Committee, 2009-2011.
- Chair, University Club, 2002-2005.
- Representative, University Mentoring Circle, 2009-2010.
- Senior Lecturer, 1984-1989.
- Lecturer, 1984-1989.

Professor Large is a Fellow of the Society of Economic Geologists and served as the society's President, 2004-2005, an Executive Committee Member, 2003-2005. Vice President, Australasia, 1993-1996. He was the society's Distinguished Lecturer, 1998.

Awards and recognition received by Professor Large include:

- Eureka Prize for Excellence in Interdisciplinary Scientific Research, Australian Museum, 2016.
- Lindgren Award for excellence in research, Society of Economic Geologists, 1983. Recipient, Distinguished Lecturer, Society of Economic Geologists, 1998.
- Fellowship, Australian Academy of Technological Sciences and Engineering, 1999.

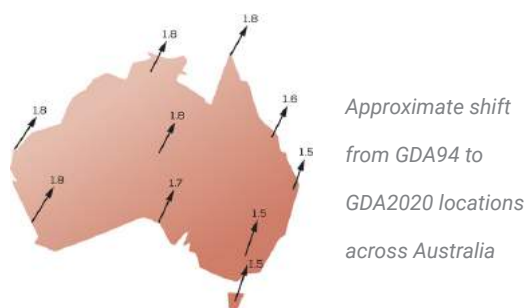


Get Ready for GDA2020

The Geocentric Datum of Australia 2020 (GDA2020) is a geocentric (earth-centred) coordinate reference system that is Australia's new official national datum. GDA2020 will eventually supersede the GDA94 datum and older coordinate systems, such as Australian Geodetic Datum 1966 and 1984 (AGD66 and AGD84).

It is a 'plate-fixed' datum that is aligned with the 2014 realisation of the International Terrestrial Reference Frame (or ITRF2014). The "earth-fixed" ITRF is typically not regarded as a "datum" – rather it is the international standard reference framework to which national geocentric datums are aligned.

GDA2020 coordinates differ from GDA94 coordinates by approximately 1.5 to 1.8 metres and are more closely aligned with the reference frameworks used by modern GNSS – such as GPS, GLONASS, Galileo and BeiDou.



The standard map projection associated with GDA2020 is the Map Grid of Australia 2020 (MGA2020), a transverse Mercator projection that conforms to the internationally standardised Universal Transverse Mercator Grid system.



Read the full article at

<https://tinyurl.com/aignews135-gda2020>

AEGC 2019 CALL FOR ABSTRACTS

Extended until
Friday 4th April 2019



Abstract submissions are welcome for consideration for the AEGC 2019 Conference, to be held on 2-5 September 2019 at Crown Perth. The theme for the 2019 conference is "Data to Discovery". The AEGC technical program committee has a focus on Geology, Geophysics, and Geochemistry and how these are applied in exploration for both Petroleum and Mineral systems in Australasia and the wider Asia-Pacific region. Abstract submissions extended until Friday 4th April 2019, 5pm AWST.

Early Bird Registration will be opening next month, be sure to secure your spot at the early bird rate!



More information <http://2019.aegc.com.au/>



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Porphyry copper-gold deposits in the circum-Pacific and elsewhere

This workshop will consist of two major parts. The first describes the tectonic and regional controls to copper and gold mineralization in the circum-Pacific region with a focus on the magmatic arcs of Southeast Asia, Western Pacific, Peruvian Andes and Ecuador. The relationships of mineralization to subduction-slab geometry, varying deformational styles, cross-orogen structures, heat- and fluid-flow focussing mechanisms

and other controls will be discussed.

The second part of the course will present the geological setting, geochemical signature and geophysical expression of porphyry copper-(gold) systems on the district-scale and provide several global examples.

This presentation will cover the key geological ingredients and physical constraints that make for productive porphyry systems. General geochemical zoning, hydrothermal alteration

models and geophysical signatures will be presented. Examples from continental and island arc settings will include deposits formed from oxidized magmas in Indonesia and Ecuador, and more reduced magmas in Nevada, with comparisons drawn to the intrusion-related gold deposits in Alaska-Yukon. Exploration models will be discussed for porphyry deposits in different geological settings, erosion levels and weathering environments.



This workshop is post-conference workshop SC6 for the PACRIM 2019 conference.

For further information, view this workshop at <https://tinyurl.com/aignews135-porphyry>



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Jon Hronsky's contributions to the mining sector recognised with Order of Australia Medal (OAM)

Congratulations to Dr Jon Hronsky on being awarded an Order of Australia Medal (OAM) in the 2019 Australia Day Honours for services to the mining sector.

Dr Hronsky, an AIG member, has almost 30 years experience in the mining and mineral exploration industry. He is a Principal of Western Mining Services (WMS), a consultancy group with offices in Perth and Denver that provides strategic-level services to the global mineral exploration industry, and a Director of Encounter Resources, a Western Australian focused base-metals explorer.

Dr Hronsky received a Bachelor of Applied Science in Mining Geology from the West Australian School of Mines in Kalgoorlie in 1983 and completed a PhD at UWA under Professor David Groves in 1994. He was awarded the Gibb Maitland Medal in 2005, the highest award of the WA Division of the Geological Society of Australia and was the 2009 Society of Economic Geology Distinguished Lecturer. He is also on the board for the Centre for Exploration Targeting at UWA and an Adjunct Professor at Macquarie University, Sydney.

The AIG Council extends congratulations to Dr Hronsky the formal recognition of his contribution to exploration and mining in Australia.



Read of Dr Hronsky's contributions to exploration and mining and more at
<https://tinyurl.com/aignews135-jhronsky>

SEC Acts to Modernize Resource Disclosure Standards for Mining

The Society for Mining, Metallurgy & Exploration Inc. (SME) and the National Mining Association (NMA) today issued a joint statement on the Securities and Exchange Commission's (SEC) announcement that it has voted to adopt amendments to modernize the property disclosure requirements for mining registrants, and related guidance, under the Securities Act of 1933 and the Securities Exchange Act of 1934.

David Kanagy, SME Executive Director, said, "I am pleased with the joint work of SME and NMA on this important SEC disclosure requirement. The issuance of this new SEC rule is a long time coming. It was made possible through the efforts of many organizations and individuals dedicated to making a positive change..."



Read more about the change at
<https://tinyurl.com/aignews135-sec>

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AIG Council Nominations now open

The Australian Institute of Geoscientists (AIG) is the leading professional institute representing geoscientists employed in all sectors of industry, education, research and government throughout Australia. AIG is a not for profit organisation, run by members for members, which aims to advance the skills, status and public perception of more than 2600 members both within Australia and overseas.

The AIG is dependent on the time and contributions of generous members prepared to serve on Council and

give back to their profession. The geoscience profession is confronted with many challenges including declining university enrolments, poor community perceptions of the minerals industry, threats of increasing government oversight and regulation, highly cyclical and unreliable work patterns, and technology rapidly changing the nature of work and the skills required to be successful. Now more than ever the AIG needs energetic members prepared to serve on Council and ensure that your association

has access to the most talented geoscientists with the capability to steer the organisation into the future.

AIG Councillors are expected to attend Council meetings (approximately 90 minutes every ~6 weeks), and contribute time and energy to the effective running of your organisation. Councillors are the legal custodians of the AIG, with the responsibilities and obligations of company directors, to effectively steward your organisation consistent with Australian laws and regulations.



AUSTRALIAN INSTITUTE OF GEOSCIENTISTS
Supporting Geoscientists

About the AIG



Our profession is facing challenges

- Declining enrolments into University
- Increasing community hostility towards mining
- Automation, data analytics and other technologies are changing the nature of work for geoscientists
- Threats of increasing government oversight and regulation of geoscientists and their work
- Orebodies are getting deeper and more technically challenging
- Highly cyclical and unreliable work patterns for geoscientists
- Age / demographics / gender

Your association plays an important role in addressing many of these challenges....

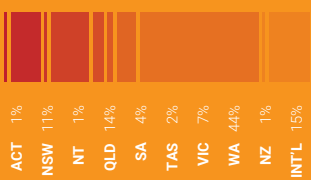
...but we need your help...

- Mentoring graduates and young professionals
- Working with regulators on professional issues
- Supporting universities around curriculum and changing nature of work
- Supporting geoscientists to find reliable work and communicating the challenges to government

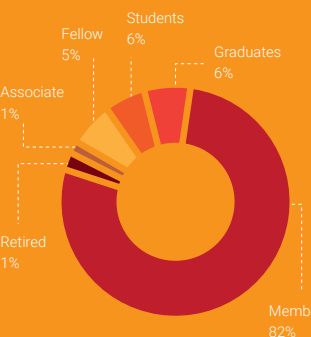
Some fast facts about our association

As at March 1st, 2019

2685 Members



State/Territory	Percentage
ACT	1%
NSW	11%
NT	1%
QLD	14%
SA	4%
TAS	2%
VIC	7%
WA	44%
NZ	1%
INT'L	15%



Category	Percentage
Members	82%
Students	6%
Graduates	6%
Fellow	5%
Associate	1%
Retired	1%

RPGEO MAIG 166 // FAIG 22



Please consider whether you or any of your peers are ready to nominate for AIG Council and give back to your profession. Nominations close 8th April, 4pm. For more information and a nomination form, please visit <https://www.aig.org.au/aig-council-nominations/>

NSW Branch Report

Sizah Nawzad

National Graduate Group and NSW Chair

After a successful 2018 with NSW being involved in the 2018 Mentoring program, Core Logging fundamentals and hyperspectral workshop as well as two Careers nights held by the Macquarie University Geoscience Society (MUGS) and the University of New South Wales geoscience society (UNSW Geosoc), NSW is delighted to be a part of the 2019 calendar.

2019 has in store further student events held by university institutions to broaden the career horizons of students and bridge the gap between academia and industry. Planning and running of these events will take place within the next few months.

Along with this, the branch is preparing for the 2019 Mentoring activity, following a successful run in 2018. Emails have been sent out for expressions of interest from mentors and mentees regarding this with further development to take place in the following weeks. 🇺🇸



Experienced Iranian Geologist/Engineering Geologist looking for work in Australia

I hold a BSc in geology and MSc in engineering geology and currently lecture in engineering geology at the University of Tehran. I am keen to find work in Australia in exploration or engineering geology and have worked in Australia (coal, gold) and Pakistan (dam and power plant construction). Australian and UK referees available.

Please contact Mahnaz at mahnaz.fallah91@gmail.com

Education Report



Kaylene Camuti
MAIG RPGeo,
Chair, Education
Committee

Many members will be aware that overall enrolments in geoscience degrees have fallen over the last few years, presumably in response to the decline in employment. While the number of applications to the AIG Geoscience Student Bursary Program have also fallen a little (as expected), we have still received in the order of 25 to 35 applications each year in recent years.

The next few years, however, look like being interesting - from the perspective of both jobs and tertiary enrolments. Employment projections from the Australian Department of Jobs and Small Business, released late last year, suggest there could be significant growth in the number of geoscience jobs. The Department's projections cover over 470 occupations for a 5-year period from May 2018 to May 2023. The projected employment growth figures range from negative 32.5% (secretaries) to 39.3% (aged and disabled carers), with an average projected growth for all occupations of 7.1%.

“ The employment growth projection to May 2023 for geoscientists (geologists, geophysicists, hydrogeologists) is 21.6%...”

The employment growth projection to May 2023 for geoscientists (geologists, geophysicists, hydrogeologists) is 21.6%, which is amongst the highest growth projections for all the occupations considered.

Based on previous cycles, the increase in available jobs is likely to translate to an increase in tertiary enrolments. The difference with this cycle, however, is that government now supplies employment projections - providing tertiary institutions with early warning of a probable marked increase in student numbers.

Roger Thomson

Consulting Geologist

Gold and Lithium exploration specialist

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This should allow universities to plan ahead and ensure teaching resources are maintained and, if necessary, increased to meet future demand.

The projection figures also provide optimism for senior school students considering a geoscience career, and allow them to look ahead with some confidence, and also select appropriate subjects to provide the best background for entry into tertiary geoscience studies.

The AIG Geoscience Bursary Program for this year will be launched in late March – early April. While we don't expect a significant increase in applications this year, the employment projection figures are promising, and perhaps we can look forward to increased student participation in the Bursary Program, and in AIG activities, in coming years. 🍷



The 2018 AIG bursary application guidelines available
aig.org.au/education-training/student-bursary-programme

AIG Bursary Supporters – March 2019

The AIG wishes to thank the following individuals and organisations for their support of the Geoscience Student Bursary Program.

DIAMOND

- **CHRIS BONWICK**
sponsoring the Bonwick-AIG Geoscience Student Bursaries
- **GEOFF DAVIS**
sponsoring the Davis-AIG Geoscience Student Bursaries
- **MACQUARIE ARC CONFERENCE – GEOLOGICAL SURVEY NSW**
sponsoring the Macquarie Arc Conference-AIG Geoscience Student Bursaries
- **SYDNEY MINERAL EXPLORATION DISCUSSION GROUP (SMEDG)**
sponsoring the SMEDG-AIG Geoscience Student Bursaries

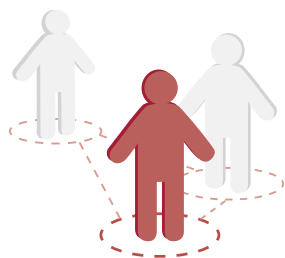
PLATINUM

- **AIG STATE BRANCHES**
- **JONATHAN BELL**
sponsoring the Jonathan Bell-AIG Geoscience Student Bursary
- **GNOMIC EXPLORATION SERVICES PTY LTD**
sponsoring the Gnomic-AIG Geoscience Student Bursary

BRONZE

- **DOUG YOUNG**
- **EXPLOREGEO**

Thank you, also, to AIG members and AIG state branches, for their support and assistance with Bursary Program.



Membership Updates

New Members

December 2018

STUDENT

GOLDING, Talitha

GRADUATE

ALLAN, Rebecca

CESILE, Stephanie

R VIGNESVARAN, Leavana

VALENCIC, Joshua Stephen

MEMBER

BURT, David Gareth

FRAWLEY, Paul Francis

GRIFFIN, Glen

HANGER, Mitch Michael

HETTIARACHCHI, Larissa Joyce

Kusnandar, Kusnandar

LE MADEC, David

LI, Ben

MAKIN, John

MARTENSEN, Marlies Evelyn Alexa Mai

MCKENZIE, Dale Scott

MERCER, Caroline Jessica Alice

MUKHAMETZHANOV, Ravil

NGUYEN, Natalie

STEPHENS, Lindsay John

STOTT, Michael James

THOMSON, Michael Peter

FELLOW

MURPHY, Finbarr

January 2019

STUDENT

AMIRI, Atiqullah

DE GROOT, Alisha

FERNANDEZ, Jose

HIGGIE, Dion

KOSTEN, Katarina

MACDONALD, Kelly

MERGARD, Shane

GRADUATE

AKLIGOH, Daniel Yao

BURROWS, Lachlan

VILLANUEVA, Dianna

MEMBER

ASAFO-AKOWUAH, John

AYDOGAN, Can

BIGGS, Neil Gareth

GARDOLL, Stephen John

GARLAND, Marama Jean

HO, David

HUDSON, Kiran

LITTLE, Murray Paul

LUNGE, Moira

MEEHAN, Tarrant Gwylim

MIZEN, Dale Michael

PORTER, James

SAROA, Dulcie

TAPIA CORTEZ, Carlos Antonio

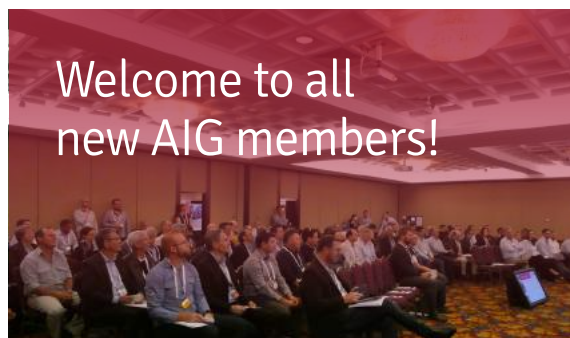
TYNDALL, Michael Colin

WILLIAMS, Lucas Peter

WINZAR, Carmen

FELLOW

SCHMEIDER, Shaun Paul



RPGeo Applications

CANDIDATES APPROVED BY AIG COUNCIL - DECEMBER, 2018

DR ADRIAN GALLARDO of Burswood, Western Australia, in the fields of Hydrogeology and Mineral Exploration.

MR DANIEL COLBORNE of Kedron, Queensland, in the field of Geotechnical & Engineering.

MR SIMON FRANCIS FOLEY of West End, Queensland in the field of Geotechnical & Engineering.

MS MEGAN WEATHERMAN of Preston, Victoria in the field of Mineral Exploration.

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

DR NICHOLAS HERBERT JANSEN of Nuñoa, Chile, is seeking registration in the fields of Mineral Exploration and Geochemistry.

MR MICHAEL STEWART KAMMERMAN of Willetton, Western Australia, is seeking registration in the fields of Mineral Exploration and Mining.

MR REGIS ANGELO NERONE OF RIVERVALE, Western Australia, is seeking registration in the fields of Geophysics and Mineral Exploration.



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The South Australian Branch of the AIG presents:

YORKE PENINSULA - FIELD WORKSHOP

Colin Conor and Graham Teale

Monday 15th - Tuesday 16th April 2019

(optional day, Wednesday 17th April, viewing core and samples at the S.A. Core Library facility)

The Yorke Peninsula Field Trip will investigate the stratigraphy of the ~1750Ma Wallaroo Group and its associated ~1585Ma alteration and mineralisation. Numerous mines and prospects will be visited and these will exhibit the various styles of alteration and mineralisation seen on the Peninsula. There are only three sites where rocks of the Olympic IOCG Domain are exposed to view, two of these are on Yorke Peninsula.

Field traverses and site visits will include:

- Field traverse along the coast adjacent to the Hillside Deposit
- Core viewing at the Hillside deposit site. View the various skarn-types and compare with unaltered lithotypes.
- Traverses along the coast north of Wallaroo to view granite phases of the Hiltaba Suite syn-orogenic Tickera Granite complex, and their relationships to the host Wallaroo Group.
- Visit the Ooralaw Mine from which is extracted brightly coloured scapolite-amphibole-epidote-magnetite skarn, this being marketed as Harlequin Stone. Also a nearby site that demonstrates the timing of alteration relative to the complex structural history.
- Visit mines sites of the historic Wallaroo-Moonta Mines, e.g. the New Cornwall, Kurilla and Poona mines.
- Site discussions on the Moonta and Wallaroo mineralisation styles that involve very different hosts and very different tectonic regimes.

Colin Conor currently has the position of Adjunct Associate Professor at the University of South Australia. He has 50 years of geological experience derived from geological survey and industry, with many of those years spent working on the geology of the Olympic IOCG Domain (including Olympic Dam and the Wallaroo-Moonta region), and also equivalent prospective rocks to the east in the Curnamona Province.

Graham Teale has over 40 years experience as a mineral exploration, mining and research geologist. He is currently carrying out research with Prof. Paul Spry of Iowa State University on the world class Broken Hill Deposit. He has worked on metamorphosed base metal mineralisation throughout Australia and in Africa, North America, India and Scandinavia. He has presented workshops on primary litho-geochemistry, low sulphur zinc mineralisation and IOCG mineralisation.

\$ 900 AIG Members \$ 1200 Non Members

A limited number of places for students (\$300) are available. All prices include GST.

Participants will need to arrange accommodation, meal costs and travel to Ardrossan.

To Register - Visit AIG's Bookings and Registration Site:

<https://www.aig.org.au/events/sa-yorke-workshop-apr19/>

For information contact: Adrian Brewer: ambrewer@ozemail.com.au



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Australian Institute of Geoscientists

Australian Geoscientist Employment Survey

Q4 (October to December) 2018 Results

Overall improvement trend in geoscientist unemployment continues, but self-employed geoscientists still doing it tough

- Call also made for greater political action to ensure more equitable and timely access to land for exploration
- More women also forging geoscience careers



Andrew Waltho
FAIG RPGeo

The latest quarterly Australian geoscientist unemployment survey for the final quarter of 2018, conducted during January 2019, revealed a slight increase in geoscientist unemployment, from 8.3% at the end of September, to 9.1% at the end of December 2018. Underemployment amongst self-employed geoscientists, however, rose significantly from 12.9% to 18.5% for the same period.

However, despite the dip for the past quarter, the new results pointed to evidence of an overall improving job trend since June 2016.

"This latest quarterly result is disappointing", Australian Institute of Geoscientists spokesperson, Mr Andrew Waltho said today, "coming at a time when there was genuine optimism regarding an improvement in exploration activity, several, significant new mineral discoveries, and speculation regarding potential skills shortages facing the exploration and mining sectors".

"Both the Federal Government and Opposition have announced initiatives to support mineral exploration research if elected in the May Federal election, but no-one is talking about improving processes facilitating equitable and timely access to land for exploration," Mr Waltho said.

"In fairness, this is a state issue, but we are still seeing bureaucratic and lengthy processes in operation that disadvantage the junior exploration sector in particular, with little sign of change," Mr Waltho said.

The unemployment and underemployment situation varied widely between states.

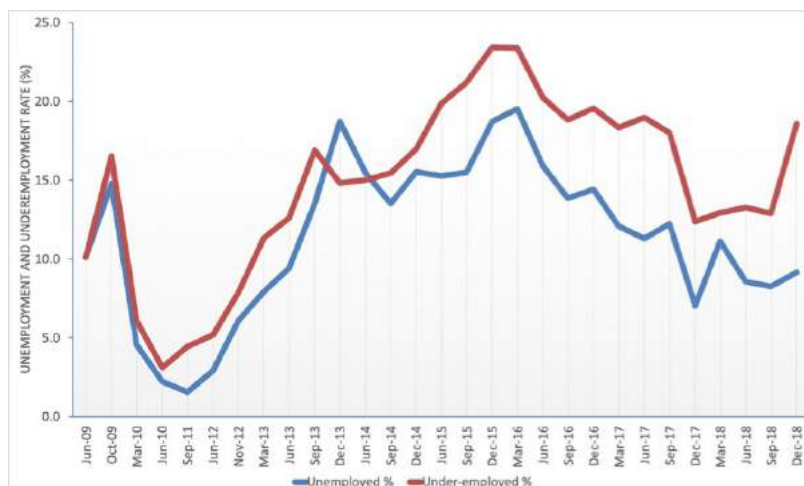
Unemployment was lowest in South Australia (5.3%), NSW and ACT (5.6%) and Victoria (5.9%), followed by Western Australia (8.3%). The results for Victoria and South Australia represent marked improvements on the previous, September quarter survey. Unemployment in Western Australia was 8.3%, up from 6.5%. Unemployment in Queensland jumped from 11.5% in the September quarter to 15.1% in this survey.

All states except South Australia saw little change or an increase in unemployment in the 12 months between December 2017 and December 2018, but an overall improving trend since June 2016 remains evident.

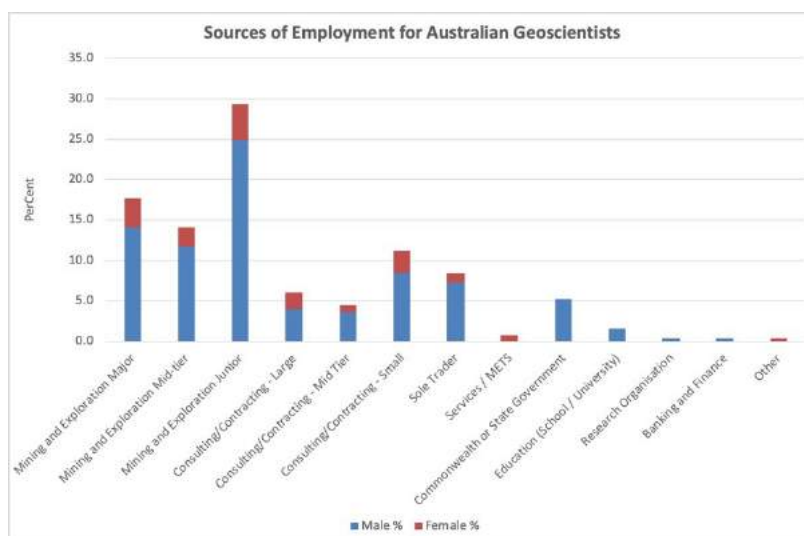
The underemployment rate in South Australia took some gloss off the unemployment figure, coming in at 36.8% for the quarter, followed by Queensland (24.2%), NSW/ACT (16.9%), Western Australia (14.9%) and Victoria (11.8%).

The survey attracted 391 individual responses. Too few responses were received from Tasmania and the Northern Territory for the reporting of state results.

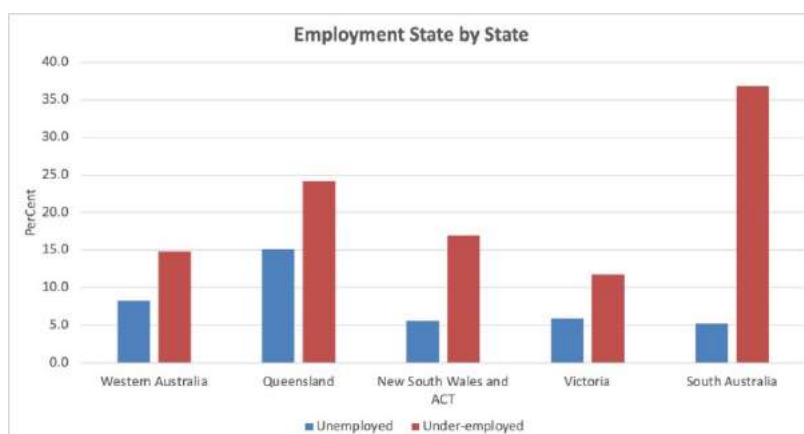
Junior exploration and mining companies employ 29% of Australia's geoscientists this survey, almost as many as major and mid-tier companies combined.



Unemployed and Underemployment rate.



Sources of Employment for Australian Geoscientists.



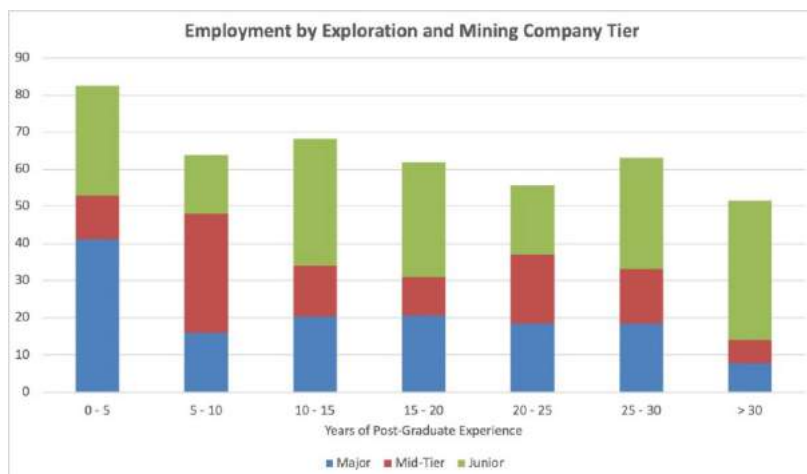
Employment State by State.

Cultural shift needed

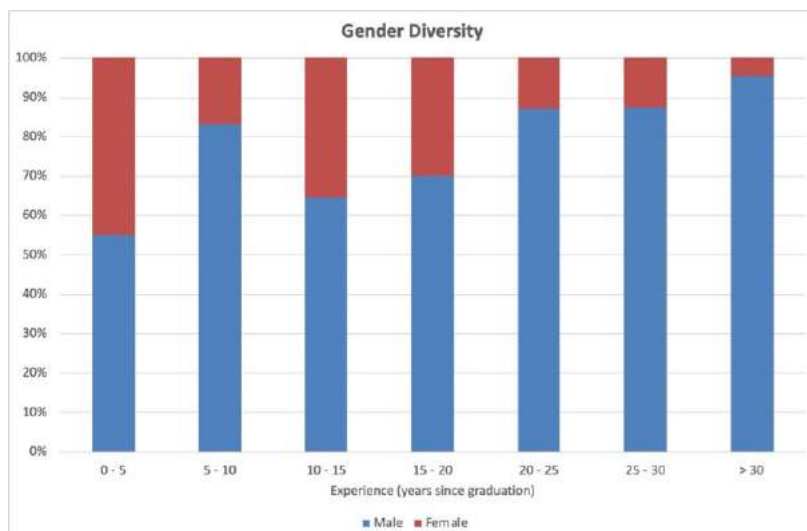
“This amply demonstrates the importance of measures to help small employers avoid burning precious capital waiting for approvals before conducting productive exploration activities”

Mr Waltho said.

“Small companies have a limited capital base on which is difficult to raise further funds and must be used productively if they are to survive,” Mr Waltho said.



Employment by Exploration and Mining Company Tier.



Gender Diversity.

“Early career geoscientists tend to be employed in greater numbers by major mining and exploration companies but this soon changes as geoscientists gain professional experience, suggesting that major companies need to look more closely at retaining talent by providing a more dynamic and professionally rewarding professional environment for their staff,” Mr Waltho said.

Women are represented almost equally in the geoscience staff of major, mid-tier and junior exploration companies.

“Gender diversity in exploration and mining, long-considered to be a male dominated profession in Australia is changing rapidly” Mr Waltho said. “Almost half of the early career geoscientists (0-5 years’ experience) who responded to this latest survey were women,” Mr Waltho said. “The sector is clearly creating career opportunities for women that are being taken up and we need to ensure that this trend continues through measures to promote and preserve gender diversity,” he said.

“A drop in the proportion of women in the 5 – 10 year experience range is evident, but the proportion of women in the profession increases again in the 10 – 15 year range, suggesting, perhaps, that we are seeing the benefit of measures such as flexible employment and favourable parental leave provisions that enable geoscientists to mix raising a family with pursuit of a career. “This again, is something we need to build,” Mr Waltho said.

“The fact that we are seeing evidence pointing to this is a real positive for both the exploration and mining industry and our profession,”

Mr Waltho said. 🗣️

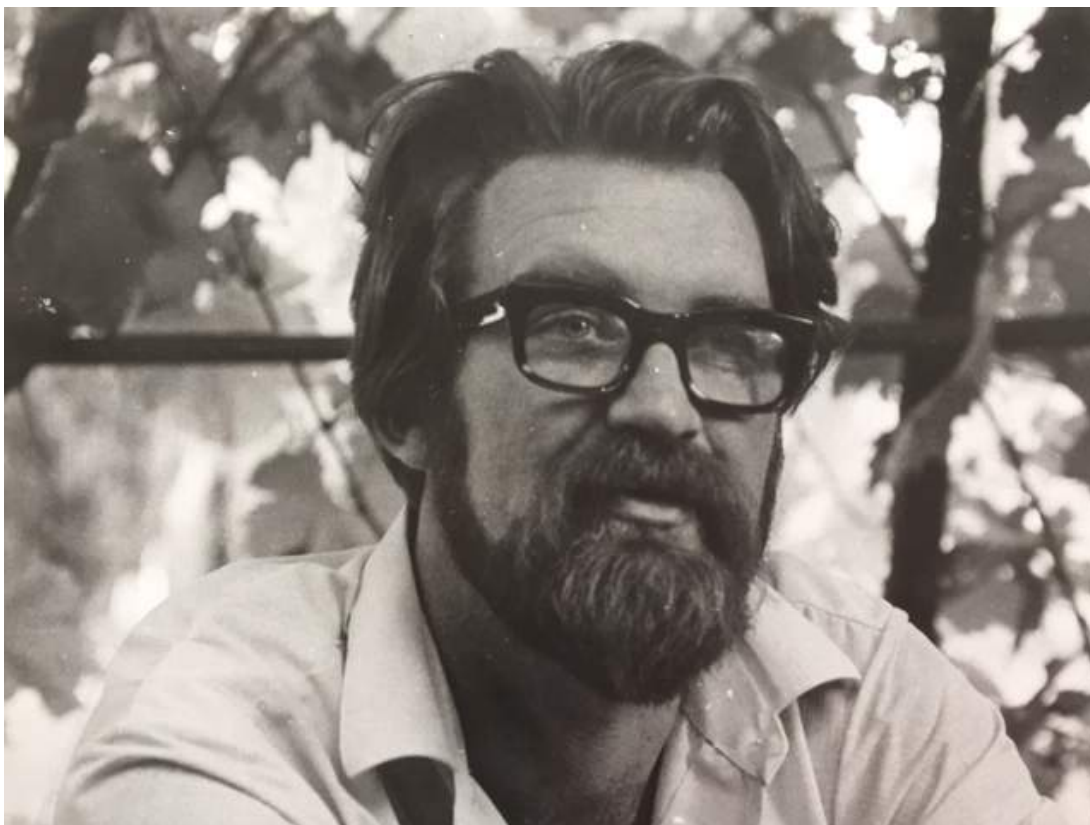
Vale Tim Hopwood

I first met Tim Hopwood in the late 1950's as an undergraduate at Sydney University where Tim was in the year ahead of me, part of a stellar group of future geologists.

Tim came from Lisarow, then a small village a few kilometres south of Gosford on the central coast in New South Wales. He was better known to a great friend, the legendary Ross Kennedy who also came from the Central Coast, and it was really through Ross that I had anything to do with Tim. I remember that Tim was a member of the Libertarian Society, about which all kinds of salacious rumours circulated, and that after graduation Tim had close working relationships with mutual friends and colleagues Ken Glasson and later, Bert Mason. Tim graduated with first class honours and followed up with his PhD.

He rapidly made a name for himself as a structural geologist through teaching, research and consulting. Tim had a long commercial association and friendship with Alan Voisey, my much loved supervisor when I did my PhD at the University of New England, and Arnold Offenberg who represented the exploration ambitions of ICI in Australia. Tim was instrumental in floating several junior companies, Sedimentary Holdings being the company with which I was most familiar. Tim took on the challenge of commercialising and promoting the Synrock invention by Professor Ted Ringwood, an invention that meant that radioactive wastes could be locked up in artificial spinels which we geologists know are extraordinarily stable and resistant to weathering or destruction for

Andy White
FAIG



most of geological time. I believe Tim was instrumental in discovering or at least unravelling the resource of the Pinnacles base metal deposit at Broken Hill, and he was the “go-to” consultant on Broken Hill for most companies confronted with the structural complexity of this great mineral system. He spent several years exploring in Saudi Arabia and later, Russia.

I could keep listing the exploration and mining ventures that Tim had worked on or promoted and the people who admired and respected him for his outstanding professional abilities, and it would become apparent that he had an extraordinary spread of expertise, experience and contacts. Such a list would be as dry as dust and Tim was never dry nor dusty.

I didn’t really have much close contact with Tim until 1984, when I had quit Comalco where I had worked for 13 years, to go out on my own. I got a phone call from Tim asking if I’d have lunch with him and over a pasta meal in North Adelaide the conversation went something like this: Tim: “what ideas have you got, Andy?” Me: “what do you mean, ideas?” Tim: “ore deposits to be found, of course”. Me: “I reckon I know where to find a high quality kaolin deposit”. Tim: “kaolin, what’s that used for?”. I explained that its

principal high value use was in coating paper and gave him a run-down on potential economics of processing and selling kaolin. Tim said OK, how much would it cost to find? On the inevitable table napkin I fleshed out a budget and Tim said “I can do that, when could you start?”

Thus began Venture Exploration, and many years of close friendship with Tim. With the help of the engineering genius, the late Roger Main, and Lynton Brown, we went to Cape York, found the Skardon River kaolin deposit and floated Venture Exploration on the strength of the discovery. Until I got side-tracked by some challenges in Poseidon Limited, I spent most days in Tim’s Jeffcott Street office in North Adelaide. Apart from the commercial and geological stuff, what do I remember of those days? Tim’s eyesight was never good and he wore glasses as long as I can remember, and I used to wonder why his glasses were rarely clean and how he managed to see through them. Now, having worn glasses since my eyesight was downgraded by long hours at an inferior computer screen, I know. I am not a tidy person, but I do file things and don’t trust my memory as to where I put files. Tim was worse than untidy and his memory was his filing system. When he

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moved to a new office in Hutt Street, he had his voluminous collection of maps, reports, reprints and files in stacks around the perimeter of a large room with his desk in the centre. I told him, mate, you will waste a lot of time looking for stuff if you leave it like this. He left it like that. The precision of his geological work I think was amply illustrated by his resource estimation for the gold deposit mined at Cracow by White Engineering. His grade estimate was 3.1g/t and reconciliation of the gold produced by the joint venture with Sedimentary Holdings indicated it was actually 3.2g/t, and his tonnage estimate was exactly what the JV produced. His work was all done with meticulously prepared cross sections, at a time when geostatistics was in its infancy and not available for his use.

Venture Exploration and later Jeffcott Investments fell over really as a result of the crash of 8th October, 1987, and its negative impact on the availability of risk capital, combined with the relatively small capital market of Adelaide where Tim operated. Eventually Tim lost control of Venture. He promptly identified the Kendall River kaolin deposit from BMR auger drilling and spent years testing to prove that it is probably the best kaolin deposit in the world, and trying to promote this truly world class resource into a mine.

Tim was an endearing, astute, gutsy risk taker in the commercial world of mineral exploration and mining. In our Jeffcott Street days, Tim would occasionally expound his views on where Australia was headed (to end up like Italy with ephemeral governments made up of coalitions of independents and major parties) and his global views on mineral exploration. It was a wonderful opportunity to hear a truly brilliant analytical



mind in action, and many of his forecasts have come true. Strangely, he made some appalling choices of people from time to time and was let down badly by some of them, but he also accumulated the admiration and respect of a very large number of his peers. He worried me with some of his risk taking and I once asked him what would he do if his ventures all went pear shaped? He said "Andy, I'd pick myself up, dust myself off and start all over again". He did.

A wild man at Uni, a gifted scientist applying his gifts to geological research, teaching and applied geology, a tireless, fearless promoter and opportunity spotter, a bon vivant, yet Tim was a very private person. I suspect he might have been surprised to know how many admirers he had, and that all those who knew him and worked with him would feel like I do, privileged to have had him in our lives, and very sad indeed at his passing. The sign on his office wall said it all: "There are those who make things happen, there are those who watch things happen, and there are those who ask "what happened?" Tim made things happen. To his family, on behalf of all the geological, mining and financial world Tim was associated with I give you our deepest sympathy and condolence. Vale Tim. 🍷🍷

Does carbon dioxide drive climate change?

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The articles by Dave Shatwell about the causes of climate change in issues 129 and 130 of AIG News in late 2017 started me thinking about this question. The topic received further thought in early 2018 when I prepared a lecture on the environmental legislation dealing with climate change in Queensland. Since July I have had plenty of spare time to delve more deeply into the physics and mathematical models that underly the various claims from both sides of the debate. There are plenty of publications supporting the link between CO₂ and climate change so I have decided to write a concise defence of the negative position from a geological perspective.

Many times I have been asked – ‘Do you believe in climate change?’ This question demonstrates a complete lack of understanding

of science. Science is not a belief in dogma. Scientists are taught to develop theories from observations and experiments and to test their theories and those presented by other scientists by checking observations or testing predictions from the theories. Observations do show that temperature and carbon dioxide levels are rising but that does not prove a causal relation (in either direction). My son and I recently discovered how frequently the causality fallacy occurs in peer reviewed papers on the epidemiology of Pb (Wilson and Wilson, 2016). The question that should be asked is – ‘Can you provide evidence that shows CO₂ is not driving climate change?’ – as that evidence could falsify the theory. I hope that the following arguments show I am a rational scientist rather than a “climate change denier”.

Evidence from geology

It is not surprising that many of the scientists questioning the effects of human actions on climate were trained as geologists. Geological theories are devised to explain the environment in which rocks formed. They involve:

- unimaginable time frames;
- massive continents moving around the world, colliding, building mountain ranges, metamorphosing rocks and triggering volcanic activity;
- the imperceptibly slow development of landscapes by weathering and erosion;
- a wide variety of sedimentary processes; and
- an evolving fossil record.

Geology is based on observing rocks and fossils, taking geophysical measurements, conducting chemical analyses and determining isotopic ratios. What evidence is there in the 4.5 billion years history of the Earth that may be relevant to climate change?

The first observation is that the Earth is constantly changing. The oldest rocks on Earth show no evidence of oxidation, implying that oxygen was not a significant component of the early atmosphere. The early atmosphere on Earth probably resembled the present atmospheres of Mars and Venus which contain more than 95% CO₂ (Visconti, 2016). They retain high levels of CO₂ because plant life evidently never developed on those planets. That is in contrast to Earth where photosynthesis commenced in the oceans about 3 billion years ago. That process converted CO₂ into oxygen. Oxygen in the ocean would have oxidised the ferrous iron in solution and precipitated banded iron

deposits which are now mined as iron ore. Any oxygen in the early atmosphere probably reacted with methane to form more CO₂ or sped up the weathering of some rocks. The oxygen content of the atmosphere and oceans increased slowly, and by 600 million years ago was at levels that allowed animals to evolve in the oceans. Free oxygen now forms almost 21% by volume of the atmosphere and about 5 ppm by weight of the oceans.

An important conclusion from this is that despite the early atmosphere containing several thousand times more CO₂ than the present, the continuous record of life and aqueous sedimentation on Earth indicates that the oceans and rivers did not boil dry (Kiehl and Dickinson, 1987). In fact, there is evidence of global glaciation about 2.4 billion years ago (Young, 2017), showing that extreme CO₂ levels did not force a hotter climate. Since then, CO₂ levels have generally decreased because of photosynthesis and the formation of carbonate rocks, despite minor additions from volcanoes, decaying vegetation and animal respiration (Wallace and Hobbs, 2006). Major reductions in CO₂ levels occurred between 350 and 250 million years ago, in the Carboniferous and Permian Periods, when land plants flourished and major coal deposits were formed. All the carbon in fossil fuels and most of the carbon in carbonate rocks came from CO₂ in the atmosphere.

Another important fact from the geological record is convincing evidence that climatic changes have occurred regularly in the past. Many of these have been cyclic, such as the recurrence of glacial events at about 300 million

year intervals. Some researchers have related these cycles to continental drift and mega-continent formation (Young, 2017). Others attribute them to changes in the solar energy output. Shorter cycles during the latest million years have been studied in detail using isotopic and chemical measurements of air bubbles trapped in ice retrieved from deep drill holes into the Antarctic ice sheet (ICPP, 2013). The data show a series of glacial events (ice ages) about 100 000 years apart, separated by short interglacial warm periods with temperatures similar to the present. Each warm period followed a rapid 8 to 10 K rise in temperature from the preceding glacial event. The most recent rise occurred about 10 000 years ago. However, since then, average temperatures have

fluctuated over a range of about 2 K, with notably colder periods such as the Dark Ages (1600 to 1200 years ago) and the Little Ice Age (700 to 150 years ago). At least some of the recent temperature rise is likely to be related to natural processes that are driving these fluctuations.

There is a greenhouse effect

Basic physics shows that the surface temperature of the Earth is about 33 K warmer than it would be if there was no atmosphere (Visconti, 2016). This implies that a “greenhouse” effect exists. Some gases absorb infrared energy radiating outward from the Earth. Only energy that is retained contributes to heating



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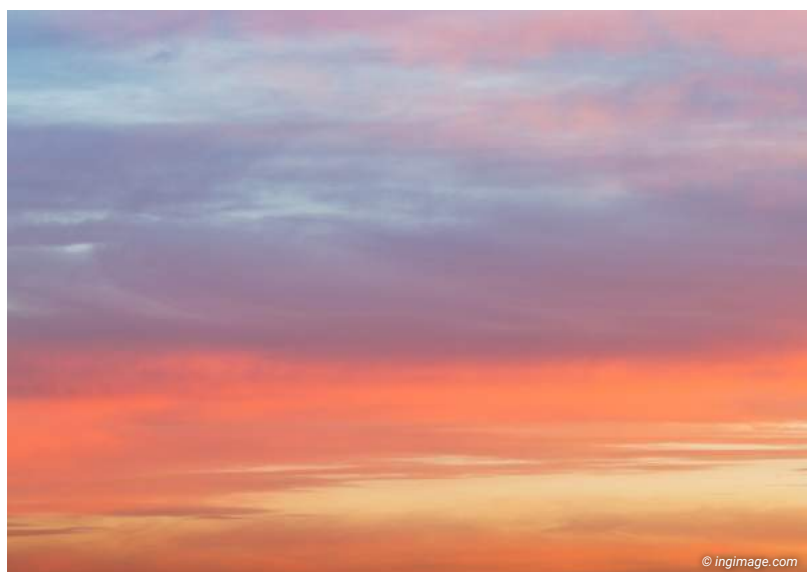
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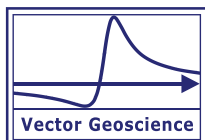
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of the atmosphere. The rest is re-radiated into space from various levels in the atmosphere. If re-radiation is predominantly from warm air near the surface, almost all of the absorbed energy is lost and there is little if any heating. If radiation occurs from higher levels, less energy is generally lost to space because air temperature generally decreases with height (up to the Tropopause at about 10 to 15 km). This phenomenon is a result of adiabatically cooling of rising air masses and is characterised by a lapse rate of between 6 and 10 K per km rise (Zhang and Moore, 2015; Wallace and Hobbs, 2006).

The decrease in radiation with height is quite large because the total radiation emitted is proportional to the fourth power of the absolute temperature of the emitting substance according to the Stefan-Boltzmann Law (Wallace and Hobbs, 2006). At the Tropopause where the temperature is near 220 K, only about a quarter of the absorbed energy is lost, so re-radiation from these levels results in retention of most of the absorbed energy and produces considerable warming. However, at higher altitudes, in the Stratosphere, temperatures begin to rise again and the energy loss increases with altitude. Petty (2006) explains this radiative transfer process and the underlying mathematics.



Since 1970 satellites at approximately 1000km altitude have measured radiation from the Earth that confirms the net absorption of various greenhouse gasses. Each radiometer measured a wide range of wavelengths and the intensity of each wavelength gives an indication of the weighted average temperature at which it was radiated (Petty 2006). This temperature, known as the brightness temperature, depends on height in the atmosphere which is determined by the concentration of the absorbing gas and pressure. The satellite results resemble the theoretical blackbody radiation pattern for the Earth's surface temperature with various bands removed by absorbing gasses.



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“ Although each set of measurements from the earlier satellites only covers about one year and were made by different types of instruments, they have been used to test climate models.”



However, those gaps are partially filled by radiation from higher levels of the atmosphere. The satellites receive radiation directly from the ground in the atmospheric window between 8 and 12 microns. At other wavelengths they “see” radiation from the level in the atmosphere where the optical thickness is unity (Petty, 2006). Although each set of measurements from the earlier satellites only covers about one year and were made by different types of instruments, they have been used to test climate models.

Griggs and Harries (2007) compared the spectra measured by satellites over the North Pacific Ocean in 1970, 1997 and 2003. The data from the atmospheric window possibly showed slight warming of the ocean after 1970. The 1200 to 1400 micron wavelengths showed a negative change between 1970 and 1997 and a slight positive change from 1997 to 2003, possibly indicating different water vapour concentrations. An asymmetric anomaly near a CO₂ line at 720 microns could indicate a mismatch of the wavelength in the 1970 spectrum with the later

spectra rather than an increased concentration of CO₂ or temperature changes. The spectra they published shows only part of the 15 micron absorption band and shorter wavelengths but there is negligible evidence of broadening of the CO₂ absorption band. An area of concern is a difference of up to 2 K between the measured brightness temperature and that calculated by two climate models. Another study by Bantges et al. (2016) compared global mean spectra based on satellite measurements from 1970, 1997 and 2012. Their results are comparable to those of Griggs and Harries (2007). However, the later study shows that the 1970 data possibly underestimated brightness temperature at higher temperatures, and therefore the ocean warming noted above may not be significant and this data set may not be a useful baseline for studies of climate change.

Some may have read the blog by the Science of Doom titled “Visualizing Atmospheric Radiation – Part Seven – CO₂ increases” that was posted on 13 January 2013

(<https://scienceofdoom.com>). It calculates that doubling the CO₂ concentration would increase absorption on the wings of the 15 micron absorption band by about 4.3 W/m² (compared to the present total absorption of the band of approximately 38 W/m²). The site warns that the calculations only address the transmittance of outward travelling emissions and do not calculate the radiative forcing (which needs to consider the re-radiation). However, the paper makes an assumption that doubling the CO₂ concentration would decrease the amount of re-radiation lost to space because of widening of the minor CO₂ absorption bands in the 15 micron band, and therefore increase warming. This argument fails to recognise that the emissions to space would no longer emanate predominantly from an altitude of 16 km but from a height of more than 20 km where the total pressure is approximately half the pressure at 16 km. There the number density of CO₂ molecules per volume would be the same as it was and the optical density would be unity. As this is in the Stratosphere, the temperature would be higher and more radiation would actually be lost to space, cooling the atmosphere.

If re-radiation was ignored, doubling CO₂ concentration would possibly cause an 11% increase in the current greenhouse effect of CO₂ which is less than a third of the 33 K present total greenhouse effect. That scenario is totally unrealistic as somewhere between a third and all of the additional absorbed energy will be re-radiated. The maximum, but unlikely, effect would be about a one degree increase in temperature. The evidence suggests we are moving towards a situation where additional CO₂ will actually cause cooling.

These conclusions are supported by the satellite data which do not show large amounts of extra energy is being lost from the wing of the 15 micron band extending towards 10 micron. Unfortunately, the satellite data do not cover the other wing or the central part of the 15 micron band. Interpretation of the satellite data is further complicated because water vapour causes significant absorption in these wavelengths and H₂O is commonly up to 100 times more abundant than CO₂ near the surface. The other reason why this absorption in the wings is not visible in the satellite data is because much of the additional energy absorbed by CO₂ has been re-radiated from relatively warm levels of the atmosphere near the surface with a relatively high brightness temperature. In which case it is not available for heating.

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The IPCC Assessment Reports

The 5th Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC, 2013) acknowledged that these recent cyclic ice ages were probably caused by Earth's variable orbit around the sun known as Milankovitch cycles. It also mentions several possible drivers of climate change including: changing amounts of solar radiation, the variable reflection of energy by clouds, volcanic dust and the moderating effects of the oceans. Despite these and other plausible mechanisms, AR5 perpetuates the use of an inaccurate formula that is central to the arguments in all previous Assessment Reports and many other publications. That formula states that

air temperature increase results from radiative forcing that is proportional to the logarithm of the CO₂ concentration.

The reference for this formula in AR5 is Myhre et al. (1998) who in turn state it is from the first Assessment Report of the IPCC (1990). That document attributes the formula to Wigley (1987) which is an internal report of the Climate Research Unit of the University of East Anglia where he was Director. The Climate Audit blog by Steve McIntyre (<https://climateaudit.org/2008/01/11/more-on-functional-forms-wigley-1987/>) reproduces the relevant sections of that report which states: "On theoretical grounds it can be shown that the relationship between radiative forcing change at the top of the troposphere and concentration change



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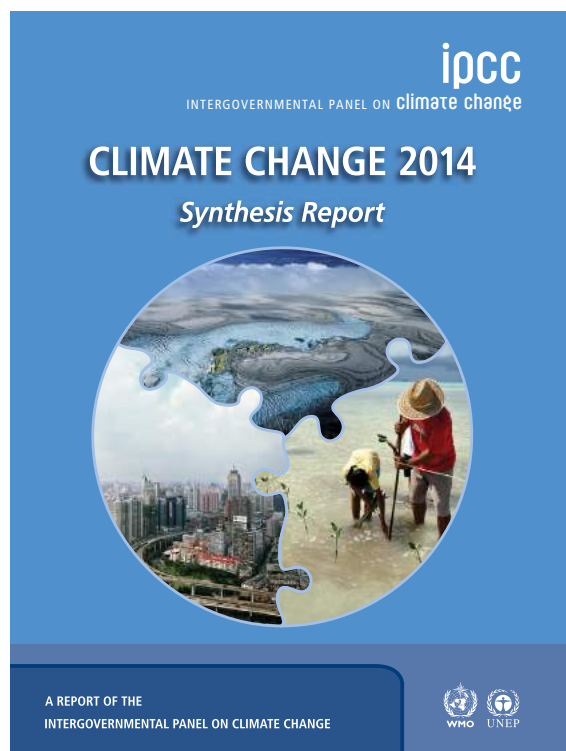


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is linear at low concentrations, square root at intermediate values and logarithmic at higher concentrations. Because of this ... [it is] logarithmic for CO_2 ". Wei et al. (2018) also present the three mathematical solutions and provide criteria when each formula is appropriate based on an exponential broad band radiative forcing model they used to calculate absorption coefficients. Neither Wigley (1987) nor Wei et al. published details of any calculations. Zhong and Haigh (2013) support use of the formula between 30 and 800 ppm of CO_2 based on unpublished radiative transfer calculations they made using very high spectral resolution gaseous absorption data.



AR5 Synthesis Report.

(Source: <https://www.ipcc.ch>)

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Derivation of the radiative transfer formulae

Petty (2006) provides a derivation for each of these approximations. He shows that for an isolated weak absorption band, the absorption is approximately a linear function of mass path (which is the integral of partial pressure of the gas or its concentration along its transmission path). He also shows that a line which has been broadened by increased pressure to a "Lorentz shape" (which resembles a slightly squashed normal distribution) will absorb energy in proportion to the square root of the mass path, although he earlier warns that this shape is not an accurate model of absorption. Lastly Petty (2006) describes two of the many band transmission models that are used to vastly simplify the calculations otherwise required in a line-by-line study to evaluate the radiative forcing for a complex absorption pattern that typically occurs at high concentrations. These patterns may involve thousands of absorption lines, some of which may overlap, and each has its own particular absorption coefficient and the potential for absorption and re-radiation from all levels of the atmosphere.

Of the two models presented, only the Elsasser Band Model produces a logarithmic relationship between concentration and absorption and that relationship only results under the assumption that each absorption band is much wider than the distance to the next band (i.e. there is massive overlap of absorption by many band). With other assumptions this model can yield limiting cases following a square root or mixed linear/exponential relationship. A concern about this model is its assumption that an infinite number of lines across the whole spectrum are thickened

by the same amount. Although a sequence of roughly evenly spaced, similar lines is found on the margins of major vibrational absorption bands due to rotational absorption bands, the statistical probability of these bands being relevant decreases rapidly within a few hundred wavenumbers (inverse of wavelength) of the central wavelength. Other facts that negate the applicability of this model include spectroscopic studies that show the intensity of actual absorption bands typically decrease 10 to 20 orders of magnitude over a similar distance and that the strength of the Earth's infrared emissions also falls to negligible amounts beyond 4 and 100 microns.

These results only relate to absorption and as stated before the amount of energy that is re-radiated must also be considered when evaluating potential atmospheric heating. The amount of absorption is irrelevant if it is all re-radiated as nothing is retained. A change in concentration only increases the amount of energy retained in the atmosphere within an absorption band if the re-radiation occurs predominantly at a lower brightness temperature than before the increase in concentration. The exception is when new radiation is beyond the limits of the previous absorption band (in its wings) and the additional absorption is not all re-radiated.

Wigley (1987) indicated that a climate model of Keihl and Dickinson (1987) established the forcing constant as 6.3 that was subsequently used by IPCC until 1995. The constant was reduced to 5.35 by Myhre et al (1998) who assumed that all the temperature change between 1850 and 1994 was solely due to increased greenhouse gases, especially CO₂ which had increased in concentration from 280 to 358 ppm (by volume).

The main greenhouse gasses

Water vapour is responsible for most of the greenhouse effect because it partially absorbs a wide range of infrared energy with wavelengths between 4 and 100 microns (millionths of a metre). This is despite the re-radiation occurring from moderately low altitudes. The concentration of water in the atmosphere is highly variable and closely related to cloud formation which releases latent heat of condensation that also affects the heat distribution. The relative energy retention varies considerably with temperature and humidity, so obtaining reliable global averages depends heavily on satellite measurements. The amount of energy typically retained by water and other greenhouse gases in a tropical cloud-free atmosphere is shown in Figure 1. The IPCC Assessment Reports tended to ignore the direct effects of water vapour because of the difficulty of predicting its concentration. They did consider water vapour and clouds created significant feedback that should be included in climate models (IPCC, 1990: 2013).

CO₂ absorbs about 8% of the Earth's radiated energy. This is mostly from the 15 micron absorption band. The lower atmosphere currently contains many times the CO₂ concentration required to absorb virtually all the energy in this band (one metre of atmosphere absorbs more than 95% of the energy at the centre of the band and the next metre absorbs 95% of the remaining 5% and so on) (Petty, 2006). Therefore, adding more CO₂ makes no measurable difference to the energy absorbed near the centre of the band because there is effectively no energy left to absorb. The absorption distances become larger for wavelengths further from the centre

Energy retained by four greenhouse gases

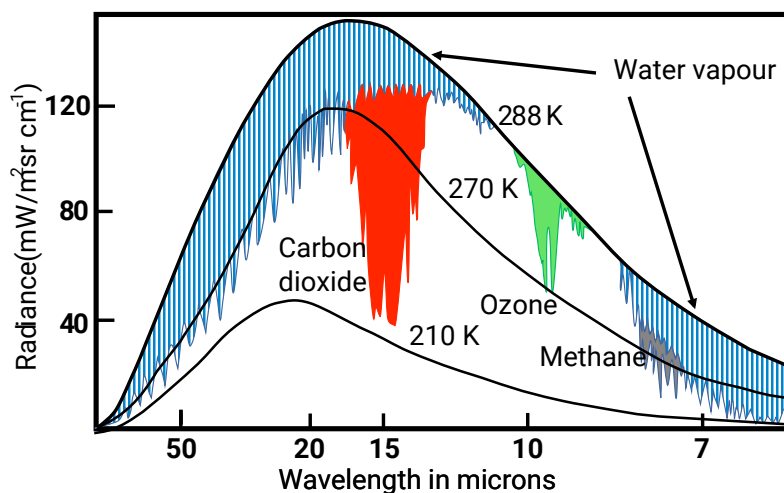


Figure 1. Infrared spectrum of the Earth as seen by a satellite at an elevation of 1000 km showing energy retained (proportional to area) by four greenhouse gases. Three brightness temperature curves calculated for blackbody radiation at 210, 270 and 288 K are shown for reference. (Modified from Petty, 2006).



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Tropopause and an increase in concentration has little effect on the energy lost. Although the increased concentration will mean that re-radiation will occur at a higher altitude, there is very little change in temperature with change of altitude in that region. A notable exception occurs at wavelengths near the centre of the 15 micron absorption band where measurements of Earth radiation from satellites show that current CO₂ levels trap those wavelengths well into the Stratosphere (Wallace and Hobbs, 2006, Figure 4.33) and an increase in concentration will cause cooling because the radiative loss will occur at a higher temperature. The purple line in Figure 5(b) in Zhong and Haigh (2013) shows that doubling CO₂ concentration would decrease temperatures.

Conclusions

and saturation is not a consideration for additional absorption from the wings of the absorption band. This additional absorption has little effect on atmospheric temperature as it mostly re-radiates to space from relatively low altitudes where temperatures are high and energy retention is low. Most of the energy absorbed by CO₂ is re-radiated from near the

The weak connection between CO₂ and atmospheric temperature is evident in contrast between the end of the last ice age when temperature rose about 8 K when CO₂ increased by about 80 ppm; and the last 150 years when temperature rose of less than 1 K when CO₂ increased by the same amount. That should not be a surprise to anyone who understands the simple energy balance in the Earth's atmosphere



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and ocean. What I would expect is that further rises in CO₂ concentration in the atmosphere may take most of the re-radiation in the 15 micron band into the Stratosphere and actually cause significant cooling of the atmosphere. It is just possible that this is the trigger that has terminated each of the recent interglacial warm periods. The concentration of CO₂ in the past being driven up by lower solubility in the warmer oceans. This may explain why a close examination of the changes in CO₂ levels in the ice cores shows that they occur several hundreds of years after the temperature changes.

The questionable "consensus" that CO₂ is causing global warming tends to overlook these facts and many other complicating factors such as loss of energy because plants turn some of the Sun's energy into chemical energy and some is converted to mechanical energy needed to drive convection cells in the air (wind) and oceans currents. The "consensus" relies heavily on climate models and the concept of radiative transfer of energy. In theory this should work but the physics is based on quantum mechanics and complex mathematics that is commonly simplified to provide approximate solutions. Many models suggest that the radiative forcing of CO₂ is proportional to the logarithm of its concentration. This does not seem to agree with the current atmospheric situation and clearly is influenced by the assumptions and approximations that are made. An ice age is a greater danger to humanity than global warming and I suggest that research would be more beneficial if it was directed towards understanding the role CO₂ and other factors have in tripping the climate system into a glacial event. 🚫

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South American Lithium Brines: How did the Lithium get there, and where did it come from?



Dave shatwell

FAIG

Introduction

The International Energy Agency (www.iea.org) estimates that there were 3 million electric vehicles on the road in 2017, and that

this will increase to 125 million, and possibly 220 million, by 2030. They will use lithium ion batteries, requiring about 170 grams of lithium per kWh. The average battery capacity of these vehicles is about 50 kWh, which translates to at least 1 million tonnes of lithium by 2030. Mohr et al. (2012) made a 'best guess' of 24 million tonnes of ultimately recoverable global lithium, defined as the amount that can be recovered net of mining losses, plus historic production, but added 'future supply and demand is extremely uncertain, and the reality... is likely to be vastly different from that predicted here'. However, there is no doubt that future demand for lithium will continue to grow.

Lithium deposits occur in continental brines, in pegmatites, and in hydrothermally-altered clays and felsic tuffs in caldera settings. About 75% of current lithium production - 43,000 tonnes in 2017 - comes from brines, dominated by evaporite deposits in playa lakes (salares) in the Central Andes of Bolivia, Chile and Argentina. This article summarises the resources, geology and general characteristics of the Central Andean salares. What is the source of the lithium, how was it transported and concentrated, and how long did it take? What were the climatic influences? In the arid climate of the region, where did the water come

from to form the evaporites? Why is so much lithium contained in a single deposit, the Salar de Atacama in Chile? And what is the relationship, if any, between the Quaternary brine deposits, Ordovician lithium pegmatites to the south, and a recently-discovered lithium deposit in Neogene tuffs to the north?

I have driven (and walked, from a terminally bogged vehicle in the Salar de Antofalla) across some of the salares and ignimbrites mentioned here at one time or another. However, this was always on the way to somewhere else, before anyone thought much about lithium, so this article is basically a literature study, backed by local knowledge of the terrain and volcanic geology.

Ericksen and Salas (1987) identify over 100 salares in the Central Andes, ranging from a few km across to the 10,000 square km Salar de Uyuni (Figure 1). Most of them are located in the southern part of the Altiplano, (a high plateau at 3800m elevation which lies between the Eastern and Western Cordilleras of the Central Andes), or in its southern extension, known as the Puna. Others in Chile are at lower elevation to the west, including the Salar de Atacama which provides a large percentage of the world's lithium. There are over a dozen Mio-Pliocene calderas with associated felsic ignimbrite sheets on the Altiplano-Puna, and the present-day magmatic arc of Quaternary volcanoes is aligned along its western margin. Collectively, these volcanic rocks make up the Central Volcanic Zone of the Andes.

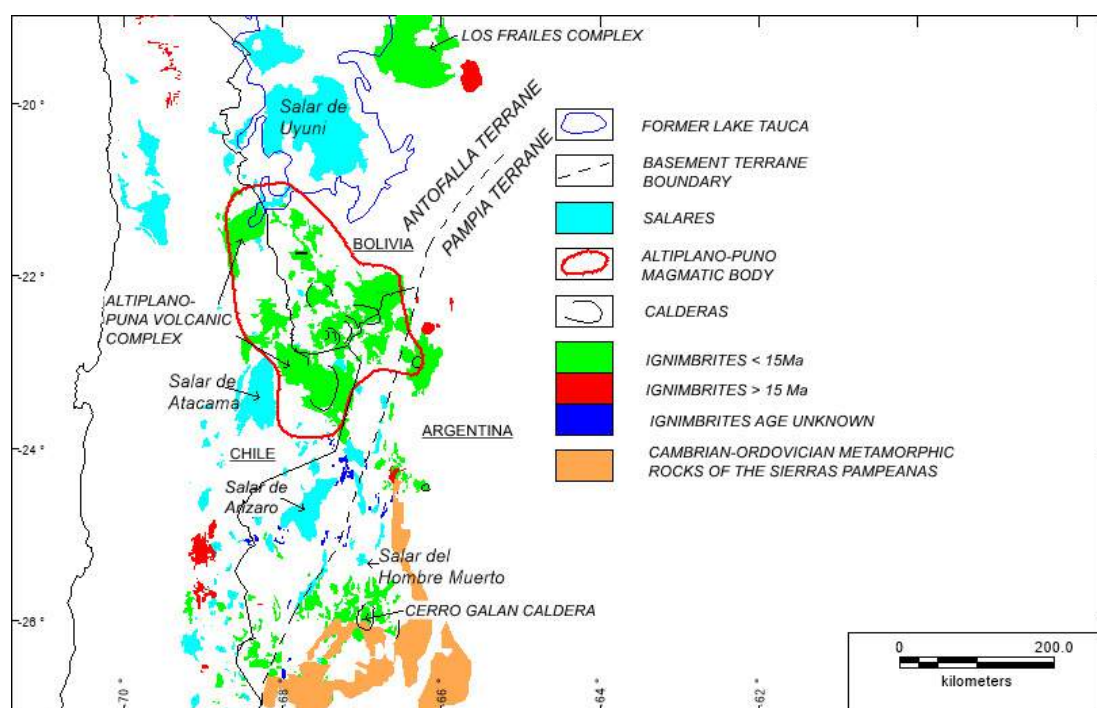


Figure 1. Central Andes showing Neogene ignimbrites and calderas (from Brandmeier and Wörmer, 2016), salares (mostly from Stoertz and Erickson, 1974), Altiplano-Puna magmatic body (from Perkins et al., 2016), former Lake Tauca (from Martin et al., 2018), terrane boundary (from Ramos, 2010) and Ordovician metamorphics (from Toselli et al., 2002).

Resources and production

Lithium resources, including past production, of four Andean salares with either current or planned production are shown in Table 1, with data from Mohr et al., (2012), Munk et al., (2016) and more recent company web pages. The lithium resources are not necessarily JORC-compliant, for example reduced porosity may restrict the depth of the Salar de Atacama resource to around 50m (Munk et al., 2016). Smaller resources have recently been announced elsewhere, including the Salares de Antofalla and Kachi in Argentina. Lithium concentrations >300 g/l and Mg/li ratios <10 have been recorded in at least half a dozen other salares in addition to those in Table 1, and there is active exploration in many more.

Lithium is normally recovered from Central Andean salares by pumping lithium-rich saline pore fluid from halite-dominated evaporites. The water is evaporated in a series of ponds to increase the Li content to about 6%, then soda ash is added to the solution, causing lithium carbonate to precipitate as the end product. The process involves pumping very large volumes of water, and evaporation over months to years.

Alternative methods are being considered for some projects – see www.saltworkstech.com for a summary. The grade of a lithium resource is normally expressed as the Li concentration of the pore fluid in ppm or mg/l, and resources as millions of tonnes of either lithium or lithium carbonate equivalent (LCE). (The conversion factor from LCE to Li is 0.188). Economic viability depends on Li concentration in the aquifer, porosity, volume, evaporation rate, and aquifer chemistry, including co-products such as potassium and deleterious elements such as magnesium.

Chile produced 14,000 tonnes of lithium in 2017 from two operations in the Salar de Atacama. In Argentina, the Salar del Hombre Muerto produced 4000 tonnes from a single facility in 2017, while operations at the salares de Olaroz and Cauchari may soon be producing 12,000 tonnes, according to company releases. The Bolivian government has been announcing imminent production from the Salar de Uyuni for years, but has yet to advance beyond a pilot-plant scale operation.

Salar	Country	Area (km ² x10)	Altitude (m)	Depth (m)	Li conc mg/L	Porosity %	Mt Li	Startup
Hombre Muerto	Argentina	565	4000	15	521	15	0.8	1997
Olaroz-Cauchari	Argentina	?	3900	?	650	6-8?	3.4	2015
Uyuni	Bolivia	9654	3650	11-20	321	35	10	?
Atacama	Chile	3000	2300	200?	1400	18	6.3-7.5	1984

Table 1. Data on four Central Andean salares with lithium resources

Climatic conditions favouring lithium brines

Munk et al. (2016) cite six conditions for lithium-rich continental brines to develop: an arid climate, a closed basin, igneous or hydrothermal activity, tectonic subsidence, a lithium source, and enough time for lithium to accumulate. All six conditions exist in northern Chile, NW Argentina, and SW Bolivia – the so-called Lithium Triangle – whose position on the western side of South America above an active subduction system provides the right climatic and tectonic environment.

“An arid climate, with evaporation greater than water influx, is essential for lithium to become concentrated in brine, as well as to allow further concentration in evaporation ponds over an acceptable period of time in the recovery process.”

An arid climate, with evaporation greater than water influx, is essential for lithium to become concentrated in brine, as well as to allow further concentration in evaporation ponds over an acceptable period of time in the recovery process. For lithium to be transported by meteoric water into depositional basins,

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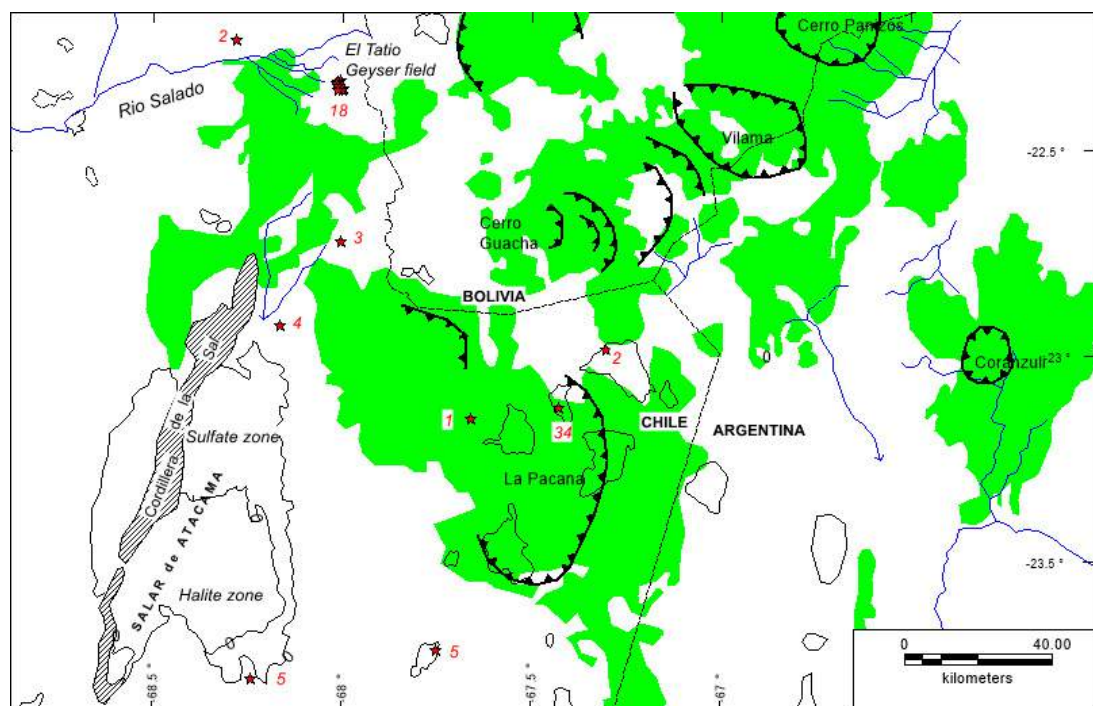
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Figure 2. Salar de Atacama after Warren et al., 2010, Mpodozis et al., 2005, ignimbrites (green) and calderas (heavy barbed lines) of the APVC after Brandmeier and Wörmer, 2016, and hot springs with ppm Li (red stars and numbers) from Risacher et al., 2010. Black polygons are salares, blue lines represent drainage.



there must be either higher rainfall in the source area than in the basin, or else seasonal or long-term climatic variability, so that lithium is transported in solution during wetter periods and concentrated during drier ones. Geothermal fluids can also transport lithium, either directly into a depositional basin, or indirectly into the surface or subsurface hydrologic system.

The Central Andean region has had an arid to hyper-arid climate since at least the Late Pliocene (Hartley and Chong, 2002), and possibly earlier. The region is within the latitudes where overturning Hadley cells bring cold dry air to South America, and where the northerly-flowing Humboldt Current brings deep, cold, up-welling water to the Chilean and Peruvian coast; it is also in the lee of the Eastern Cordillera, which blocks warm, moist air from the Amazon basin. As hyper-aridity set in over the last 3 m.y., former lakes dried out leaving thick accumulations of halite, gypsum and other salts, while lithium remained in solution in pore fluids.

However, the general aridity has been punctuated by wetter intervals, at least in

the Quaternary. Bobst et al, (2001) studied a 100m halite core (87% halite) from the Salar de Atacama which provided a climatic record over the last 106,000 years. They found evidence of wetter conditions than today in the form of sediment intervals and solution textures in the halite at 75.7-60.7 and 53.4-15.3 ka, and also for shorter periods during the Holocene. In the northern part of the Altiplano, the Salar de Uyuni is the evaporated remnant of the former Lake Tauca. The lake reached its highest level between 18.1 and 14.1 ka - the largest lake expansion in the last 130 ka - when rainfall in the region was 130% higher than today (Martín et al., 2018). Baker et al., (2001) identified four intervals of ancestral lake sediments, corresponding to wetter climate intervals, over the past 50 ka in the top 40m of a drill core in the Salar de Uyuni, while Stoertz and Ericksen (1974) identified 35 former lakes from surface features in northern Chile alone. These studies show that salt precipitation and lithium concentration occur episodically in repeated cycles of input and evaporation.

Tectonic and magmatic activity

Climatic conditions won't lead to lithium brine formation unless accompanied by active tectonic and magmatic activity, as shown by the almost total absence of lithium in salt lakes in the stable Precambrian shield areas of Western Australia. The active continental margin of western South America provided the conditions for subsiding fault-bounded basins to form (Mpodozis et al., 2005; Munk et al., 2016). Equally important are caldera-related silicic volcanic rocks which are the most likely source of the lithium supplied to the salares. Ideally these source rocks are at a higher elevation than the depositional basin, so as to provide the hydraulic gradient for surface or subsurface water to flow into the basin.

In the Central Andean region of southern Bolivia, NW Argentina and northern Chile (Figure 1), there is an extensive, elevated region of Neogene ignimbrites known as the Altiplano-Puna Volcanic Complex, (APVC). Ignimbrites in the APVC range in age from <0.5 to 12 Ma, with a weighted average of 5.3 Ma, their total volume is at least 11,000 cubic km (Brandmeier and Wörner, 2016), and they were erupted onto the plateau surface in a dozen calderas. Tomographic imaging has detected a 500,000 cubic km zone of partially melted crust at 10-20 km depth below this region (Perkins et al., 2016). The ignimbrites were derived from mantle-sourced magmas which assimilated a large amount of crustal material from this magma body, and contain about 50:50 mantle and crustal components. Smaller concentrations of ignimbrites occur in the Los Frailes complex to the north of the APVC in Bolivia, and to the south in the Cerro Galán caldera in Argentina (Figure 1).

Crust below the APVC is believed to consist of metamorphic rocks of the Mid-Proterozoic Antofalla Terrane, accreted to Gondwana during the Late Proterozoic Sunsas Orogeny (Ramos, 2010). To the east lies the Pampia Terrane, which includes a 900 km belt of Lower Paleozoic metamorphic rocks and highly differentiated Ordovician S-type granites in the Sierras Pampeanas of northern Argentina. Some of the granites are associated with LCT (lithium-cesium-tantalum) pegmatites, which occur widely in the Sierras Pampeanas. These Precambrian rocks and the Paleozoic metamorphics and granites derived from them are the most likely primary sources of lithium which ended up in the Central Andean salares.

Ignimbrites in the APVC contain on average about 30 ppm Li (Risacher et al., 2010) which equates to a reservoir of almost a billion tonnes of lithium. Lithium is an incompatible element, which means it doesn't easily enter the lattice of common silicate minerals found in volcanic rocks. Instead, it becomes concentrated in late-solidifying phases of ignimbrites, especially volcanic glass. Alteration and devitrification of glass in the ignimbrites liberates lithium to be transported by surface and subsurface meteoric water and probably by geothermal fluids into lakes in low-lying closed basins surrounding the APVC.

There are few salares in the APVC itself, and no large ones, however there are a number of small salares in former caldera lakes, about which more below. The large salares are located in lower-lying areas marginal to the APVC, in the region underlain by the Antofalla Terrane:

*Salar de Uyuni, Bolivia,
looking west towards the
Cordillera Occidental.*



the Salares de Uyuni (a remnant of the former Lake Tauca) in Bolivia to the north, Arizaro in Argentina to the south, and Atacama in Chile to the west. Further SE, there are many smaller salares in northern Argentina, in the region underlain by the Pampean Terrane and spatially associated with LCT pegmatites.

Salar de Atacama

The Salar de Atacama (Figure 2), with an area of 3000 square km, lies at an elevation of 2300m, where annual rainfall is only 30-40 mm. The salar is flanked to the west by Mesozoic sediments of the Cordillera de Domeyko, and to the north and east by ignimbrites and calderas of the APVC. Stretching along the western side of the salar is the Cordillera de la Sal, a deformed ridge of Oligocene to Pliocene evaporate-rich sediments and ignimbrite (Mpodozis et al., 2005), essentially a salt anticline. About 70 km north of the salar, the El Tatio geyser field, at 4270m elevation, is discharging a neutral chloride geothermal fluid which contains up to 61 ppm Li (Nicolau et al.,

2014). A number of other geothermal springs at up to 4700m elevation to the east of the salar are discharging water containing several ppm Li, and one spring in a small salar in the Pacana Caldera contains 34 ppm Li (Risacher et al., 2010).

The salar contains a central zone up to 900m thick, in which at least the top 200m consists of halite with interbedded saline lake sediments. The halite core covers an area of 1100 km², surrounded to the south and east by sulfate-bearing mud (Figure 2). The upper part of the halite zone contains a saline pore fluid which averages 4000 mg/l Li. The ignimbrites to the east supplied K, Li, B and Mg, and some Na and Ca, to the pore fluid, whereas Na, Ca, Cl and SO₄, but not necessarily Li, were supplied from the Cordillera de la Sal to the west (Warren et al., 2010; Warren, 2017).

A number of factors favored the high concentration of lithium in the pore brine of the Salar de Atacama. The salar is within a very large catchment whose low elevation of 2300m provides a steep hydraulic gradient for surface and subsurface water draining westward into

the depression from the APVC, where elevations are over 4000m. The rainfall on the Altiplano is somewhat higher than in the salar, generally >100 mm, voluminous ignimbrite erupted from the Pacana and other calderas provides a likely source of lithium, and lithium may also have been mobilised by hot springs which border the salar.

Caldera lakes

Near the town of Corani in the Eastern Cordillera of southern Peru, a deposit called Falchani contains an indicated resource of 40.58 million tonnes grading 1589 ppm Li (NI 43-101 Technical Report, The Mineral Corporation, 2018). The deposit consists of a felsic tuff member 40-150m thick, in a sequence of Pliocene

ignimbrites and related sediments, deposited in what is described as a crater lake. Volcanics near the Falchani deposit also contain uranium. An association between lithium and uranium has been noted in the McDermitt Caldera, on the Utah-Nevada border in the US, where Benson et al.(2017) stated that 'intracaldera ignimbrite... provided glassy rhyolitic material with moderate Li concentrations from which meteoric water mobilized Li and deposited it within the closed basin of the caldera'. These authors also cite lithium-rich magmatic fluids as a second source of lithium in caldera settings. Small salares within (for example) the Pacana Caldera (Chile) and their association with Li-rich geothermal springs as shown in Figure 2 are potential exploration targets for deposits of this type.

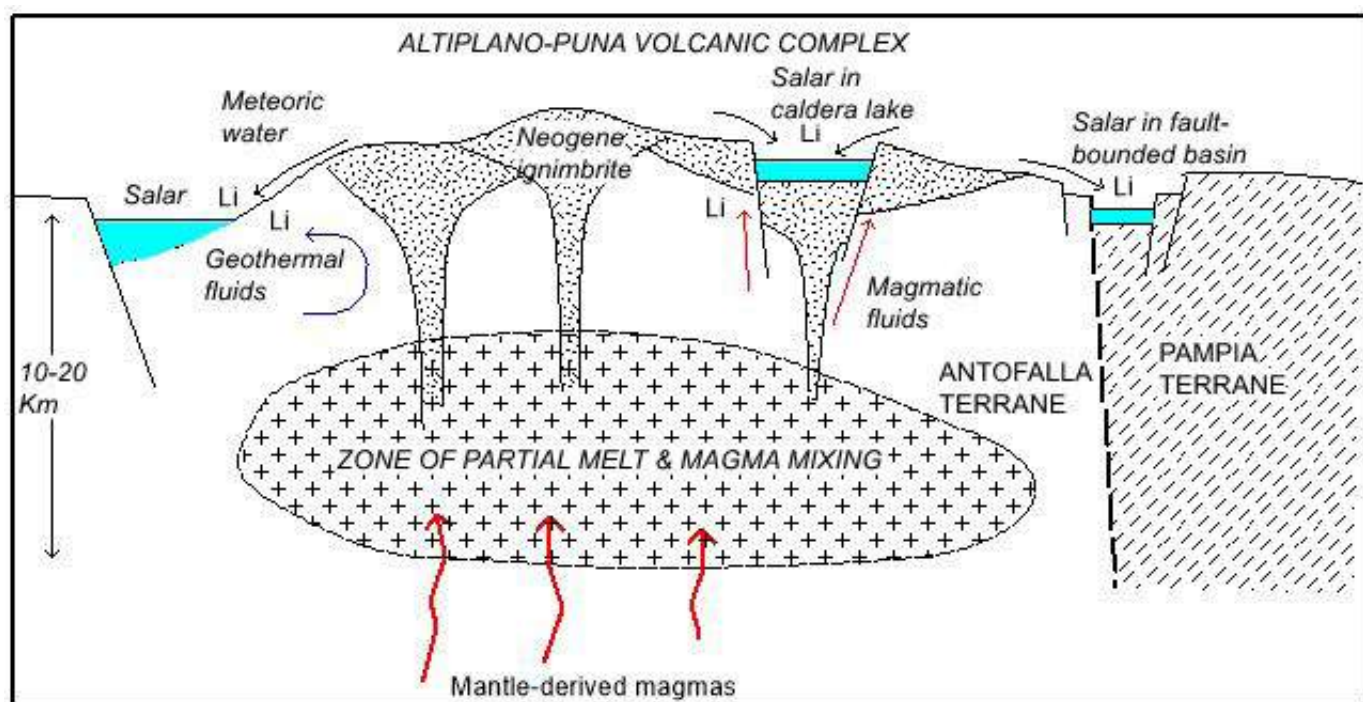


Figure 3. Cartoon model of Central Andean salares showing lithium sourced from Neogene ignimbrites. Zone of partial melting is based on Perkins et al., (2016). See text for explanation.

Conclusions

The Central Andean region contains a continent-scale lithium anomaly defined by: Lower Paleozoic granites and lithium pegmatites in the Sierras Pampeanas of Argentina; Quaternary lithium-bearing evaporites on and adjacent to the Altiplano of Argentina, Chile and Bolivia; and Neogene lithium-uranium bearing tuffs in the Cordillera Oriental of southern Peru and possibly elsewhere. Partial melting of some of the basement rocks formed a magma chamber at 10-20 km depth (Figure 3); mantle-derived magmas assimilated some of this crustal material and erupted as voluminous lithium-enriched ignimbrites on the Altiplano-Puna surface. Lithium, concentrated largely in volcanic glass, was released from ignimbrites by alteration and devitrification into surface and subsurface meteoric water and geothermal fluid, and transported episodically into closed basins at lower elevation. Arid to hyper-arid conditions caused evaporites to form in these basins, and lithium became concentrated in halite pore fluid.

Small salares in calderas at higher elevation may also be found to contain lithium resources in tuffs and lake sediments, especially where they are associated with lithium-bearing neutral chloride springs, and possibly with radiometric anomalies.

The potential of Central Andean salares to contain economic lithium concentrations depends, among other factors, on whether the salares contain voluminous Neogene ignimbrites at higher elevations within their drainage catchments. 🇵🇪



If you are interested in more information on this topic, you are welcome to contact me (shatwell.dave@gmail.com).

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Our 2019 program is about to kick-off and we invite you to join us!

AIG Mentoring Program

Our program connects undergraduate students, honours, MSc and PhD candidates, and early career geoscientists (0-5yrs) with experienced industry professionals. The aim is to build our community by providing emerging geoscientists with connections, knowledge and experiences from knowledgeable professionals who are looking to give back. Our professionals provide practical advice and guidance on a number of areas of interest, particularly aimed at beginning and maintaining a healthy career within geoscience.

Program details

- The program is free for both mentees and mentors!
- During the program mentees and mentors meet regularly to discuss and work on their mentoring program objectives.
- In addition to mentor-mentee meetings, the program includes three formal events:
 - Kick-Off Event – April/May
 - Mid-term Social Event
 - Final Event/Program finish - Oct/Nov
- Programs are currently running in WA, VIC, NSW and QLD city and regional centres (Kalgoorlie, Orange and Townsville).
- For people located outside these urban areas or in a state without an active program, the **Distance Program** is for you. This program uses online technology to facilitate mentoring, regardless of location.

Join us!

Fill out and submit an expression of interest form for the program you'd like to join via www.aig.org.au/mentoring-program/. Note the deadline for submissions is

31 March 2019

Participants will be notified of their acceptance into the program in April 2019.

AIG membership is a pre-requisite to participate in the mentoring program as a mentor or as a mentee. If you are not already an AIG member then this is a great reason to join up – sign up for membership online at www.aig.org.au/membership/

AIG membership for students is free!

Call for state champions

If you are passionate about giving back and want to make an impact in your community, we are seeking mentoring program state champions for Tasmania and SA to establish programs in Hobart and Adelaide. You will help connect our program across the nation by joining our network of established programs in WA, NSW, VIC and QLD.

Any questions? For more details about the AIG Mentoring Program please contact us at aigmentoringprogram-nationalchair@aig.org.au

Whether you are a mentee or mentor – Sign up now!

Geology: quo vadis? Walking where angels fear to tread



Definition of geological mapping; acquisition of the full knowledge of the 3D-time geological architecture and resources of the area mapped, using all means available and tested by systematic and thorough ground-truthing on foot.

It is well-known that a career as a commercial geologist, particularly in the minerals industry, is a roller-coaster of booms of employment followed by under-employment and redundancy in the busts. The exploration geologist is last-on, first-off as market forces prevail. One is reminded of those once-familiar, everyday queues outside the British dockyards, when queues of unemployed men lined up, each man with the hope that he would be picked up for that day's work because some ships had come in and there were cargoes to be unloaded. So it is with we geologists; in a somewhat more genteel and professional manner we accept unemployment as part of the job. No geologist is a union militant; union militancy is an anathema to most professionals and we seek the work because we enjoy it.

The boom-and-bust cycle leads not only to personal financial difficulties and gaps in career-development but also to marked losses in corporate memory and skills when experienced

Bob Findlay
MAIG

geologists get laid off and move to new , more stable careers, or find that the last boom has finally paid-off that mortgage and they can take early retirement on their superannuation and part-time earnings by running a hobby business, such as AIR BnB or rental property; in that respect we are far better off than the British dockers of 80 years ago and earlier.

Yet still we bemoan the boom-and-bust business cycle of geological work, and we wonder what we can do to better improve our lot.

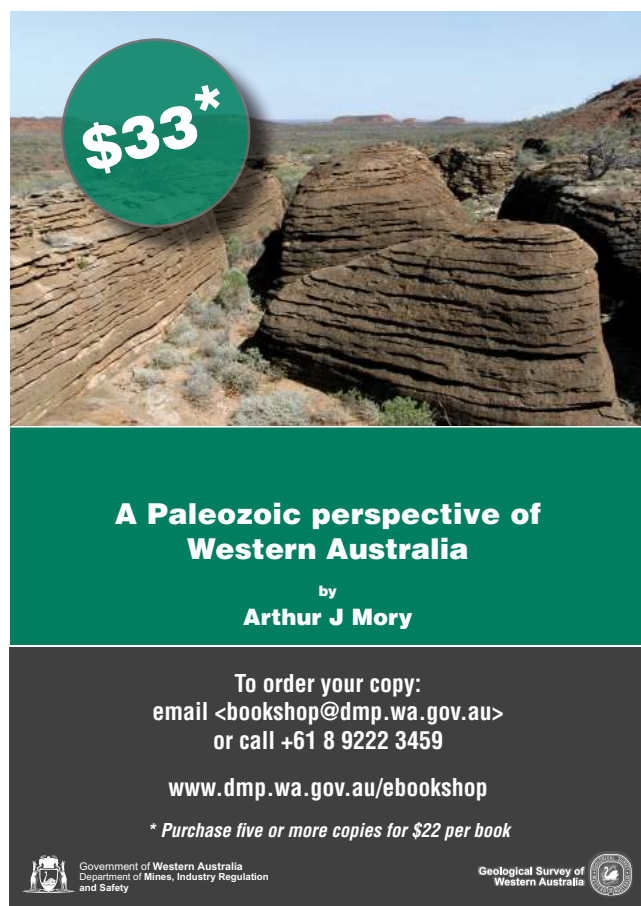
The argument of loss of corporate memory and skill seems to matter little to either industry or government, both of whose approaches tend to the short-term notion of balancing the books at year's end rather than carrying forward a loss as an investment for the future.

Yet a financial debt is often seen as investment when it relates to purchase of material infrastructure; in contrast, it would seem that these days intellectual infrastructure, that is, knowledge, gets written off if it is not making an immediate profit. Politically, government debt leads to the accusation of economic mismanagement and all political parties are now slaves to this short-sighted challenge; government Geological Surveys have suffered from the results of this political challenge since I began my professional career in 1972 and, as a result, the intellectual geological infrastructure necessary for national development is lagging.

There is one approach to lessening the unemployment problem faced by geologists and this is a simple market-force solution that is surely amenable ideologically to the followers of Adam Smith. Reduce the number of geologists available for employment, so that the demand for our services remains continuous.

This can be done quite easily; raise the bar for entry to university geology courses so high as to reduce the intake to classes that can be taught properly (let us say 20 students per year from 1st year through to completion of Honours). Having such properly trained geologists would surely reduce the modern complaint that our new geologists emerging from university are increasingly lacking in knowledge and field-skills. This could entail a reduction in the number of universities teaching geology and would allow a financially logical consolidation of resources and staff; but as such it would be remarkably unpopular.

Yet this follows the type approach that the society accepts for medicine; the bar to entry for a Degree course in medicine is exceptionally high, to which is added an intelligence test so



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that even those who score highly enough to apply for the Degree course may fail to be accepted for training. After that there is the issue of entry to a Royal College of specialisation which not only requires stringent and lengthy course-work, but also references from several referees to support the application for undertaking the course-work; and even that does not guarantee entry to a course for training in the chosen specialisation.

The only problem with this would be that in the boom part of the business cycle, there could be too few geologists for industry. But that is "market-forces", the underpinning argument for modern economics, penned by Adam Smith a couple of centuries ago, which is that society's interests are served best through the encouragement of personal self-interest.

“ Geology, a demanding science encompassing the basic scientific disciplines of physics, mathematics, chemistry and zoology ...

Geology, a demanding science encompassing the basic scientific disciplines of physics, mathematics, chemistry and zoology, a science that demands both the ability to think in a 4-dimensional framework (time and 3D space) and the necessary skills to live at ease in uncompromising environments, is more often than not seen in the first year of university training as an easy option for scoring points towards a BSc; thus classes may be as large as 100 students. Such classes are utterly impracticable for proper field-training.



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Chris De-Vitry is a geologist and geostatistician with 25 years' experience. Chris also has significant practical experience working in open pit and underground mining operations.

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Therefore perhaps a higher bar to university entry is indeed essential and would benefit industry, as perhaps might certification of geologists along the lines followed by the medical industry.

Australia has been mapped geologically; yes. Australia has been mapped geologically mainly at the reconnaissance level of 1:100 000, with only some exceptions such as in Tasmania where the geological maps have been produced at the 1:50 000 scale. In Tasmania, it takes a team of about 4 geologists working through 3 field-seasons to produce a properly professional 1:50 000 geological map; that is 48 man-months of fieldwork, allied to 48 man-months of laboratory work and writing to properly analyse and publish all the data. When the Tasmanian Geological Survey was in full swing before 1987, geologists carried out field-work in the wild and bush-clad west for about 4 months during the summer and 2-3 months in the State's more comfortable east in the winter. Those days are long gone as, since 1987, government has cut back on funding for geological mapping.

No doubt in the less heavily bush-clad regions of mainland Australia, ground can be covered more quickly and remote-sensing used more effectively than in Tasmania; but the facts still remain that mainland Australia is covered by geological mapping at a reconnaissance 1:100 000 scale. This scale more-or-less tells industry the very broad style of rocks a target may lie within (e.g. greywacke as opposed to volcanic rocks, granite, gabbro, schist or greenstone), but lacks completely the necessary detail as to geological structure and properly dated lithostratigraphy, among other issues.

And what of groundwater mapping? Water is THE most important mineral resource in Australia and will become increasingly so as the population and concomitant urban sprawl increases and the continent continues to dry out. Do any States or Territories have a full inventory of their groundwater resource? The answer is a resounding NO. Soil mapping is also of vital importance; what is the state of soil mapping in Australia? Possibly better than ground-water mapping, but probably less adequate than the now inadequate 1:100 000 scale reconnaissance lithological mapping across Australia.

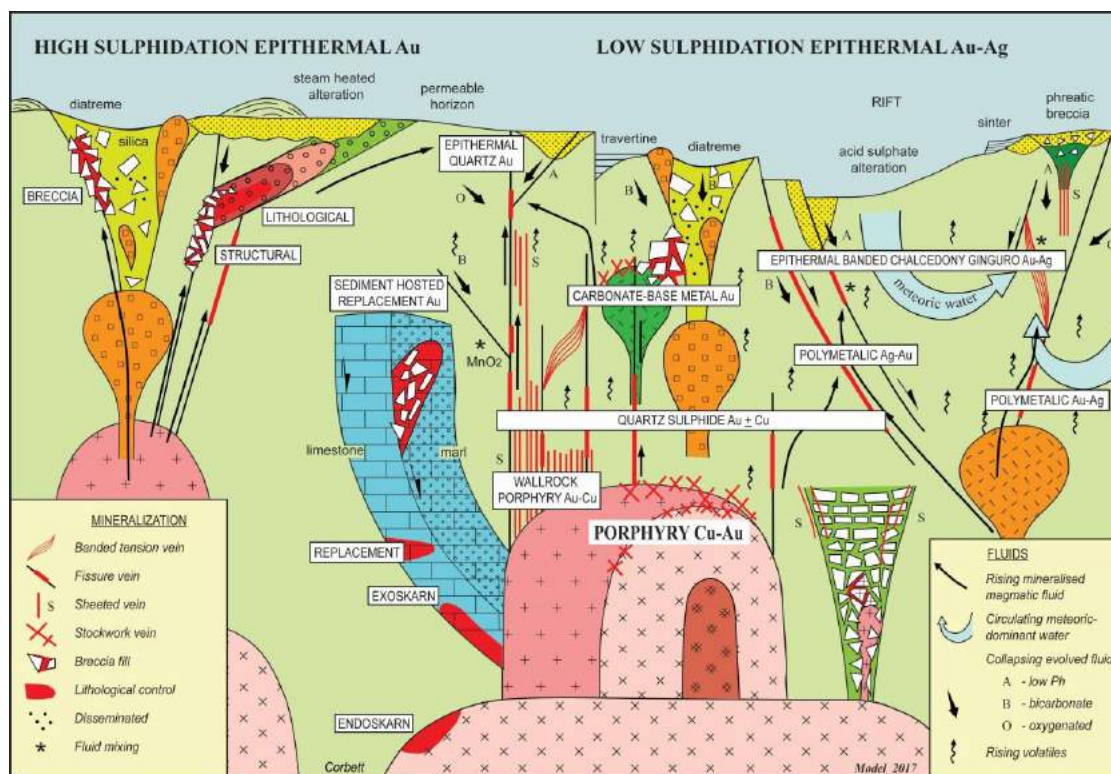
Here then lies one answer as to how to soak up the surplus geologists produced by the stock-markets' busts; employ, and if necessary retrain, the periodically surplus industrial geologists to work on contract for government geological surveys for targeted but systematic geological survey work, which should include soil and groundwater mapping along with high-quality geological mapping. The synergy of industrial and government geologists would be powerful, and both the taxpayer and industry would benefit. It is simple; all it would take is a scientifically literate government to make the money available. 📢

SHORT COURSE

EPITHERMAL Au-Ag and PORPHYRY Cu-Au EXPLORATION

Lectures and practical, 14-16 May 2019

by Greg Corbett and Stuart Hayward



MAY 14 & 15

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 earlier 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 a current draft of the new short course notes. Drafts of the first few chapters are available at: <http://corbettgeology.com/Publications/>.

MAY 16

A practical exercise held at the W B Clarke Geoscience Centre, Londonderry, uses diamond drill core referred to in the lectures (above) and a set of teaching specimens 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.

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Visitor taking advantage of the "geotrail" where many of the original buildings collapsed. Signboards show the buildings and describe the consequences of the ground movements.

A Blow-Up Pub Selling Ground-Shaking Beer

A Different Perspective on a Geotrail

Michael Freeman
MAIG

For the beer-buffs, 14TH October 2018 saw the marketing of a new style of beer with a ground-shaking heritage. Curious? Well it went on sale at Meckering in Western Australia's Wheatbelt Region. Named Richter Ale it was sold at the commemoration ceremonies to remember 50 years previously when the little farming community was totally shattered by a Richter-Magnitude 6.5 earthquake on that date in 1968.

The earthquake arose from a 37-kilometre-thrust fault that passed within 2.7 km to the west of the town. The fault actually consisted of a series of anastomosing thrust surfaces that dipped easterly and related dextral lateral side-slip offsets that produced a maximum mapped offset of 2.5 m with up to 1.5 m of uplift.

Much of the surface evidence of the faulting has become degraded in the 50 years since the movement, particularly as much of it was on

grain-growing paddocks and was ploughed to allow ongoing planting and harvesting activities. However, a length of the scarp has been preserved on a farm 10 km south-southwest of the centre of Meckering (located at GR 50J, 497 880 mE, 6 491 425 mN).

Destruction within the town was very severe with only about 18 out of 82 buildings not suffering serious damage. The fact that nobody died was extremely fortunate, and even the numbers of injuries was relatively small considering the nature of how many of the older brick and stone buildings were highly susceptible to collapse in response to such ground vibrations.

The 2018 remembrance ceremony was extremely well attended with up to 2000 people attending to share memories, listen to and watch recordings from the earthquake and from the experiences who lived through the earthquake and then participated in the clean-ups and rebuilding. Many of the original collapsed buildings were simply removed and not rebuilt. The Shire of Cunderdin has opened a walking trail with displays and signboards

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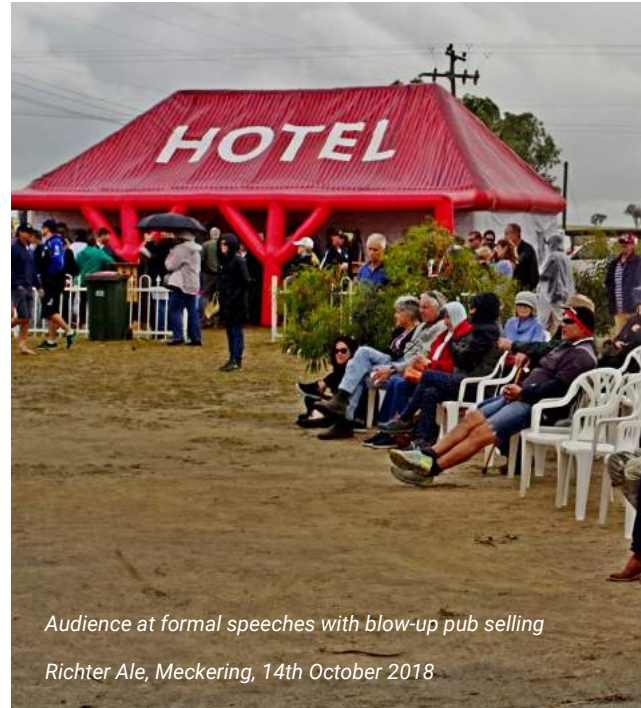
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showing the buildings and describing results of the earthquake. This effectively now constitutes an “ad hoc” walking geotrail. Members driving through the town are encouraged to take a short break and follow the walk (located at Grid Reference 50J-500 785 mE, 6 500 770 mN where Byfield Street meets the Great Eastern Highway in Meckering).

The Geological Survey of Western Australia was complimented by State Minister for Regional Development, Agriculture and Food, the Hon Alannah McTiernan, who noted an excellent booklet on Understanding the Meckering Earthquake. She made particular note of the authors Jean Johnston and Stephen White



Audience at formal speeches with blow-up pub selling
Richter Ale, Meckering, 14th October 2018



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*Semper Sursum
Always Aim High*



saying they deserved accolades for the foresight and very good general description of the geological background. Scitech also attended and had a number of demonstrations and activities on earthquakes for kids. Visits to a farmhouse located right next to the scarp at one site were promoted and bus trips for the 1.5 km viewing were put on. The farmhouse collapsed and remains as it fell, a poignant memorial to the destructive forces in nature. Fortunately an infant inside was saved from injury, or worse, when the wall next to the it fell outside away from the cot it was lying in! (located at GR 50J 497 880 mE, 6 491 4215 mE). Similarly visits to the protected remnant scarp were popular.

The Meckering scarp, as it turns out, is one of upwards of a dozen similar scarps mapped by the Geological Survey within the Yilgarn Craton. All are similar in trending north-south and result from westward-directed upward



Scitech earthquake and similar activities for youngsters.

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“Many earthquakes occur in this region, though most are of low magnitude.”

Farmhouse located adjacent to a fault surface as it fell 50 years earlier.

thrusting on easterly-dipping surfaces. While previous mapping had identified a number of these scarps, the dating of movements was unknown, although inferred to be Cenozoic. Meckering was a wake-up call. However it is now in the Southwest Seismic Risk zone that extends roughly from Albany towards Geraldton. Many earthquakes occur in this region, though most are of low magnitude. However, between 30th July 2018 and today (19th January 2019)

781 small earthquakes have been recorded immediately northeast of Lake Muir in Western Australia's southwest corner, some 60 km east of the town of Manjimup and 320 km south of Meckering, with the largest being Magnitude of 5.2 recorded on 16th September 2018. 🇲🇵



Visitors viewing the 1.5 metre scarp still preserved, after 50 years, on farmland 10 km SSW of Meckering.



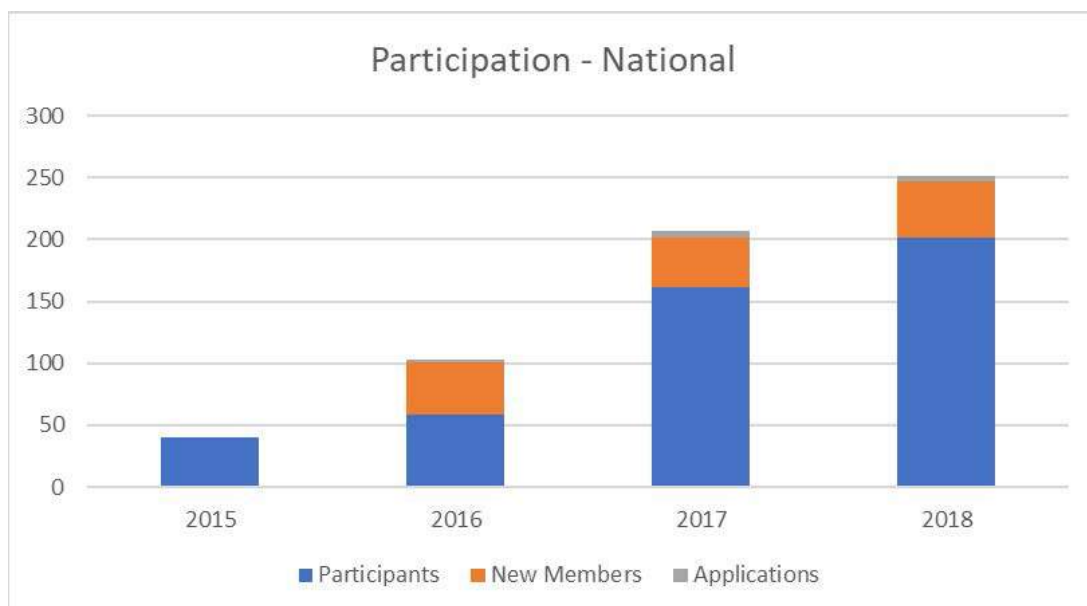
The AIG Mentoring Program

– building connections, careers, networks

The AIG Mentoring Programs are an initiative of the AIG National Graduate Group. Since inception in 2015 the participation rate in the programs has consistently increased to the point where the programs had 250 participants in 2018. The desire to participate in the programs is also attracting a significant proportion of new members (both mentees and mentors) to the AIG.

There has been strong industry support for the programs with sponsorship Australia wide increasing each year as the programs get more exposure.

Doug Young
AIG Mentoring
Committee; FAIG
RPGeo



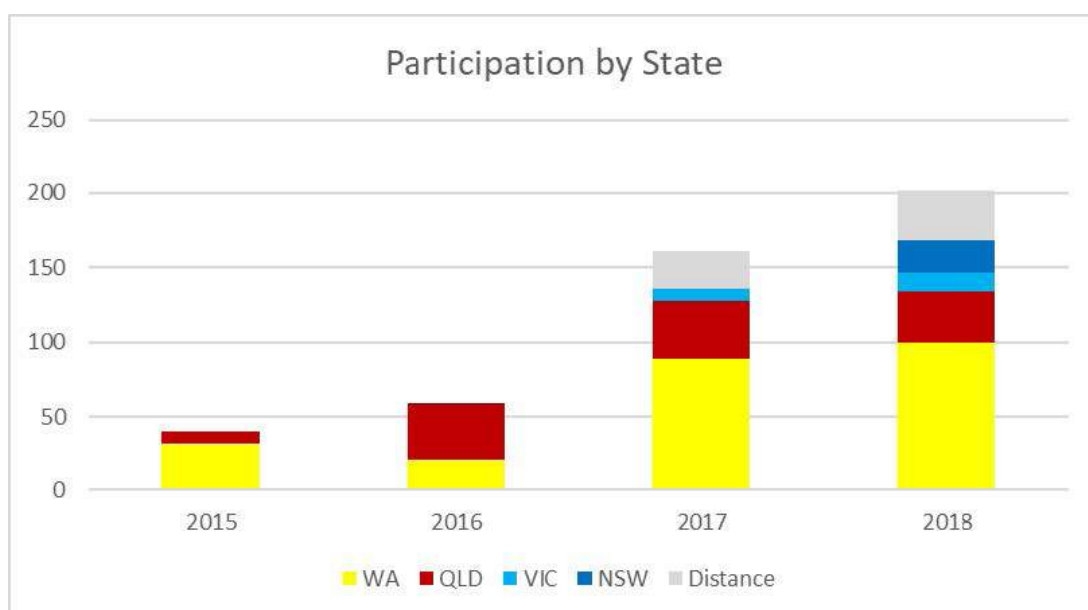
The Programs

There are now five active programs in WA, QLD, Vic, NSW and the Distance program. The state-based programs run from and meet in the state capitals where membership is strongest. In WA, NSW and QLD there is also significant participation from key regional centres leading to the establishment of mentoring “pods” in Kalgoorlie, Orange and Townsville where participants can meet, share experiences and network.

For members who are based remotely from established programs participants can join the Distance Program. Communication in the Distance Program is primarily via Skype, email, chat and phone. While this program is not as effective as face to face programs with limitations due to travel, remote locations, poor communications, working around rosters, time zones etc it is still quite achievable given a strong commitment from the participants.

In 2018, nearly forty members have joined the distance program from all the states and the Northern Territory, New Zealand, England and Chile. This year we are particularly encouraging participation from our northern neighbour PNG.

Each of the programs consist of three formal events where participants in the program can meet, mix and share experiences. The Kick Off event introduces the program and participants for the year and generally is held in April. The Mid Term event (July-August) offers opportunities for connecting with other mentors (and mentees), enhancing and broadening networks. The Final event (October-November) completes the formalised program for the year with opportunities for feedback and further connections. Many successful pairings continue past the formal end of the program and keep in touch for many years to come.



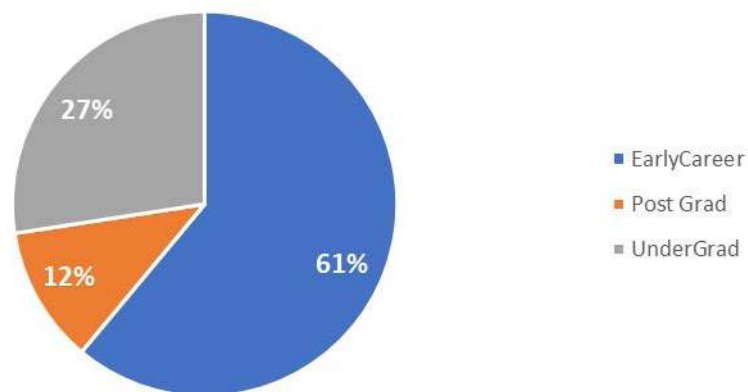
Who Participates in the Mentoring Programs

The programs are aimed at but not limited to mentees who are students and early career graduates. The following chart shows the career stage distribution of mentees in the 2018 program.

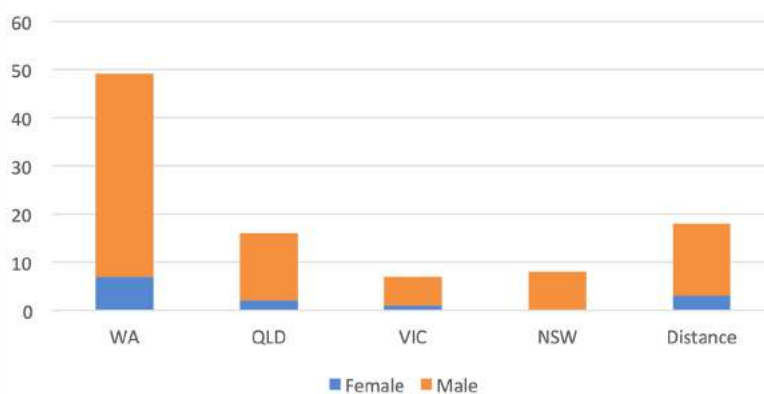
It is interesting to note the gender distribution of mentees and mentors in the 2018 programs with 57% of mentees female whereas mentors are dominantly male (87%). This reflects the gender distribution of the AIG membership where male members dominate the more senior age brackets (Waltho A, "Australian geoscience Today" AIG News 134 December 2018). Of course, this can cause some difficulty in pairing where in some cases mentees may request a certain gender for their pairing. For this reason, the program is always looking for and encouraging participation from female mentors.

While most mentors are senior geoscientists, the mentors are made up of members who vary between 8 years and 50 years of experience. Younger mentors are also actively encouraged to participate because they offer more recent knowledge of the transition from study to the workforce and are also more likely to have experience of work practises mentees are likely to encounter such as rosters, fly in fly out, part time work etc.

Career Stage Deomgraphic - National



Gender - Mentors



Gender - Mentees

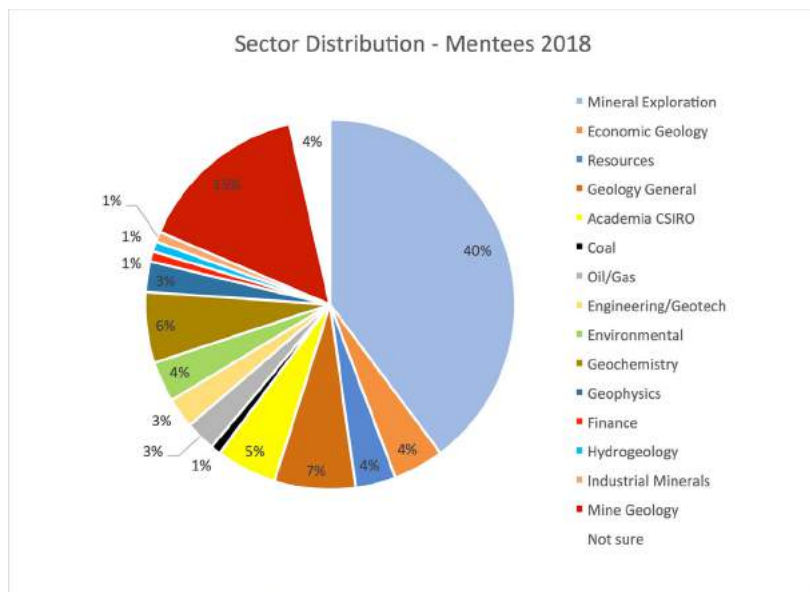
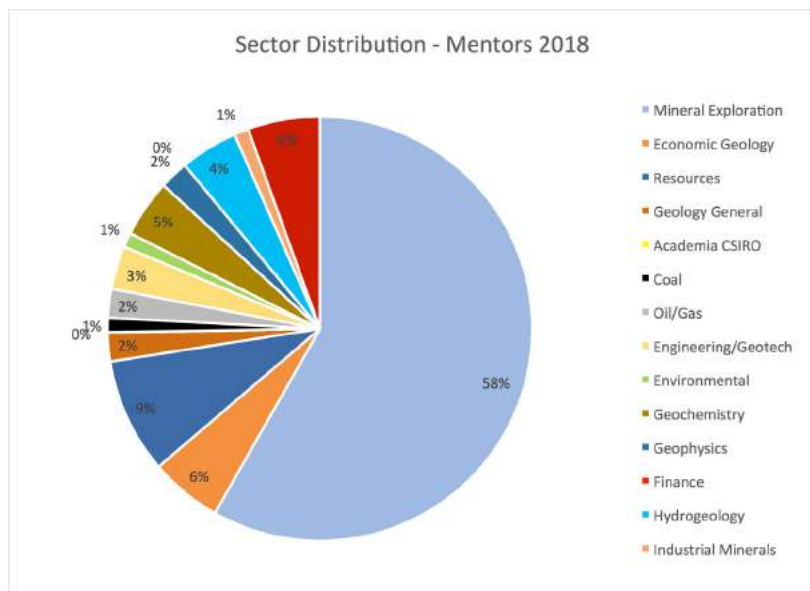


Sector Distribution of Participants

Geoscience is a very broad domain with a variety of employment opportunities. It can be difficult for people commencing study and/or work in the field of geoscience to identify and then break into the industry sector of choice.

Many young graduates and particularly students are still looking for a direction that their careers may take. As part of the mentoring programs' registration and pairing process, the mentoring committees review the experience and interest areas of the mentees and then attempt to match mentees interests with a mentor experienced in that sector. The primary areas of interest of the 2018 mentee cohort can be roughly categorised into 16 sectors as shown in the following chart. These (along with their recorded secondary areas of interest) are then matched (paired) to the most appropriate mentors experience.

Both these charts show that the sectors of mineral exploration, economic geology, mine geology and resources dominate the interests of both mentees and mentors. However, mentees are often seeking a wider range of experiences than the available mentors can provide, so we are always seeking new mentor participants with experience in the smaller sectors.



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Feedback from participants

Some key quotes from our feedback surveys highlight the sorts of issues and responses from participants:

- "I got a better understanding of what industry looks for when applying for jobs. Assistance in writing my resume and cover letters, and great suggestions of employment agencies and contractors. As well as this I got advice on decisions I was making in terms of my career path and what would be best for me."
- "Great program. I feel I am in a better position than before starting the program as I have been able to develop my professional communication skills. I feel that setting goals and spending time discussing areas of my profession I find interesting has enabled me to understand where I would like to take my career."
- "Confidence in managing up and taking charge of my career. I feel I am starting to develop better communication skills and business acumen."
- "Knowledge from the exploration side of Geology, meeting senior Geologists, expanding my networks, and offering alternative paths to my career in the future. All crucial in striving towards a balanced and interesting career ahead."
- "Sharing experience and lessons learned with a young, interested person is an enjoyable experience"
- "I really enjoy seeing the Mentee land a job and help them start to open up their network and give them advice" 📌

The 2019 Programs need you - if you are interested in being mentored, are a potential mentor or if you see an opportunity to support the programs with sponsorship or are willing to assist in any way. In particular, we are seeking to setup state-based programs in SA and Tasmania to meet mentee demand in those areas.



You can register now for the 2019 programs at

<https://www.aig.org.au/mentoring-program>

Or if you can provide assistance, sponsorship or any support you can contact the Mentoring Programs National Chair at aigmentoringprogram-nationalchair@aig.org.au

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Bipartisan support by the Coalition and Labor will help our resource sector dig deeper for Australia's secure future

Resource: Australian Geoscience Council (AGC)

Media Release
19 February 2019

The peak body for Australia's 8,000 geoscientists – the Australian Geoscience Council (AGC) – has strongly welcomed commitments from both the Coalition Government and Australian Labor Party to boost support for the exploration of 'next generation' hidden mineral deposits in Australia.

"While Australia is endowed with significant mineral resources and the resources sector contributes massively to our economy, the 'easy to find' minerals of past decades have largely been discovered and exploited"

AGC President, Dr Bill Shaw, said today.

"There is now a need to explore much deeper underground for the nation's new 'hidden' mineral fields."



"Bipartisan support is crucial to ensure we champion new exploration approaches, new technologies, extremely accurate data collection and modeling. Not surprisingly, this requires significant long-term investment and the AGC seeks joint bipartisan commitment that will bring renewed confidence."

"If Australia is to benefit from the huge demand for the minerals supporting sustainable technologies – copper, cobalt, nickel, lithium, graphite and the rare earth metals needed for solar panels, electric vehicles and the batteries they need for storing renewable energy – significant investment will be required in new technologies and approaches to uncover 'harder to find' minerals."

"The Australian Geoscience Council has been actively involved in the UNCOVER initiative and Decadal Plan for Geoscience – two initiatives of the Australian Academy of Science that have brought together government Geoscience agencies, industry, academia and research bodies in a unique collaboration to initiate and fast-track much-needed Geoscience research, data collection and new technologies to find and better exploit 'hidden' mineral deposits deep under the Earth's surface."

"A Resources 2030 Taskforce established by the Coalition Government has also focused attention on the need to attract and encourage resource development investment, and many

countries are watching how Australia takes this forward as they try to catch up with our initiatives. We also welcome the recent investment in the MinEx CRC and AuScope, which will mesh with and complement further initiatives.”

“It is clear that the world-leading vision of these cross-sector Geoscience collaborations has been noticed, with both the Coalition Government and the Australian Labor Party announcing they will significantly invest in long-term plans to boost and support minerals exploration in Australia.”

“The Australian Geoscience Council notes that the Coalition has just released a National Resources Statement outlining how it will attract investment, develop new resources and markets,

and share the benefits of success with more regional communities.”

“This will include supporting the development of new resource provinces through co-operation with state and territory jurisdictions; continuing to invest in advanced seismic and airborne electromagnetic surveys through the \$100 million Exploring For The Future program; and improving the consistency and scope of data across the resource sector.”

“Such programs use cutting-edge technology and are having a huge impact on new views of potential minerals and groundwater provinces. The Coalition has also announced priority status for funding applications related to critical minerals projects under the \$20 million Round 7 of the Cooperative Research Centres Project.”



**AUSTRALIAN
INSTITUTE OF
GEOSCIENTISTS**
Supporting Geoscientists

The voice of Australia's professional geoscientists

Purpose

The Australian Institute of Geoscientists supports the work of professional geoscientists, inspires interest in geoscience and connects science, profession and society.

Our Values

What we do is driven by geoscientific excellence, professional ethics and integrity.



We will be impartial, objective, trustworthy and transparent.



We promote and value ethical treatment and respect for others across the geoscience community.



We promote sustainability, responsibility and natural resource stewardship.



We seek and value opportunities to work collaboratively with kindred groups within Australia and internationally, as a valued partner, seeking to address challenges facing geoscience.



"Similarly, we welcome the Australian Labor Party's announcement of their Future Mines and Jobs plan that will kick-start the discovery of new mines across the country. It will also establish an Australian Future Mines Centre to co-ordinate exploration work and lead the scientific research and development necessary to explore under deep cover. The Centre will be funded through a \$23 million Australian Research Council Special Research Initiative, with input from the Australian Academy of Science and the sector. Labor will encourage industry co-funding as part of the Centre's work, and will also invest \$2 million to provide 100 scholarships to arrest the decline in mining engineering degree commencements."

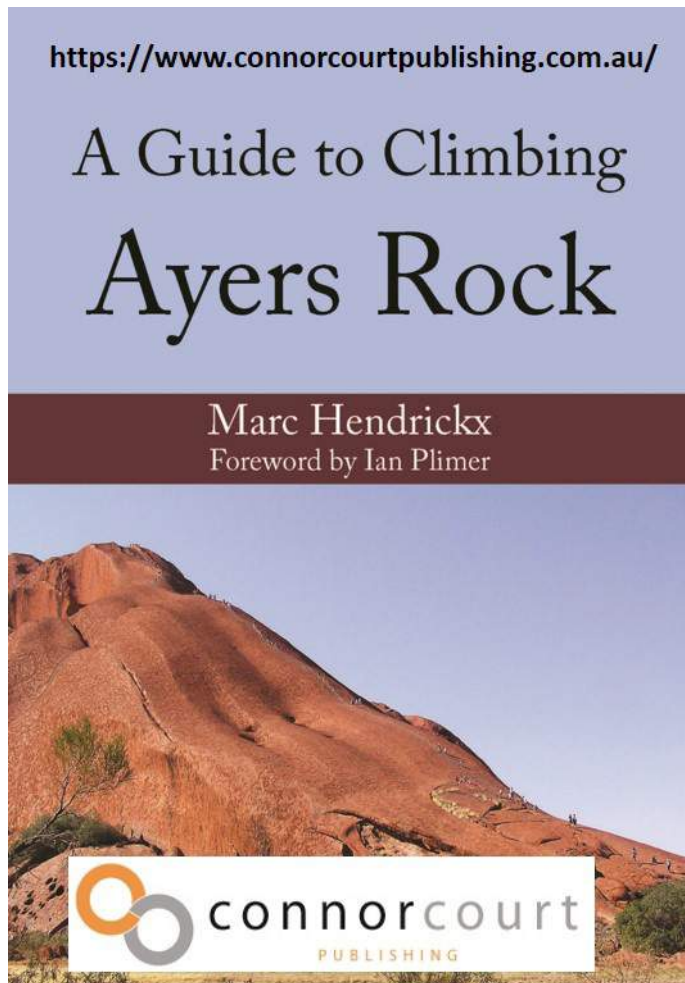
"The Australian Geoscience Council strongly welcomes the significant focus of the major

parties on supporting the resources sector to discover the next generation of 'hidden' mineral resources and increase Australia's minerals and energy security. The markets and competitive profile around the globe are always changing, and they impact on Australia's mineral resources and export opportunities, so there is no cause for complacency. We must have the knowledge to be able to plan and act strategically."

"The years of easy exploration and extraction are largely over. The road ahead is going to require more innovation and substantial lead-times in discovering and developing the resources that Australia and the world needs. These must be found and extracted safely, cleanly and efficiently if we are to continue to support and maintain the community values that we expect in Australia."

"Recognition by the major parties of these realities – and their understanding that the resources sector remains essential to Australia's future prosperity, standard of living and resource security – is greatly welcomed in the lead-up to the next federal election and beyond."

"We look forward to working with all politicians to help put their commitments into action." 🇦🇺



FURTHER INFORMATION:

- More information on UNCOVER can be found at <http://www.uncoveraustralia.org.au>
- The Decadal Plan can be found at <https://www.science.org.au/supporting-science/science-policy-and-sector-analysis/decadal-plans-science/australian-geoscience>
- The Resources 2030 Taskforce Report can be found at <https://www.industry.gov.au/data-and-publications/resources-2030-taskforce-report>



PACRIM 2019

The PACRIM 2019 conference “Mineral Systems of the Pacific Rim” in Auckland 3-5 April brings together the most recent advances in academic research and geological understanding, regional surveys by government agencies and the industry’s latest discoveries and projects to showcase the importance of the Pacific Rim for global mineral wealth and investment.

Its appeal extends far and wide to geologists, geophysicists and geochemists exploring in the Pacific Rim, and to people interested in the mineralisation processes of active tectonic margins as well as those developing the projects which follow discovery in these regions.

There are 17 keynote papers from world-renown geoscientists with the program strongly supported by fellow professional associations including AIG, GSA, AAG, SEG, SGA, IAGOD and GSNZ. Members of these organisations also attend the event at a discounted price.

<http://pacrim.ausimm.com/keynotes/>

The full conference program has been released and includes a total of 22 sessions over the 3 days including five keynote plenaries. There is a huge range of content covering multiple key areas relevant to Pacific Rim exploration activity.

<http://pacrim.multisite01.ausimm.com/wp-content/uploads/sites/10/2019/01/PACRIM-draft-program-as-at-20190108.pdf>

Dale Sims
PACRIM 2019
Chair; MAIG



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Additionally, an exciting series of short courses and field trips create a rare opportunity for researchers and minerals professionals to grow their understanding and share experiences on a variety of topics.

Participation in short courses and field trips does not require conference registration and national/international field trips are open to all on a first come basis.

Field trips include New Caledonia, Central NSW, Otago Goldfields and the NZ North Island as well as two one day options around Auckland.

<http://pacrim.ausimm.com/tours/>

<http://pacrim.ausimm.com/workshops/>

The International Hydrothermal Fluid Society will also meet at PACRIM so bring a bottle of your favourite vino for the joy of the competition and that wonderful feeling the following day.

Since its first inception in 1987 on the Gold Coast PACRIM has always been an industry-focussed exploration event looking at the practical application of research and learning on globally significant mineral systems. Don't miss it!

Register before 11th February for the early-bird discount and to join volcanic-related field trips (New Zealand and overseas) and the conference workshops. I hope to see you there! 🇳🇵



For more information and to register, visit <http://pacrim.ausimm.com/>



Events Calendar

Keep up to date with AIG and Geological events at www.aig.org.au/events

QGIS for Geologists

30-31 March, 2019

James Cook University, Townsville QLD

QGIS for Geologists

2 April, 2019

Transcontinental Hotel, Brisbane QLD

PACRIM 2019

3-5 April, 2019

Cordis, Auckland, Grafton Auckland NZ

Porphyry copper-gold deposits in the circum-Pacific and elsewhere

6 April, 2019

Cordis, Auckland, Grafton Auckland NZ

Workshop: Applied Exploration

Geochemistry "The Fallacy of the Deep"

8 April, 2019

Western Australia, WA

Applied Mineralogy In Exploration

9 April, 2019

Lahtlain Function Center, Lathlain WA

GPIC April 2019 - Humpty Dumpty had a great fall: the Century Orebody's fall into a Meteorite Impact Crater, NW QLD

9 April, 2019

Basement on View, Bendigo VIC

Workshop: Applied Exploration

Geochemistry "The Fallacy of the Deep"

10 April, 2019

Ascot Kayak Club, Ascot WA

A Better Understanding of Exploration

Geochemistry

10 April, 2019

Perth WA

Exploration Geochemistry : Getting it right to extract maximum value for minimal cost

12 April, 2019

UQ Business School, Brisbane QLD

AIG SA - Yorke Peninsula - Field Workshop

15-17 April, 2019

TBA, Adelaide SA

QAQC for Mineral Exploration & Beyond

27 April, 2019

James Cook University, Townsville QLD

Integrating Geochemistry & Mineralogy for Exploration

28 April, 2019

James Cook University, Townsville QLD

Introduction to the JORC Code

29 April, 2019

James Cook University, Townsville QLD

A JORC Code Refresher for Existing and Aspiring Competent Persons

29 April, 2019

James Cook University, Townsville QLD

Assessing and Communicating Geological Uncertainty and Risk to Non-Geologists

30 April, 2019

James Cook University, Townsville QLD

A Better Understanding of Exploration Geochemistry

1 May, 2019

Kalgoorlie WA

SHORT COURSE - Epithermal Au-Ag and Porphyry Cu-Au Exploration

14-16 May, 2019

Chatswood Club, Chatswood NSW

Sn-W-Critical Metals & Associated Magmatic Systems

24-28 June, 2019

Tinaroo Lake Resort, Tinaroo QLD

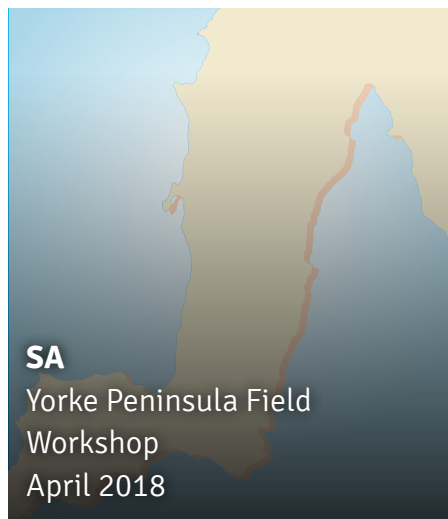
Advanced Field Training

29 June - 6 July, 2019

Cloncurry Region (Eastern Mt Isa Block), NW Minerals Province, QLD



NZ
PACRIM 2019
April 2019



SA
Yorke Peninsula Field
Workshop
April 2018



QLD
Exploration Geochemistry
Seminar
April 2018

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AIG NEWS



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June	April 30th	June 3rd
September	July 31st	September 2nd
December	October 31st	December 2nd
March	January 31st	March 2nd

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