Australian Society of Exploration Geophysicists

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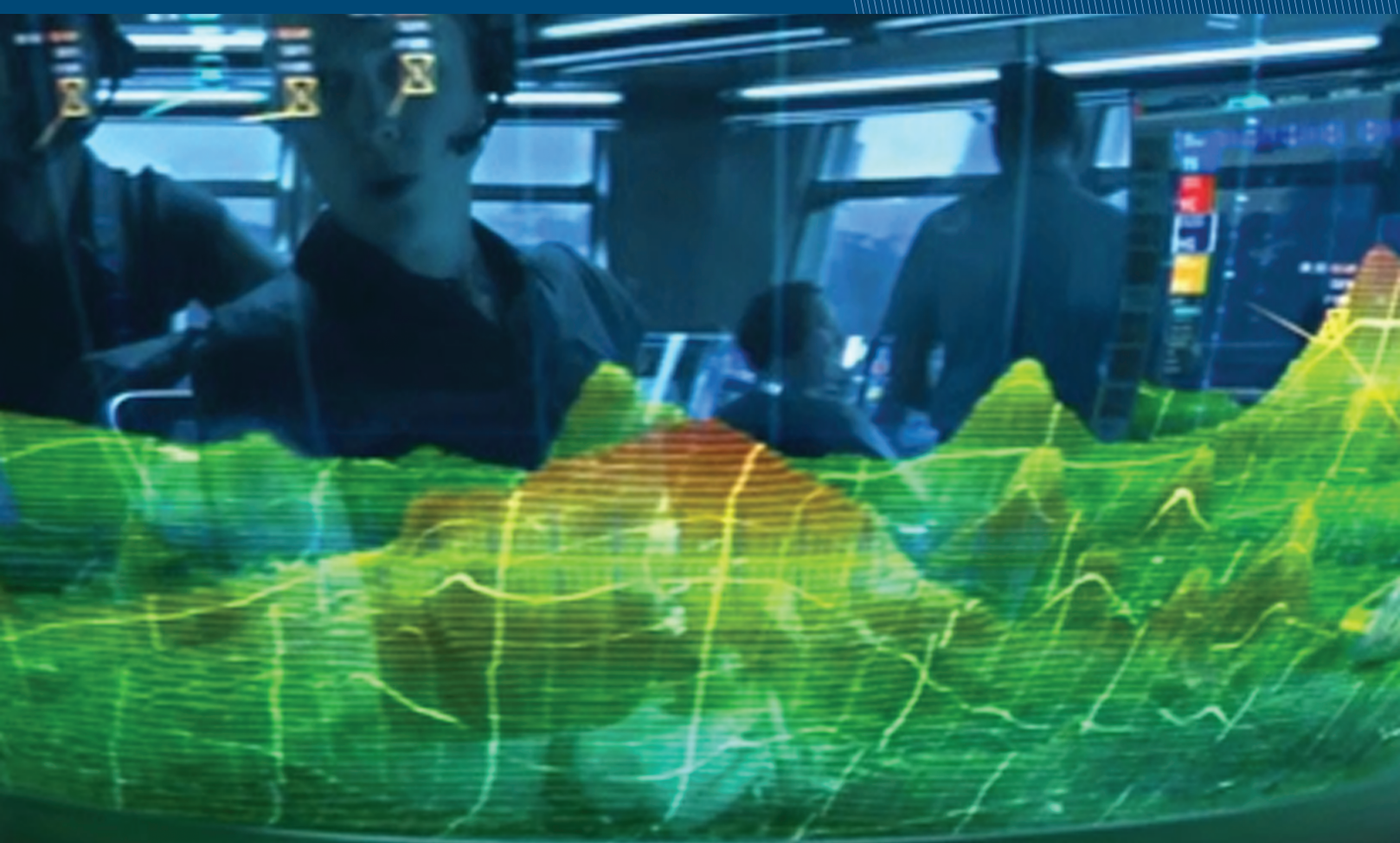
PREVIEW

CELEBRATING THE 200th ISSUE OF PREVIEW



NEWS AND COMMENTARY

FEATURE

ASEG CORPORATE PLUS MEMBER

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FRONT COVER

Members of Team "On the Rocks" viewing one of rear-projection models developed for their 2107 winning entry in the Frank Arnott Award (Apprentice Category). See *Education matters* in this issue for more information.

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Editor's desk

This 200th issue of *Preview* features an article by James Grove and his colleagues on the widespread impact that historical gold mining has had on Victoria's riverine landscapes. It is no exaggeration to say that some of these landscapes have been completely reworked. The Victorian population reacted in horror in the late 19th century as fertile floodplains were destroyed over what is estimated to be a quarter of the length of Victorian rivers. In upstream reaches the stratigraphic column was inverted, in downstream reaches flooding dumped overwhelming volumes of sludge. The physical changes wrought in these landscapes have significant ramifications for the movement of water through the landscape. It is obvious that rivers are still adjusting, but the impact on groundwater systems is unknown. Needless to say, the design and interpretation of near surface geophysical surveys in these regions would be a challenge, and the design and interpretation of near surface geochemical surveys an absolute nightmare! It is interesting to note, however, that collective memories are short and many tree-changers would be completely unaware of the history of their prized bush blocks. I have found such blissful ignorance to be the norm amongst tree-changers living in former tin mining regions in far north Queensland.

This 200th issue of *Preview* also brings us a kaleidoscope of news and commentary from around Australia and around the world. Ken Witherly summaries the latest report on Exploration Trends and Developments, and Dick Irvine reviews Norm Paterson's book on Canadian mining geophysics. We have reports on a new national geophysical survey in Sierra Leone, and on new surveys, geophysical data and products from the Geological Surveys of Western Australia, South Australia and Tasmania.

David Denham (*Canberra observed*) looks back at the Federal election that was. Michael Asten (*Education matters*) reminds students about the Frank Arnott Award, reports on the mentoring of early-career professionals in Victoria, and brings us news about the SEG Honorary Lecturer and the recently announced SEG Distinguished Instructor Short Course. Terry Harvey (*Minerals geophysics*) returns to the "real" world of potential field modelling. Nobody bit after his last column on a world without mining, but I note that the piece is a popular download! Mick Micenko (*Seismic window*) revisits pitfalls in seismic processing. Tim Keeping (*Data trends*) takes a look at open data formats for a post DOS world. And, our new webmaster, Ian James, reviews the performance of the ASEG's website (*Webwaves*). He lists the countries in which the ASEG doesn't have a digital presence – it is surprising to discover that there are only thirteen – so, if you are visiting Bhutan or Burundi, Svalbard or Turkmenistan, Ian would like to have a word with you!!

Enjoy!

Lisa Worrall
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President's piece

My path to exploration geophysics and my involvement with the ASEG from the early foundation era go directly back to Professor Laric Hawkins, one of the founders of the Society, our 1st Gold Medallist, an inspirational teacher and an influential mentor in my undergraduate days and early career. As a consequence, it has been a real pleasure for me to (re) join the ASEG Federal Executive in April 2018 as President-Elect and to immediately experience the strong working partnerships and the positive camaraderie within the Executive team under our inspiring President Marina Costelloe.

Our Annual General Meeting, hosted on 4 April by the ACT Branch in the Sir Harold Raggatt Theatre, Geoscience Australia (GA), was a very efficient affair with a large number of guests who joined us to hear our special Guest Speaker, Dr Steve Hill, Chief Scientist GA, present "Welcome to Planet, Continent and Country and why geoscientists like you hold a key to that greeting". Thank you to all supporting ASEG Members present at the AGM and by proxy, and a big thank you to Dr Steve Hill for his entertaining and compelling address.

Congratulations to our newly elected 2019 Federal Executive! Thank you for volunteering to lead our Society as we approach such a key milestone in our history – the 50th Anniversary in 2020. David Annetts, our long-term Webmaster, is now our President-Elect, Danny Burns remains as our Federal Treasurer, and Megan Nightingale continues as Federal Secretary. David, Danny and Megan join me as the listed Directors of our Society.

Leslie Atkinson, Marina Pervukhina and Kate Robertson continue as great contributors on the Executive and we welcome to our new team members, Ian James, Tim Dean, Jim Austin and Mark Duffett. The responsibilities for each Executive member are listed in the following pages of *Preview*.

In her President's piece (*Preview* 199), Marina touched on some of the achievements of the Federal Executive over the past year. I would like to highlight:

- The successful 1st AEGC in 2018;
- The active promotion of STEM initiatives and Diversity in Geoscience;
- Important leading practice changes to the ASEG Constitution;
- Updates to the Code of Ethics and the ASEG Procedures and Policies;
- The transition to our new publication arrangement with Taylor & Francis Australia;
- A strong programme of communication to Members and beyond through our new ASEG Newsletter and social media platforms;
- Development of the AEGC joint conference arrangements with PESA and AIG;
- The strengthening our partnerships with international affiliate societies and with the other eight member societies of the Australian Geoscience Council.

A HUGE thank you and congratulations to Marina on leading and navigating such a hectic and productive year of change as President – Marina has achieved a great deal, set high standards of business and service performance, and brings high energy and a great leadership culture to the ASEG Executive. Marina has done a fabulous job as President and now as Immediate Past President will continue to support the Executive and our 50th Anniversary preparations.

I also want to give high level praise and appreciation to Kim Frankcombe, who stepped down from the ASEG Executive at the recent AGM after a long period of dedicated service. Kim is one of our well known past ASEG Presidents, an ASEG Conference Convenor, and an SEG Councillor. Kim has extraordinary knowledge and experience of the ASEG's history, business processes, procedures, policies, and a broad and well-connected network in our industry. Kim remains a key liaison point to the ASEG's Conference Advisory group. Kim is also the ASEG's hard copy archivist of all ASEG publications plus a lot more. Kim's contribution is enormously appreciated. Kim now takes on his newly elected role as Secretary of Australia's geoscience representative body, the Australian Geoscience Council.

In preparing a recent presentation to the NSW Branch, I was taken by all of the positive milestones that are lining up for the ASEG in 2019–20:

- 50th anniversary of the ASEG
- 50th volume of *Exploration Geophysics*
- 40th year of successful exploration geophysics Conferences & Exhibitions, Workshops and Forums
- 33rd Year (Issue 200) of *Preview*
- 30th year of the ASEG Research Foundation supporting Australian Honours, MSc and PhD research projects in exploration geophysics
- 2nd Australasian Exploration Geoscience Conference – AEGC 2019 (with our key partners PESA and AIG) – incorporating the 27th ASEG Geophysical Conference & Exhibition

Our Society's first technical journal was published in September 1970 as The Bulletin of the ASEG Volume 1, No.1, and continued through to 1984, when it was re-named *Exploration Geophysics*. In February 2019 Volume 50, Issue 1 of *Exploration Geophysics* was published on-line, marking a major milestone: continuous quarterly publication of the Society's technical journal year on year over five decades!

From 1970 to 2019, the ASEG has been incredibly fortunate to have ten truly

Ted Tyne, Blair McKenzie and Dave Pratt enjoying an ASEG moment at AEGC 2018.

dedicated and outstanding Editors for *Exploration Geophysics*. In the most recent era our five Editors have been: Don Emerson (1984–93); John Denham (1994–99); Shanti Rajagopalan (2000–01); Lindsay Thomas (2001–08) and Mark Lackie (2009–19).

Congratulations on this outstanding milestone and thank you to all of our past and present Bulletin and *Exploration Geophysics* Editors and our many Associate Editors! In addition my personal congratulations on the publication of Vol. 50 Issue 1, to Mark Lackie, our Editor for more than 10 years.

As we move closer to our 50th Anniversary, there will be much more to say on 50 years of Australia's exploration geophysics journal.

Thirty three years in the making, our dedicated *Preview* Editor and contributors have delivered the 200th issue – a fantastic milestone for our Society!

Preview was first published in January 1986 as the ASEG Newsletter *Preview* No.1, edited by Peter Elliot, who led the early development years of the *Preview* Newsletter. *Preview* began to morph from a newsletter to a magazine with the first colour pages appearing in *Preview* with much fanfare in December 1992, under the editorship of Anita Heath (1988–1992) and then Geoff Pettifer (1992–96). Anita and Geoff were followed by Mike Shalley (1996–97), Henk Van Paridon (1997–99), and then a decade of further progress and a long period of dedicated editorship by David Denham (1999–09). The readership of *Preview* expanded further under the guidance of Ann-Marie Anderson-Mayes (2009–12) and John Theodoridis (2012–14).

Lisa Worrall, our current *Preview* Editor, continues to receive the highest level of acknowledgement for her outstanding editorship of *Preview*. Very recently I was cc'ed into some email praise to our Editor from David Pratt, who said

"I really appreciate the effort that you and your associate editors put into the production of this high quality newsletter. I really look forward to reading *Preview* as it gives me some idea of what is happening in the industry between conferences. Like many of my generation, I really appreciate the high quality, printed version. Your dedicated efforts have made this a must-read newsletter which makes us all feel like we are part of a community that cares about each other and where we are going."

On behalf of the ASEG Federal Executive and our Membership, congratulations and thank you to all of our past and present *Preview* Editors, Associate Editors and our contributors over the years, and a further BIG thank you to Lisa Worrall for a great *Preview* Issue 200!

Ted Tyne
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Henderson byte: Nikola Tesla

In *Preview* 194, it was explained that there are 29 SI units, all of which are used in geophysics, and 19 of which use the names of scientists. One such name is Nikola Tesla, a tesla (T) being the unit of magnetic flux density or magnetic induction (informally; magnetic field strength), first named in 1960. In magnetic exploration the nanoTelsa (nT) is more common.

Because Tesla was such a great inventor, the Wikipedia biography on Tesla, https://en.wikipedia.org/wiki/Nikola_Tesla runs to 42 pages (whereas the number of pages in the same format for Isaac Newton is 31, and for many other inventors is less than ten). The page also lists 27 books and journals and four documentary videos about Tesla. He is also distinctive in having a flourishing Memorial Society devoted to him.

Nikola Tesla was born in 1856 in what was Serbia, now Croatia, and emigrated to New York in 1884 - where he died a poor man in 1943. His greatest invention was an alternating-current system, which was much more efficient than the direct-current system promoted by Thomas Edison at around the same time. Tesla received funding for his AC systems from George Washington, and they became central to many present-day systems used throughout the world in industry and household appliances.

Tesla also patented the basic system of radio in 1896. His published schematic diagrams describing all the basic elements of the radio transmitter were later used by Marconi. He combined radio technology with a remote control device, to demonstrate remote wireless operations, which he called "teleautomation" or, as we would call it today, robotic control. In 1896 he made X-rays of a man, one year after Roentgen announced their discovery. Among his other discoveries are the fluorescent light and laser. He foresaw interplanetary communications and satellites.

Very much more information on Nikola Tesla is available in his biography, which is available from the Tesla Memorial Society of New York (www.teslasociety.com/biography.htm). The Society also holds the "Tesla Collection" of 1700 newspaper and periodical articles written about him from 1886 to 1920. There is even an FBI file on Tesla running to 156 pages and containing letters signed by J Edgar Hoover.

For the last ten years of his life Tesla lived, and died, in the New Yorker Hotel, occupying rooms 3327 and 3328. Both of these rooms now have a plaque on the wall with a short biography of the great man.

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Executive brief

The ASEG Annual General Meeting, held in Canberra in April, saw the election of new ASEG office bearers for 2019, and the departure of others.

Dr Ted Tyne assumed the position of President. Ted has already made a big impact on the Federal Executive in the last 12 months as President Elect, working diligently with our Treasurer Danny Burns, *Preview* Editor Lisa Worrall, and *Exploration Geophysics* Editor Mark Lackie to navigate safely into a new publication arrangement with Taylor & Francis. The decision to seek a new publisher was made in an attempt to reduce publication costs and strengthen the financial security of the Society. We look forward to the next 12 months under Ted's stewardship, and to further developments that progress our Society.

We wish to extend an enormous thank you to our now Immediate Past President Marina Costelloe for her tremendous contribution to the ASEG over the last 12 months. Under Marina's leadership we saw numerous changes including the new publishing agreement, new memorandum of understandings with sister societies KSEG and SEGJ, and updates to membership pricing including increased support for graduates with the introduction of a new membership level.

Marina has been instrumental in modernising how the Society operates and refreshing our image by updating the constitution to allow secure electronic voting and removal of gendered language, not to mention facilitating updates to our website, increasing the awareness of our Society through a substantial increase in social media posts, and the introduction of the Members newsletter based on feedback from the 2017 Membership Survey. Marina has travelled considerably during her time as President, visiting all the State and Territory Branches, again improving our visibility and awareness of the ASEG brand and strengthening relationships with our affiliate organisations. We know that Marina will continue to contribute to the Society as she remains on the Federal Executive as Immediate Past President. Thank you again Marina.

Megan Nightingale and Danny Burns will continue in their roles as Secretary and Treasurer respectively. We thank them both for their efforts, particularly Danny Burns who as previously mentioned was instrumental in negotiations for the new publications contract with Taylor & Francis.

This year we see the resignation of some long standing Federal Executive members including Katherine McKenna, Andrea Rutley and Kim Frankcombe. We wish to extend another big thank you to Kim Frankcombe for his outstanding contributions to the Federal Executive over the past eight years. Kim was a very busy member of the Executive and created an astonishing 292 reports for 64 Federal Executive meetings during his tenure! Kim leaves very big shoes to fill and we're glad that he has agreed to become a founding member of the new Director's Forum, created as a "brains trust" to ensure the future success of the Society. If you are a former Director of the Society and would like to be a part of the Director's Forum please email secretary@aseg.org.au to register. The terms and references of the forum will be the first item the group will establish.

Thank you to returning members of the Federal Executive: Marina Pervukhina (Professional Development Committee Chair, State Branch Representative, Specialist and Working Groups Liaison), Kate Robertson (Communications Committee), and Leslie Atkinson (Membership Committee). Thank you for your efforts over the last 12 months, efforts that have also contributed to the Society's successful year.

This year we welcome Jim Austin (Conference Advisory Committee Representative), Mark Duffett (Technical Standards Committee Representative), Ian James (Web Committee Chair) and Tim Dean who will take over from Andrew Squelch as the Education Committee Chair, to the Federal Executive Team. Photos and short biographies of these new members will appear in the next issue of *Preview*.

The day after the AGM the Federal Executive met to discuss the short and long term issues facing the Society. The *Preview* Editor Lisa Worrall, and representatives from the Secretariat The Association Specialists (TAS) also attended the meeting.

The mission of the Society is to provide an environment for the science of applied geophysics to grow for the benefit of its Members and the wider community. Our aims are:

- to promote the science of geophysics, and specifically exploration geophysics, throughout Australia
- to foster fellowship and co-operation between geophysicists
- to encourage closer understanding and co-operation with other earth scientists
- to assist in design and teaching of courses in geophysics and to sponsor student sections where appropriate

As documented in *Preview* after the 2018 Strategy Day, the ASEG, in line with its aims and the activities defined in the Constitution, has adopted several aspirational strategic goals for 2018–2023 to ensure that the Society retains vitality and relevance in an exploration industry that is continually changing.

Throughout 2018 and 2019 to date, the ASEG Federal Executive has already made impressive headway in achieving and further defining these strategic goals including:

- Strengthening and future-proofing our publications (*Exploration Geophysics* and Preview), promotions and member communications through arranging a new publishing contract to reduce expenditure, increasing our online presence including updating our website content, increasing social media usage posting on LinkedIn, Facebook and Twitter, and creating the ASEG Monthly Newsletter.
- Advancing geophysics as a science to benefit our Members, the wider community and young professionals to secure the future of the ASEG, and grow the relevance of the ASEG in local regions – as mentioned, a strategy for community engagement is increasing our social media coverage and cross promotion of courses, conferences, and educational opportunities among other societies within Australia and internationally. The Federal Executive has identified the need to create stronger connections with our universities and are looking into improving member benefits and strengthening our relationships with corporate and state Sponsors.

The Federal Executive would like to thank the ACT Branch of the ASEG for their assistance in organising, and Geoscience Australia for hosting, the 2019 AGM and Strategy Day.

Megan Nightingale
ASEG Secretary
fedsec@aseg.org.au

Welcome to new Members

The ASEG extends a warm welcome to 27 new Members approved by the Federal Executive at its April and May meetings (see Table).

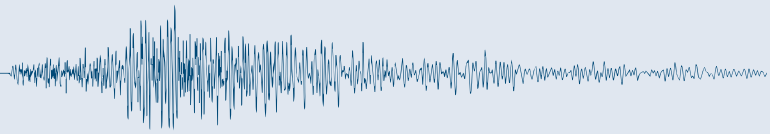
First name	Last name	Organisation	State	Country	Membership type
Harrison Scott	Button	University of Queensland	QLD	Australia	Student
Wan Ji	Chia	University of Adelaide	SA	Australia	Student
Emma	Dangerfield	University of Adelaide	SA	Australia	Student
Chloe	Dean	University of Adelaide	SA	Australia	Student
Tom	Dronfield	Resource Potentials	WA	Australia	Graduate
Tristan	Fenn	University of Adelaide	SA	Australia	Student
Benjamin John	Forrest	University of Adelaide	SA	Australia	Student
Dale	Harpley	University of Queensland	QLD	Australia	Student
Ivano	Ivano	Australian School of Petroleum	SA	Australia	Student
Monica	Jimenez Lloreda	University of Adelaide	SA	Australia	Student
Callum John	Kowalski	University of Queensland	QLD	Australia	Student
Jasmin	Laundy	University of Adelaide	SA	Australia	Student
Piter	Lepong	Mulawarman University	INT	Indonesia	Active
Jarrad	Luce	First Quantum Minerals Ltd	WA	Australia	Associate
Brendon	Mitchell	Oceania Geo	QLD	Australia	Active
Polyanna	Moro	University of Western Australia	WA	Australia	Student
Matthew	Rankmore	University of Adelaide	SA	Australia	Student
Michael	Roach	University of Tasmania	TAS	Australia	Active
Kalimna	Roe-Simmons	University of Adelaide	SA	Australia	Student
Robert James	Rudd	University of Adelaide	SA	Australia	Student
Thomas	Schaap	University of Tasmania	TAS	Australia	Student
Evgenii	Sidenko	Curtin University	WA	Australia	Student
Erica	Van Der Wolff	University of Adelaide	SA	Australia	Student
Martyn	Van Isselt	University of Adelaide	SA	Australia	Student
Sheng	Wang	Research School of Earth Sciences, The Australian National University	ACT	Australia	Student
Hannah	Williamson	Monash University	VIC	Australia	Student
Arshia Gerami	Zadegan		WA	Australia	Associate

Science meets Parliament 2019: Scholarships available

The next Science meets Parliament (13–14 August 2019) is your chance to influence the way science and technology shapes Australia. A range of scholarships are available:

- Indigenous STEM Scholarships for people with Aboriginal or Torres Strait Islander heritage
- STEM Pride scholarships for people who identify as LGBTQI+
- Regional STEM scholarships for STEM practitioners who work in remote or regional Australia (>150 km from a major capital city)

The scholarships will cover full registration including the gala dinner in the Great Hall at Parliament House, as well as travel, accommodation, meals and transfers. Financial assistance for childcare is available upon application. For more information go to https://sta.eventsair.com/science-meets-parliament-2019/



ASEG Research Foundation: Grants awarded

The ASEG Research Foundation received eight grant applications in late February for the 2019 year. Four of these applications were on minerals oriented topics, and four were on petroleum related topics. The Foundation is pleased to announce it has made four grants totalling $48 890 for the 2019 year. This brings the total amount granted to university students to over $1 430 000 since the ASEG Research Foundation commenced in 1991.

A brief summary of each of the grants for 2019 is as follows:

(1) Curtin University. Project title "Elemental analysis via prompt gamma neutron activation for diamond drilling", PhD student Snezana Petrovic, supervisor Dr Michael Carson, $16 000 over 2 years.
(2) University of Melbourne, Project title "Characterising the depth to basement using HVSR passive seismic in the Murray Basin: Implications for gold exploration undercover", BSc Honours student Matthew Sultani, Supervisor Dr Mark McLean, $3 890.
(3) Monash University. Project title "Using analogue interpretations of geophysics to understand geology hiding undercover. A case study from the Mount Isa Inlier", BSc Honours student Hannah Williamson, Supervisor Professor Peter Betts, $5 000.
(4) University of Adelaide. Project title "The impact of magmatism on petroleum systems of the Carnarvon Basin", PhD student Michael Curtis, supervisors Associate Professor Simon Holford and Dr Mark Bunch, $24 000 over 3 years.

The grant recipients are required to report back to the Foundation on an annual basis on the progress and results of their projects, and to provide a financial reconciliation. Publication of results in *Exploration Geophysics* and *Preview* is the preferred outcome, and preference is given to applicants with a track record in this regard. In addition, grant recipients are being asked to publish regular project updates in *Preview*.

The ASEG Research Foundation is registered with the Australian Charities and Not-for-profits Commission (ACNC). The Research Foundation is funded in two ways, directly from the ASEG and by Corporate and Member contributions. Anyone can make a donation. Members of the ASEG are encouraged to donate when they pay their annual subscriptions. Donations of $2.00 and over are tax deductible at 100% of the donation amount.

The ASEG Research Foundation is operated by volunteers from the ASEG, and is currently recruiting interested persons who can assist with reviewing the annual grant applications and also with the Foundation management. Please get in touch with Phil Harman or Doug Roberts if you are interested.

The Research Foundation gratefully acknowledges the support of ASEG Members and ASEG Federal Executive.

Doug Roberts
ASEG Research Foundation Secretary
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ASEG Young Professionals Network: An update

With the AEGC 2019 rapidly approaching, it is time to think about booking your ticket for the Early Career Geoscientist Networking Evening, which will be held on Monday September 2 at Australia's largest pub, The Camfield, located on the banks of the Swan River (and just a stone's throw from the conference venue). Cameron Adams is the Student and YP representative on the Conference Organising Committee and he has been busy planning this event along with other events for our newer geoscientists. Several sponsorship opportunities have already been snapped up, but please contact Cameron for more information as he may have some flexibility to tailor a package suitable for your company. Heavily subsidised tickets are available to AEGC-registered students and early career geoscientists. For more info please visit: https://2019.aegc.com.au/social-program/.

A number of early career geoscientist-tailored workshops are also planned at the AEGC 2019. Please register your interest (https://2019.aegc.com.au/workshops/) to attend and receive updates on these workshops. Better still, book into your workshops at the same time as taking advantage of the early bird registration process. The workshops will only proceed if minimum registration numbers are exceeded by a cut-off date that is well before the conference.

Meanwhile, the Victorian YPs have been active again, this time hosting a very well received course on Sequence Stratigraphy by Rob Kirk (discussed in a separate article in this edition of *Preview*). Also, our mentoring programme has passed its first review stage and we are taking on new mentees (please contact Jarrod Dunne at Karoon Energy for more information about that). The YPs, led by Daniel Thompson, have commenced planning our 2019 seminar series, and our speaker slots look likely to be filled soon – and well into 2020. More on that in the next report.

Jarrod Dunne
ASEG Young Professionals Network
ypadmin@aseg.org

ASEG Honours and Awards: Final call to nominate a colleague for an ASEG Honour or Award for 2019

NOMINATIONS CLOSING 17 JULY 2019

The ASEG acknowledges the outstanding contributions of its individual Members, both to the profession of geophysics and to the ASEG, through the presentation of the Society's Honours and Awards across a range of categories. The next awards are scheduled to be presented in conjunction with AEGC 2019, 2–5 September 2019, Perth, Western Australia.

All ASEG Members, as well as State and Federal executives, are invited to nominate those they consider deserving of these awards. The available awards are:

- **ASEG Gold Medal**
  For exceptional and highly significant distinguished contributions to the science and practice of geophysics, resulting in wide recognition within the geoscientific community.
- **Honorary membership**
  For distinguished contributions by a Member to the profession of exploration geophysics and to the ASEG over many years.
- **Grahame Sands Award**
  For innovation in applied geophysics through a significant practical development in the field of instrumentation, data acquisition, interpretation or theory.
- **Lindsay Ingall Memorial Award**
  For the promotion of geophysics to the wider community.
- **Early Achievement Award**
  For significant contributions to the profession by a Member under 36 years of age, through publications in *Exploration Geophysics* or similar reputable journals, or overall contributions to geophysics, ASEG Branch activities, committees, or events.
- **ASEG Service Award**
  For distinguished service by a Member to the ASEG.

ASEG Members are eligible for all award categories. Non-members also are eligible for the Lindsay Ingall and Grahame Sands awards. Under exceptional circumstances the other awards may be offered to a non-member of the ASEG who has given appropriate service to the ASEG or to the profession of geoscience, and who has been duly nominated by the Federal Executive.

Nomination procedure

Any Member of the Society may submit nominations for an award. These nominations are to be supported by a seconder and, in the case of the Lindsay Ingall Memorial Award, by at least four geoscientists who are members of an Australian geoscience body (e.g. ASEG, GSA, AusIMM, AIG, PESA, or similar).

The awards carry considerable prestige within the ASEG and the geoscience profession. Therefore, appropriate documentation is required to support each nomination. Nominations must be specific to a particular award and all aspects of the defined criteria should be addressed.

Further details of the award categories, lists of previous awardees and citations for recent awards, award criteria, nomination guidelines and nomination forms can be found on the ASEG website at: https://www.aseg.org.au/about-aseg/honours-awards

Further information can be obtained by contacting the Chair of the Honours and Awards Committee. All correspondence and nominations will be treated confidentially.

Nominations including digital copies of all relevant supporting documentation are to be emailed to:

Andrew Mutton
ASEG Honours and Awards Committee Chair
awards@aseg.org.au

Nominations close Wednesday 17 July 2019.

Andrew Mutton
Honours and Awards Committee Chair
awards@aseg.org.au

ASEG Branch news

In March **Boris Gurevich**, the SEG Distinguished Lecturer from Curtin University and CSIRO, presented a talk entitled "Seismic attenuation, dispersion, and anisotropy in porous rocks: Mechanisms and models". Boris spoke about how understanding and modelling of attenuation of elastic waves in fluid-saturated rocks is important for a range of geophysical technologies that utilise seismic, acoustic, or ultrasonic amplitudes. Boris gave the outline of a consistent theoretical approach that quantifies these phenomena and discussed rigorous bounds for attenuation and dispersion. Much discussion followed, the talk being enjoyed by all.

In April we held our AGM and the usual suspects (**Mark Lackie**, **Steph Kovach** and **Ben Patterson**) were elected to the roles of President, Secretary and Treasurer. **Simon Williams** (GBG), **Stuart Clark** (UNSW) and **Josh Valencic** (GHD) volunteered, and thus were elected, as committee members.

For the technical meeting **Ted Tyne,** the recently elected ASEG President, gave a talk entitled "The Australian Society of Exploration Geophysicists: The President, diversity and science". Ted spoke about the Society, its values, the recent planning session and where it was heading. In addition, Ted touched on some of his history and finished up with some photos taken a "few!!!" years ago … .there was much fun trying to identify the ASEG Members in the photos and much smiling when it was finally revealed who they were.

Ted Tyne (ASEG President) accepting bottle of red from Mark Lackie (NSW ASEG President) for his talk about the Society.

An invitation to attend NSW Branch meetings is extended to interstate and international visitors who happen to be in town at that time. Meetings are generally held on the third Wednesday of each month from 5:30 pm at Club York. Meeting notices, addresses and relevant contact details can be found at the NSW Branch website. All are welcome.

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Stephanie Kovach
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Queensland

Our year has continued as it started with a number of talks leading into our AGM, with more planned.

We welcomed the SEG 2019 Pacific South Honorary Lecturer **Boris Gurevich**, Curtin University and CSIRO, on Tuesday 19 March. Boris gave a talk on "Seismic attenuation, dispersion and anisotropy in porous rocks: Mechanism and models".

The QLD Branch AGM was held on 16 April. **Henk Van Paridon** of Energeo stood down as Treasurer after 10 years of service, a fantastic contribution to our state branch, recognised with a gift presented by our 2018 and re-elected 2019 President, **Ron Palmer**. **Eric Battig** was elected as the new Treasurer and **James Alderman** was re-elected as Secretary. The new committee would also like to thank **Janelle Simpson** for her ongoing work looking after the mentorship programme, and to make a special mention of **Nick Josephs** at Energeo for his support to the committee.

Henk Van Paridon escaping after being presented with a gift by QLD President, Ron Palmer, in recognition of ten fantastic years of service to the QLD Branch as Treasurer.

Eric followed up his election as Treasurer by giving an interesting talk on "Adopting and adapting 3D seismic methods for open-cut coal mining". The talk and AGM were well attended, with lots of people interested in hearing how recent improvements in source and receiver technology have fully justified the application of 3D seismic to open cut coal mines, where it was previously deemed to be too expensive. We also welcomed **Wayne Stasinowsky** on Tuesday 14 May and enjoyed his presentation on "The Magnetic Tensor: What is it and why should we use it?"

We have more talks in the pipeline for later in the year so, as always, please get in touch if you are interested in presenting. We also extend an invitation to attend our meetings to all interstate or international Members who happen to be passing through Brisbane.

James Alderman
qldsecretary@aseg.org.au

South Australia & Northern Territory

On Friday 15 March we held a successful student pizza night at the Mawson Building in the University of Adelaide, with around 25 students attending ranging from undergraduates to PhD candidates with diverse study paths. The students and Members who attended were treated to talks from both Dr **Stephan Thiel** (Geological Survey of South Australia) and **Bonnie Lodwick** (Santos) who gave their own unique and valuable insight into what it's like having a career in geophysics; from academia into Government for Stephan with a minerals background, to an industry petroleum perspective from Bonnie who entered Santos through the graduate programme.

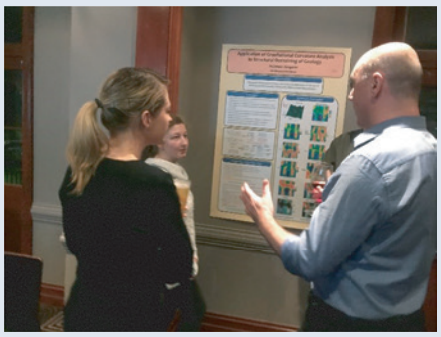
Bonnie Lodwick presenting at the SA-NT Branch annual student pizza night.

Stephan Thiel presenting at the SA-NT Branch annual student pizza night.

On Monday 25 March, Prof **Boris Gurevich**, Curtin University, CSIRO, a SEG/ASEG Honorary Lecturer spoke about, "Seismic attenuation, dispersion, and anisotropy in porous rocks: Mechanisms and models", explaining the importance of modelling attenuation and dispersion of seismic waves in fluid saturated rocks.

Boris Gurevich presenting at the SA-NT Branch March Technical Evening.

On Wednesday May 8 **Matthew Zengerer** from Gondwana Geoscience spoke about some work he had presented at an international conference a few weeks before; "Application of gravitational curvature analysis to structural domaining of geology." We had Matt's posters on display throughout the evening, which encouraged easy discussion. This talk was recorded and will be made available on the ASEG YouTube channel in the coming weeks.



Matthew Zengerer discussing his poster at the SA-NT Branch May Technical Evening.

We have two National Geoscience Champions (as awarded by the Australian Geoscience Council in 2018) speaking in the next few months. Professor **David Groves** will speak on the evening of 20 June about "A holistic subduction/metasomatized lithosphere model for orogenic gold deposits", and Dr **Marita Bradshaw** on August 1 about "Australian petroleum exploration – a game for long term players."

As always, very happy to hear any feedback or suggestions at sa-ntpresident@aseg.org.au.

Hope to see you soon at an ASEG event soon.

Kate Robertson
sa-ntpresident@aseg.org.au

Tasmania

There was a flurry of Tasmanian geophysical activity in March. **Paul Winberry** from Central Washington University presented "How Much? How Fast? Seismology's role in understanding the future of Antarctica's ice sheets" to a joint meeting of ASEG and GSA Tasmania Branches on the evening of the 21st. The cryospheric stage for Paul's talk was serendipitously set less than a week earlier by Macquarie University's **Kate Selway** and **JP O'Donnell**, who generously took time out of their Tasmanian holiday to give a joint UTas Physics/Earth Sciences seminar on "Adventures in (polar) magnetotellurics and seismic studies of the Antarctic Peninsula."

ASEG/SEG Pacific South Honorary Lecturer **Boris Gurevich** of Curtin University and CSIRO brought his presentation "Seismic attenuation, dispersion, and anisotropy in porous rocks: Mechanisms and models" to Hobart on 27 March. Twenty five members of a strongly interdisciplinary audience gained insights into fundamental interactions of seismic wave propagation and fluid flow.

Boris Gurevich presenting to the ASEG Tasmanian Branch. Photo taken by Matt Cracknell.

An invitation to attend Tasmanian Branch meetings is extended to all ASEG Members and interested parties. Meetings are usually held in the CODES Conference Room, University of Tasmania, Hobart. Meeting notices, details about venues and relevant contact details can be found on the Tasmanian Branch page on the ASEG website. As always, we encourage Members to also keep an eye on the seminar programme at the University of Tasmania / CODES, which routinely includes presentations of a geophysical and computational nature as well as on a broad range of earth sciences topics.

Mark Duffett
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Victoria

Autumn is generally a fabulous time to be in Melbourne. Events such as the family-friendly Moomba Festival, the extravagant Australian Grand Prix, the magic Melbourne International Comedy Festival and of course, last but not least, the sensational phenomenon of a technical meeting event of the Victorian Branch of the ASEG; all of which are testament to Melbourne's temperament during the autumnal months.

It was a noticeably frenzied period for the Victorian Branch as we showcased three rather contrasting and sometimes contentious (maybe even scandalous!), thought-provoking addresses to our Members. First cab off the rank was Professor **Boris Gurevich**, the SEG Pacific South Honorary Lecturer for 2019, making a tour stop in Melbourne on March 21 to greet a small gathering of zealous Members at the Kelvin Club. The Professor's presentation, generously entitled "Seismic attenuation, dispersion and anisotropy in porous rocks: Mechanisms and models", overwhelmed the reasonably behaved crowd with fluid mechanics and mathematics that was acutely foreign to those who were seen scratching their head after nodding in acknowledgment of having understood said concepts. Members certainly appreciated the ideas and some even got a giggle out of the term "squirt-flow", lol.

For our April Technical Meeting, we greeted **Don Furseth**, CEO of CRM GeoTomography Technologies. The meeting was the brainchild of **Joe Cucuzza** of AMIRA International, who broached the idea of having the VIC ASEG Branch jointly host a technical session.

We certainly jumped at the opportunity for a bilateral gathering and salivated at the prospect of blooding new Members to our great Society! Of course, our euphoria barely lasted an hour before we discovered the topic for the proposed joint technical meeting was intimately related to … wait for it … particle physics! Thanks for dragging us in, Joe. We totally see now why the AusIMM didn't return your calls – only kidding! Don's subject "Muon geotomography" was certainly a topic from very, very far left field with the make-up of attendees that day included one astrophysicist! Yes, an astrophysicist! The application of this relatively new, recently certified geophysical technique for density mapping and imaging, especially within the mining industry, is simply astonishing. Who would have thought that measuring an elementary sub-atomic particle from the omnipresent background cosmic radiation could help us one day detect ore bodies, hmmm?!?!? Mind. Blown.

To round out our autumn technical series, we welcomed **Mark Gujic** of Solve GeoSolutions. Members attending the meeting had been told that they would have a unique opportunity to participate in an Old Muscat wine tasting experience (more on this a little later). Mark's address, entitled "Geophysics and neutral networks: learning from computer vision" drew quite a ruckus from the audience during his presentation, with some Members questioning the legitimacy of the information and relationships that were extracted from his neural network and machine learning solutions. Recognising or even defining relationships in image data can be extremely complex, but Solve GeoSolutions have enough bravado and smarts to help unscramble data-related problems, and to support visualisation of new unseen trends with an entirely different outlook. We were certainly impressed with its potential to swiftly crack an everyday problem we all seem to have – too much data and not enough time to make sense of it. Well done, Mark! We look forward to seeing more collaborations that could benefit our industry.

Now, back to our promise of a free Old Muscat wine tasting event. It certainly drew a record number of Members to our Technical Meeting. Unfortunately, representatives from the chosen winery made a last-minute cancellation due to unforeseen circumstances, much to the disappointment of our Members in attendance that night. We apologise for the inconvenience but hope to conduct the wine tasting event in tandem with our next guest speaker, the ASEG President-elect himself, **Ted Tyne** on May 21 at the Kelvin Club. We'll report to the wider ASEG community on that event in the next issue of *Preview*.

An invitation to attend Victorian Branch meetings is extended to interstate and international visitors who happen to be in Melbourne at the time. Meetings are generally held on the third Thursday of each month from 5:30 pm in the Kelvin Club, 18–30 Melbourne Place, Melbourne. Meeting notices, addresses and relevant contact details can be found on the Victorian Branch page of the ASEG website.

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Thong Huynh
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Western Australia

The month of April was a busy one for the WA Branch with four technical events held for Members. The April 10 Tech Night featured an interesting presentation by Professor **Wayne Pennington** from Michigan Technological University on "Our evolving view of time lapse seismic monitoring: 20 years of the same old Teal South data". Wayne highlighted the various datasets and 4D seismic over the Teal field in the Gulf of Mexico, and outlined the migration of gas and fluid within the area overtime.

The Branch also hosted a very well attended lunch event in April for ASEG, AusIMM, and AIG Members with a presentation on "Muon geoTomography for Exploration" by **Don Furseth** of CRM GeoTomography Technologies. A second Tech Night was held on April 15 and featured a presentation by SEG Distinguished Lecturer, **Felix Herrmann** on "Sometimes it pays to be cheap – compressive time lapse seismic data acquisition" at the CSIRO / ARRC building.

The first young professionals event in 2019 was held on April 16 at Mayfair

Wayne Pennington presenting to the WA Branch Tech Night held at the Celtic Club, West Perth.

Don Furseth presenting to the joint ASEG, AusIMM, and AIG event at the Celtic Club, West Perth.

Darren Hunt presenting to the WA Branch at the Celtic Club, West Perth.

Lane and featured two presentations by **Claudia Valenti** (Carnarvon Petroleum) on "Exploring the Triassic oil potential on the North West Shelf, Australia" and **Alex Costall** (UWA) on "Groundwater throughflow and seawater intrusion in high quality coastal aquifers". The May Tech Night saw **Darren Hunt** from Teck present on the "Teena Zn prospect – new insights for geophysical discovery of shale-hosted zinc deposits". Darren's presentation comprised an excellent summary of the geophysical data acquired over Teena and how it integrated with other geological information. An added bonus for ASEG Members was the presence of rock samples to view afterwards!

Upcoming WA events include:

June 12 Tech Night – Dr **Tim Dean** – "Recent advances in land seismic acquisition technology"

July 10 Tech Night – **Andrew Long** – "The growth of automation in marine seismic acquisition and processing"

The Tech Night schedule is subject to change due to speaker availability. Please check the website for up-to date information.

The WA Branch look forward to seeing all our Members at upcoming events and the AEGC in September at Crown Burswood.

Heather Tompkins
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Australian Capital Territory

In early April the ACT Branch hosted the ASEG Federal Executive AGM at Geoscience Australia. This was accompanied by a strategy meeting the following day where the Fedex discussed a range of issues that the Society needs to address over the next twelve months.

At the AGM we were treated to a thought-provoking talk by GA's Chief Scientist, **Steve Hill**. In the talk, titled "Welcome to planet, continent and country and why geoscientists like you hold a key to that greeting", Steve discussed the increasing detachment of society from the country in which we live and the general lack of recognition that we live on an active planet. Steve shared some personal examples from his career and his journey towards a better understanding and reading of landscapes and planet Earth, as well as challenges for the future; a reminder of the role and mission that we have as geoscientists to contribute to our society and the future of our life on Earth.

We are currently planning the presentation calendar for the remainder of the year. Later this month we will have a talk from GA's **Alex Ip,** on the subject of "Open, efficient geophysical data encodings – how to have your data cake and eat it, too", which will outline current advances in the use of modern scientific container formats for efficiently encoding, storing, and accessing point, line and n-dimensionally-gridded geophysical data.

Finally, an initiative to reinstate a Branch undergraduate geophysics award at the ANU is under way. It is encouraging that the university is offering a geophysics course after a lapse of several years and it is hoped that the addition of this prize, which will sit alongside the existing broader student award, will raise awareness of the Society amongst the student body and encourage more membership participation.

Grant Butler
actpresident@aseg.org.au

ASEG national calendar

Date	Branch	Event	Presenter	Time	Venue
12 Jun	WA	Tech Night	Tim Dean	TBA	Celtic Club, West Perth
19 Jun	NSW	Tech Night	John Triantafilis	17:30	99 on York Club, 99 York Street, Sydney
20 Jun	SA-NT	Tech Night	David Groves	TBA	TBA
27 Jun	WA	IMP	Mentors only panel session		TBA
10 Jul	WA	Tech Night	Andrew Long	TBA	TBA
24 Jul	WA	IMP	Mid-term session	TBA	TBA
27 Jul	NSW	Annual Dinner	TBA	TBA	TBA
1 Aug	SA-NT	Tech Night	Marita Bradshaw	TBA	TBA
20 Aug	QLD	SEG DISC	Manika Prasad	09:00	XXXX Brewery (Alehouse), Black Street, Milton, Brisbane
22 Aug	VIC	SEG DISC	Manika Prasad	09:00	Kelvin Club, Melbourne
27 Aug	SA-NT	SEG DISC	Manika Prasad	09:00	Hotel Richmond, 128 Rundle Mall, Adelaide
29 Aug	ACT	SEG DISC	Manika Prasad	09:00	Geoscience Australia, Symonston, Canberra
6 Sep	WA	SEG DISC	Manika Prasad	09:00	TBA
23 Oct	WA	IMP	Close out event and wrap up	TBA	TBA

TBA, to be advised (please contact your state Branch Secretary for more information).

Exploration trends and developments 2019

The 2019 edition of ETD (Mineral Exploration Trends and Developments) tracks the recent developments in exploration technology around the world.

ETD has been published since 1965, and in that time has been under the stewardship of only two editors; Dr Peter Hood and Dr Pat Killeen. Peter Hood started the ETD (initially just called Trends and Developments) and continued until 1992 when Pat Killeen took over. Until 2016 KEGS (the Canadian Exploration Geophysical Society) was the primary patron for ETD, but gradually more commercial support was found for the publication. Since 2016 DMEC (Decennial Minerals Exploration Conferences) has taken over as the major patron of the ETD and with it, the responsibility for raising the funds needed to cover the publication costs. The current supporters of ETD are now listed on a special page in the publication, and their support is gratefully acknowledged; this year there were 37 sponsors over three levels of support. Any group working in exploration technology can publish in the ETD; including, but not restricted to, survey companies, manufacturers of equipment and software, and consulting groups. Those interested in submitting material can contact Pat via email (contact is provided at end of this article).

The 2019 edition of ETD can be found online at http://www.kegsonline.org/?dir=6&sub=23&typo=news and http://condorconsult.com/downloads/index.html

In summary, the business climate in 2018 (copy is acquired in the year prior to the publication) was seen as an improvement over 2017, but possibly Australia saw more of a rebound in minerals than North America. North American investors still appear to hold a "grudge" for perceived past profligate behaviour on the part of mining and exploration companies, but also have alternative investment opportunities with the widespread legalization of cannabis in both Canada and the USA. Also troubling is a recent peer-assessment of the performance of geophysical technologies (Schodde 2018); summarised in Figure 1.

Schodde's view is that geophysics is possibly not even "holding its own" since geophysics entered the scene in a major way in the early 1950s. Such trends are a concern as they can be interpreted by exploration managers as meaning geophysics has lost its "edge". Quite arguably, however, the service industry and academia have continued to support exploration with continual improvements in equipment and data processing. What would appear to affecting the overall impact of geophysics is inappropriate survey choices, and the lack of proper assessment of the survey data. These aspects of the business are most typically end-user decisions. This means that the service industry must work even harder to communicate to our customers and clients that, if geophysics is to have the impact that we believe it can in exploration, success requires more than picking a contractor and then hoping it all turns out well.

Killeen noted the following as his headliner for the 2019 report:

"Airborne survey contractors reported conducting large surveys worldwide on numerous government projects. The UAV (drone) market seems to be taking off as the number of flight tests of new lighter, smaller versions of geophysical technology increased, including magnetic, radiometric, EM and even gravity. Airborne survey systems were updated to fully digital, and some new techniques and new versions of earlier AEM systems appeared.

Several airborne survey contractors outfitted new aircraft, some with increased capabilities (e.g. twin-turbine engines), and several completely new

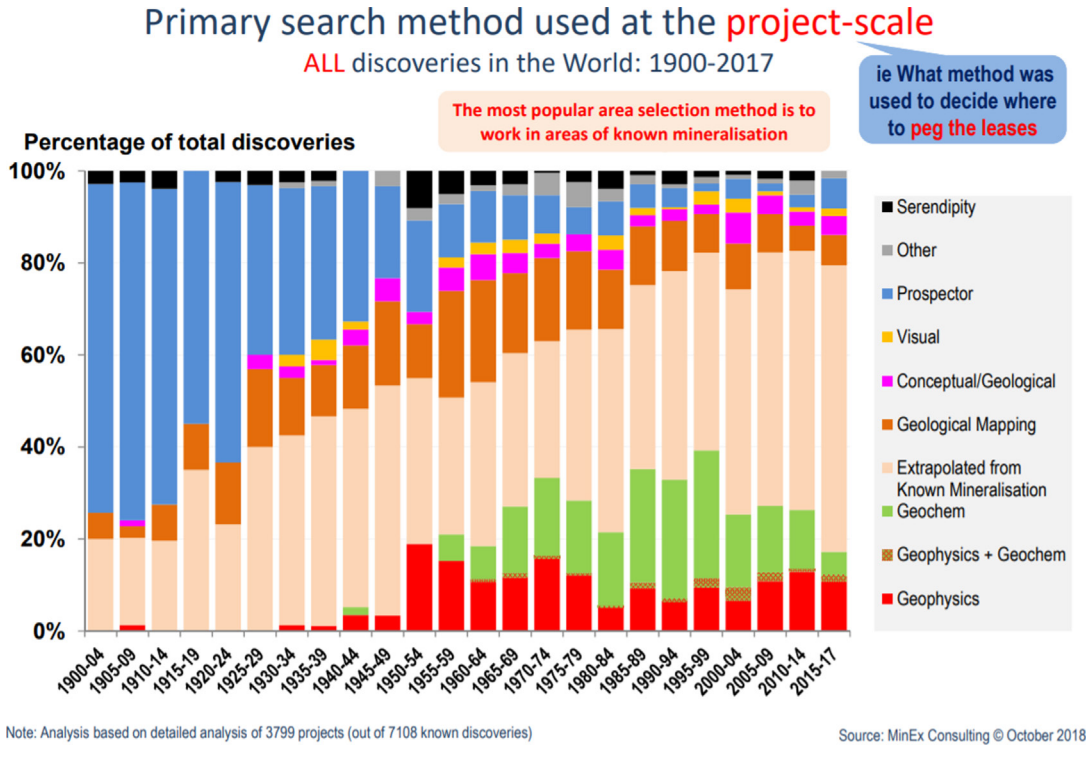

Figure 1. *Outcomes of methods used at project-scale exploration; 1900–2018. Source Schodde (2018).*

aircraft were modified in Canada for multi-parameter surveys, had the equipment installed, tested and then delivered to clients overseas. Airborne IP (AIP) is becoming more commonly used but being relatively new, work is still ongoing to determine and fully use its capabilities as well as find any limitations. SQUID-based Full Tensor Magnetic Gradiometer technology, previously proprietary, was released into the commercial market.

On the data processing side there seems to be a shift towards "pay-as-you-go" which means, instead of purchasing software that may be used infrequently, clients pay only when they use it. Software is also becoming easier to use so it doesn't require a specialist to run. There have been many software improvements especially for viewing data in 3D. There is new software for processing tensor magnetic data to go along with the increasing number of tensor mag and gradiometer developments. The use of AI and neural networks is increasing, especially for AEM. There is also increased ability to merge disparate data sets. Borehole geophysics saw improved gravity logging, a new neutron tool, a spectral IP (SIP) tool and an optical tele-viewer with a UV light to identify minerals by their characteristic fluorescence.

Companies reported increased use of new ground geophysical technology introduced last year such as RIM, for imaging conductors between boreholes, as well as one company's first borehole electrical resistivity tomography (ERT) survey. A new IP technique uses a hybrid borehole-surface approach. Ground EM and electrical surveys saw new higher power Tx's and lower noise, higher sensitivity Rx's, that are ultra-wide band and can be used in wireless arrays. One company can combine up to 6 transmitters for maximum power and depth penetration. The use of 3D technology continued to expand from data acquisition methods to data processing. For example, 3DIP is now offered by numerous companies. In GPR, advances saw development of signal stacking methods that double the penetration depth and can record signals 100 times smaller than before."

Airborne developments

The greatest diversity and, arguably, the most money, gets spent on airborne surveys, and airborne EM is the primary focus for most companies. A summary of airborne EM systems from Killeen's *Capabilities of Airborne Geophysical Survey Contractors 2019* is listed in Table 1. Note, the primary supplier of a system is shown unless the system is no longer manufactured, and VLF systems are not included.

Table 1. Airborne EM systems.

System	Type (Time domain-TD Frequency domain-FD)	Company	Base
AGP EM	TD	Aerogeophysica Inc.	Russia
AirTEM	TD	Triumph Surveys	Canada
BIPTEM	TD	Thomson Aviation	Australia
EQUATOR	TD/FD	GeoTechnologies	Russia
E-THEM	TD	EON Geosciences Inc.	Canada
EXPLORERHEM	FD	Aerophysics	Mexico
GPRTEM2	TD	Geophysics GPR	Canada
Heli-SAM	FD	Discovery Inter. Geo.	Canada
HeliTEM	TD	CGG MultiPhysics	Canada
Hummingbird	FD	EON Geosciences Inc.	Canada
HyRez	TD	Terraquest	Canada
IMPULSE	FD	Geotech Ltd.	Canada
ITEM	TD	Precision GeoSurveys	Canada
MobileMT	FD	Expert Geophysics Ltd.	Canada
NOVATEM	TD	Novatem Inc.	Canada
Nu-TEM	TD	NUVIA Dynamics	Canada
ProspecTEM	TD	Prospectair Geosurveys	Canada
P-THEM	TD	Pico Envirotec	Canada
Resolve	FD	CGG MultiPhysics	Canada
SGFEM	FD	Sander Geophysics	Canada
SkyTEM	TD	SkyTEM	Denmark
Spectrem2000	TD	Spectrem Air	South Africa
Tempest	TD	CGG MultiPhysics	Canada
VTEM	TD	Geotech Ltd.	Canada
Xcite	TD	New Resolution Geophysics	South Africa
ZTEM	FD	Geotech Ltd.	Canada

Drone carrying radiometrics package.

News

The drone story continues to advance, with the main service providers being smaller companies who may have had a focus on ground magnetics to start with, or are simply caught up in the "romance" of carrying out aerial surveys and appreciate the low-cost-entry of drone systems. While it seems clear that drone systems will not be a "disruptive" technology that will put the main survey groups out of business, it is equally clear that profiting from a drone system could be challenging. Presumably a shake-out of this technology space will happen over the next two to three years, and will result in a few groups dominating various regional markets.

Developments in airborne gravity appear modest, with the landscape looking similar to what it did when last reviewed two years ago. Governments appear to be the major users of gravity, along with the oil sector.

SQUID magnetometer technology is emerging into the market after a long gestation period. Spectrem Air is offering this as a service, as is DIAS Airborne. The technology is termed HeliFTMG (Heli-Full-Tensor Magnetic Gradiometer). This development could draw more attention to the world of aeromagnetics, which has been fairly quiet for some time.

Finally, something new in the commercial space is a report by a group Visiongain entitled: *The Airborne Geophysical Services Market Forecast 2019–2029.* An attention grabber from this assessment is the line: "The airborne geophysical services market will see increasing revenues over the next decade and is forecasted to be $4.3bn in 2019 due to surging demand for natural resources". The report sells for £2,999.00. See https://www.visiongain.com/report/the-airborne-geophysical-services-market-forecast-2019-2029/

Ground developments

The major focus of ground services is likely to be the continued roll-out of 3D IP services and equipment. As shown in Table 2, there are five groups who advertise they provide 3D IP services using their own proprietary equipment, and two groups who offer the equipment for an independent service provider to contract 3D IP services. One group, Newmont, keeps their internal system for proprietary commercial work.

Processing of 3D IP data remains challenging but some papers are starting to appear that provide some guidance on how to tackle the often very large data sets (Devriese, Ellis, and Witherly 2019).

Table 2. 3D IP services and equipment on offer.

System	Mode-Service/Equipment	Company	Base
Orion	Service	Quantec Geoscience	Canada
DIAS	Service	DIAS	Canada
Volterra	Service	SJ Geophysics	Canada
3D E-SCAN	Service	Crone	Canada
MIMDAS	Service	GRS	Australia
NEWDAS	Service/proprietary	Newmont	USA
Elrec Pro-Rx/TIPIX or VIP-Tx	Equipment	IRIS Instruments	France
Allegro	Equipment	Instrument GDD	Canada

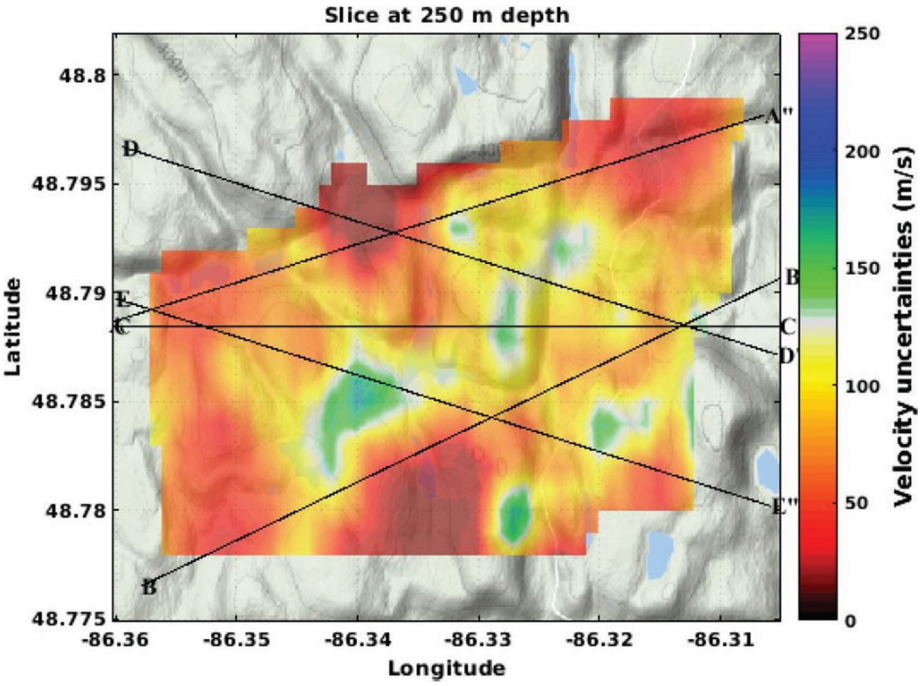

Figure 2. *Depth slice derived from passive seismic trial. Source SISPROBE (2018).*

One emerging technology that is starting to produce some interesting results is passive seismic. While not generally able to produce data of the same quality or depth as active source systems, passive seismic, because to its lower cost and small environmental footprint, could possibly fill a niche that is challenging for other methods. Figure 2 shows a depth slice from a passive seismic trial survey that was carried out at a Ni-PGE property in 2018 (SISPROBE 2018).

If you have a story you'd like included in the next ET&D, please contact Pat Killeen at pkilleen@xplornet.ca.

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Devriese, G. R. D., R. Ellis, and K. Witherly. 2019. Sensitivity-based data reduction of large 3D DC/IP surveys (accepted for presentation at AEGC 2019 Conference, Perth Australia, September 2019.

Schodde, R. 2018. Where, what, when and who?Highlighting key global exploration opportunities, trends and a perspective on the cycle of mineral exploration. International Mining and Resource Conference (IMARC) 31st October 2018. Melbourne http://minexconsulting.com/wp-content/uploads/2019/04/R-Schodde-IMARC-Presentation-31-Oct-2018.pdf Accessed 28 05 2019

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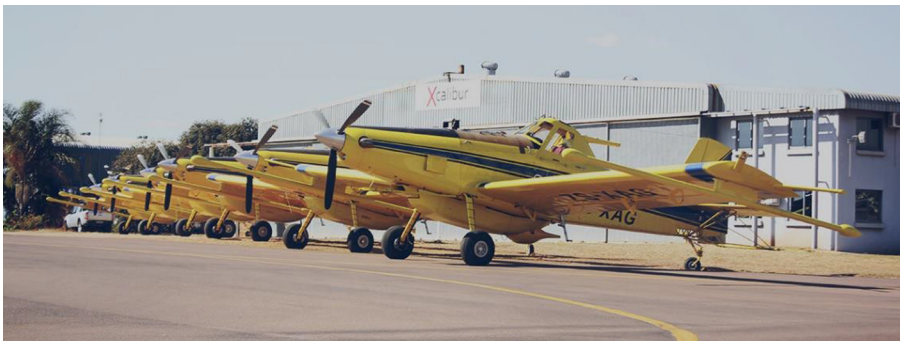
New nationwide airborne geophysical survey in Sierra Leone



The government of Sierra Leone has commissioned a high-resolution airborne geophysical survey of the entire country (71 740 km^2). Funded by the World Bank, and executed by the Ministry of Mines and Mineral Resources, the survey will collect more than 543 000 line km of magnetic and radiometric data at a flight line spacing of 150 m and a nominal terrain clearance (subject to safety constraints) of 50 m.

Five survey aircraft have been employed in data acquisition over a field season that will last approximately six months. The survey has been progressing well so far, with more than 50% (or nearly 273 000 line km) of field data being collected and independently approved within the first 90 days of survey operation.

The survey was officially launched on 29 January 2019 by HE Julius Maada Bio, the President of Sierra Leone, who stated that the lack of geological data has constrained effective policies required to boost the mineral resources sector, and added that a high quality national dataset will reposition the need for natural resources development.

The main objective of the nationwide survey is to obtain integrated geophysical data that will form the basis for a review of the country's geology and mineral resources and their distribution. The ultimate goal is to gain improved knowledge of the quantity and distribution of the country's mineral resources so as to ensure their sustainable exploitation in future.

Data acquisition is being carried out by South African/Spanish contractor Xcalibur Airborne Geophysics, which has operational experience in most African countries, the Middle East, Asia and Canada. Survey supervision, including data QC, is being provided by UK-based Reid Geophysics.

As explained by Sierra Leone's Director of Geological Survey, Prince Cuffey, the survey benefits from several interesting features. These include the use of aircraft specifically designed to fly low and slow for improved geological imaging, magnetic sensors mounted on each wingtip to improve geophysical data quality, and an externally-mounted head-up display for better and safer survey navigation. Each aircraft is additionally equipped with 40 l of radiometric crystal pack, mounted in a belly pod to provide maximum detection capability on this once-in-a-lifetime nationwide exploration initiative.

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Henderson byte: Georg Ohm

You know that ohm is the SI unit for electrical resistance but, do you know who Ohm was?

The person whose name is used for the unit of electrical resistance was Georg Simon Ohm (1789 - 1854), born into a family of seven children in Erlangen, Germany. Georg and his brother Martin, who also became a well-known mathematician, were initially taught by their father, who brought them to a high standard in mathematics, physics, chemistry and philosophy.

In September 1806 Ohm left home to accept a position as a mathematics teacher in a school near Bern, Switzerland. This was followed by other postings until, in April 1811, he became a lecturer in mathematics at the University of Erlangen where his previous private studies prepared him for his doctorate. He ended his somewhat turbulent academic career by becoming a professor of experimental physics at the University of Munich in 1852, just two years before his death.

Using equipment of his own creation, Ohm found that there is a direct proportionality between the potential difference (voltage) applied across a conductor and the resultant electric current. The constant of proportionality is the resistance of the circuit. This relationship is known as Ohm's law.

Ohm's most important publication was, in 1827, Die galvanische Kette, mathematisch bearbeitet (The galvanic circuit investigated mathematically) in which he outlined his complete theory of electricity. Ohm's law first appeared in this publication. His work was finally recognized by the Royal Society in 1841 with the award of the Copley Medal.

Ohm also gave his name to Ohmmeter, an instrument for measuring electrical resistance and ohmic, for electrical devices that obey Ohm's Law.

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AEGC2019 Data to Discovery

Australasian Exploration Geoscience Conference
2-5 September 2019 • Perth, Western Australia
Incorporating the AIG, ASEG, PESA, and WABS

The Leading Exploration Geoscience Conference in Asia-Pacific

Australasian Exploration Geoscience Conference 2019: Set to be sell-out!

The second Australasian Exploration Geoscience Conference (AEGC) will be held at the Crown Resort in Perth 2–5 September 2019. The AEGC is co-hosted by the Australian Institute of Geoscientists (AIG), the Australian Society of Exploration Geophysicists (ASEG) and the Petroleum Exploration Society of Australia (PESA). Over 1,000 delegates from around the world are expected to attend the AEGC, which will ensure it is the largest exploration geoscience conference in the southern hemisphere. Themes cover the full spectrum of Australian geosciences from the mineral, petroleum and water resource industries, government and academia. Given its location in Perth, there will be dedicated streams for Western Australian sedimentary basins, discovery techniques, mineral mapping and remote sensing applications.

Technical program

AEGC 2019 is already shaping up to be bigger and better than the inaugural event in Sydney last year. More than 360 papers have been submitted for consideration by the Technical Program Committee.

Helen Debenham, the AEGC 2019 Technical Program Committee Chair, said that the Committee was "delighted" with both the quality and quantity of speakers queueing up for this year's gathering. "At the moment, with more than 360 papers to be considered, the reviewers have some hard decisions to make". "The number of papers submitted is about double the number submitted for the first AEGC held in Sydney last year."

A total of 24 industry-respected keynote speakers will be scheduled in the technical programme. The list of keynote speakers includes: Clive Foss, Steve Garwin, David Groves, Ken McClay, Sandra Occhipenti, Neil Phillips, Manika Prasad and David Turvey. ASEG Members will be particularly interested in the appearance of Clive Foss and Manika Prasad.

Clive Foss

Clive Foss is a senior research geoscientist in CSIRO Mineral Resources, based in Sydney. Clive's specialisation is in potential field geophysics, particularly the inversion and interpretation of gravity and magnetic field data. Clive's PhD research at Leeds University was on the palaeomagnetism of Archaean rocks in southern Africa, following which he lectured in applied geophysics at the University of Malaya, and then took a position as senior geophysicist with the Indonesian-Australian Geological Mapping Program in Bandung, training Indonesian geophysicists and conducting gravity mapping in Kalimantan. In 1995 Clive moved to Sydney to join Encom Technology, where he led the ModelVision development team and undertook international consultancy projects for petroleum and mineral exploration. In 2009 Clive moved to his current position in CSIRO, where his research focusses on recovery of source magnetisation direction and source depth estimation from magnetic field data.

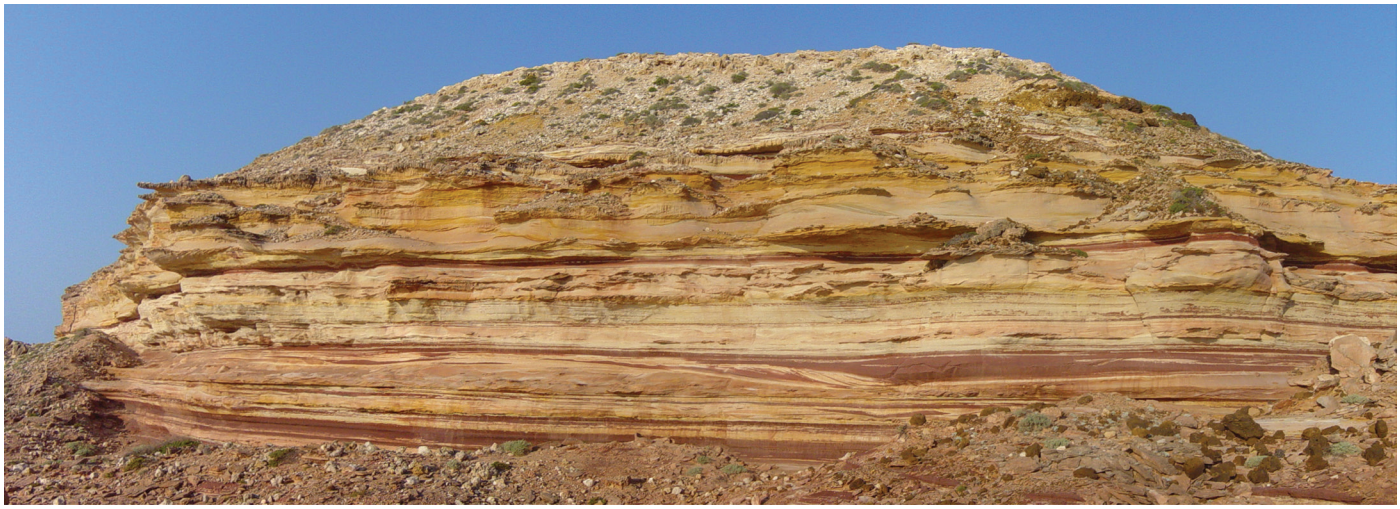
Manika Prasad has been at Colorado School of Mines (CSM) for the past 14 years, and was previously at Stanford University and University of Hawai'i. She received her BSc from Bombay University and MSc and PhD from Kiel University in Germany. Prasad's main interests lie in understanding microstructural controls on geophysical data. She is the recipient of the Virgil Kaufmman Gold Medal in 2017, Outstanding Educator Award (2015) and the AAPG-SEG Distinguished Lecturer Award (2012). Known as the mud queen among her peers and students, she pioneered integral research in source rich rock and fluid properties using tools and techniques from geoscience and engineering domains. In addition to teaching and research duties at CSM, Prasad serves as Associate Editor for *Geophysics* and is 2nd Vice President of SEG.

Manika Prasad

In addition to the packed technical programme, 30 workshops are planned in various conference rooms at Crown Resort or around Perth. These workshops will be held in the days before and after the actual conference https://2019.aegc.com.au/workshops/

Fieldtrips

Registrations are open for three field trips and, with only four months to go before the conference commences, early registration is advised to ensure accommodation for the field trips can be secured. This is particularly so for the two trips to the northern Perth Basin, because they are visiting areas that are popular with tourists during the wildflower season and, as a result, there is a shortage of local accommodation space.



Coastal exposure of Tumblagooda Sandstone.

Geology of the northern Perth Basin is a 5-day field trip that will examine the Permian – Lower Triassic core, including from the Waitsia field and wells used to evaluate shale-gas, and the equivalent outcrops at Irwin River. The excursion also takes in Cretaceous exposures on Murchison House Station that are well known from the offshore Carnarvon Basin, the Siluro-Ordovician in spectacular coastal cliffs and the Murchison gorge.

The purpose of the 3-day field excursion **Sequence Stratigraphy & Sedimentology of the highly prospective Early Permian oil and gas play in the northern Perth Basin** is to examine the beautifully exposed, regressive to transgressive, Early Permian sedimentary sequence along the Irwin River in the Coalseam Conservation Park. The excursion will focus on sedimentology and ichnofacies within a predictive sequence stratigraphic context and how these relate to depositional environment, lateral facies changes and changes in relative sea-level. Well logs, core and seismic examples will be used to compare the outcrop to the prospective play in the basin, providing attendees with the opportunity to better understand this actively explored depositional system.

Coal Seam Conservation Park - Shallow dipping outcrops to inspect.

The **Mines and Wines of southwestern WA** excursion will examine five mines and a gasfield, view high-grade Leeuwin Complex metamorphics in a spectacular coastal setting, and visit several wineries in the highly-renowned Margaret River wine region. Mineral deposits include those of gold, bauxite, lithium-tantalum, coal and titanium-zircon (heavy mineral sand) as well as the Whicher Range gasfield. Delegates will also be driven past a number of mineral downstream processing facilities.

Examining the rock dump for minerals, Greenbushes.

All three field trips will be run after the conference, commencing on the 6 September 2019. The field trip costs include all transportation, accommodation and meals. The conference committee is confident that the field trip participants won't be disappointed with the enlightenment and discussion of the geology provided by local expert geoscientists and the excellent outcrops that Western Australia has to offer.

Registrations are now open and you can find out more at https://2019.aegc.com.au/

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The 19th International Symposium on Deep Seismic Profiling of the Continents and their Margins

The 19th International Symposium on Deep Seismic Profiling of the Continents and their Margins (SEISMIX 2020) will take place from 15 – 20 March, 2020. This event will connect scientists with their equally knowledge-thirsty colleagues from industry. The focus of this meeting is on new methods, new science, new thinking, the latest technologies and blue-sky projects. We invite you to participate in SEISMIX 2020 and share your latest ideas, achievements and case histories with the International scientific community. The Symposium will be held in Fremantle (Freo) near Perth, Western Australia.

Symposium programme

The SEISMIX symposiums are unique in the way they bring together geoscientists from around the world in a quest to investigate the interior of the Earth using the latest technologies. It unites active and passive source-imaging communities, and those who study the Earth from the near surface to exploration, and down to the continental scale. As usual, there will be a single session for oral presentations (no parallel sessions) and ample time allocated for discussions and poster presentations. We anticipate a number of keynote presenters addressing different continents and their margins.

The conference topics will include but are not strictly limited to:

- Novel seismic imaging and inversion methods
- Mineral exploration seismics, integration with other geological and geophysical data
- Active and passive seismic interferometry
- Active and passive seismics: together or not?
- Active continental margins and subduction zones
- Mid-ocean ridges and oceanic lithosphere
- Global processes—collisions and accretion
- Comprehensive geological interpretation
- Near-surface seismology—case histories
- New developments and advances in DAS applications
- Moho in 3D
- Special topic: ET (extra-terrestrial) resource potential
- Unconventional case histories—lessons learnt
- Big data issues: machine learning and artificial intelligence

Map of the post-conference field trip including a visit to the super pit in Kalgoorlie; the turquoise beaches of Esperance nested between humongous granites; the world-famous Wave rock; the point of Oz departure from Antarctica; the beauty of Denmark (Greens pool, Elephant beach, Mad Fish bay); the Valley of the Giants; and, via Mandurah, back to Freo.

Post-conference field trip

The post-conference field trip will offer a unique experience of Western Australia. It will cover a large area of the south west of WA over seven days, stretching across nearly 2000 km. The aim of the field trip is to visit some of WA's geological wonders and experience the immense beauty of the Southern Ocean coastal plains. Some of the attractions include a visit to the Kalgoorlie Super-pit, Wave Rock, the ancient granites of Esperance (Recherche Granite, Migmatite, Esperance granites), the point of detachment of Antarctica in Albany, the Gap and Bridge, Denmark Granite terraces surrounding turquoise beaches, the geology of the Margaret River wine region, land breakups and scarps created by shallow earthquakes during the last two years, and many "on the way" attractions including the Valley of the Giants Tree Top Walk.

Important dates

- Early bird registrations and abstract submissions open: 02 09 19
- Abstract submissions close: 01 11 19
- Abstract acceptance: 25 11 19
- Early bird registrations close: 14 12 19
- Late registrations close: 03 01 20
- Symposium: 15 – 20 03 20
- Post-conference field trip: 21 – 28 03 20

Please visit the symposium web page (http://www.seismix2020.org.au) for more information.

See you in Freo!

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Update on geophysical survey progress from Geoscience Australia and the Geological Surveys of Western Australia, South Australia, Northern Territory, Queensland, New South Wales, Victoria and Tasmania (information current on 9 May 2019).

Further information on these surveys is available from Dr Yvette Poudjom Djomani at GA via email at Yvette.PoudjomDjomani@ga.gov.au or telephone on (02) 6249 9224.

Table 1. Airborne magnetic and radiometric surveys

Survey name	Client	Project management	Contractor	Start flying	Line km	Spacing AGL Dir	Area (km²)	End flying	Final data to GA	Locality diagram (*Preview*)	GADDS release
Tasmanian Tiers	MRT	GA	TBA	TBA	Up to an estimated 66 000	200 m 60 m N–S or E–W	11 000	TBA	TBA	TBA	The National Collaborative Framework Agreement between GA and MRT is being updated
Tallaringa N (1A)	GSSA	GA	Thomson Aviation	26 Oct 2017	97 922	200 m 60 m E–W	17 320	26 Mar 2018	TBA	190: Oct 2017 p. 26	TBA
Tallaringa S (1B)	GSSA	GA	Thomson Aviation	26 Sep 2017	145 367	200 m 60 m E–W	26 010	12 May 2018	TBA	190: Oct 2017 p. 26	TBA
Coober Pedy (8A)	GSSA	GA	Thomson Aviation	18 Sep 2017	90 425	200 m 60 m N–S	16 140	21 Dec 2017	TBA	190: Oct 2017 p. 26	TBA
Billa Kalina (8B)	GSSA	GA	MAGSPEC Airborne Surveys	10 Oct 2017	90 353	200 m 60 m N–S	16 140	18 Dec 2017	27 Jul 2018	190: Oct 2017 p. 26	TBA
Childara (9A)	GSSA	GA	MAGSPEC Airborne Surveys	5 Nov 2017	134 801	200 m 60 m N–S	23 910	2 May 2018	30 Nov 2018	190: Oct 2017 p. 26	TBA
Lake Eyre (10)	GSSA	GA	MAGSPEC Airborne Surveys	2 Oct 2017	91 938	200 m 60 m E–W	16 180	22 Mar 2018	9 Oct 2018	190: Oct 2017 p. 26	TBA
Streaky Bay (5)	GSSA	GA	GPX Airborne Surveys	21 Jun 2018	90 630	200 m 60 m E–W	15 966	28 Sep 2018	TBA	194: Jun 2018 p. 19	TBA
Gairdner (6A)	GSSA	GA	GPX Airborne Surveys	31 Jul 2018	105 075	200 m 60 m N–S	18 307	23 Jan 2019	TBA	194: Jun 2018 p. 19	TBA
Spencer (7)	GSSA	GA	MAGSPEC Airborne Surveys	11 Jun 2018	50 280	200 m 60 m E–W	8716	6 Aug 2018	8 Apr 2019	194: Jun 2018 p. 19	TBA
Kingoonya (9B)	GSSA	GA	MAGSPEC Airborne Surveys	5 Aug 2018	150 565	200 m 60 m N–S	26 651	Jun 2019	TBA	194: Jun 2018 p. 19	98% complete to 30 May 2019
Tanami	NTGS	GA	Thomson Aviation	14 Jul 2018	275 216	100/200 m 60 m N–S/E–W	48 267	2 Dec 2018	TBA	195: Aug 2018 p. 16	TBA

TBA, to be advised.

Table 2. Ground and airborne gravity surveys

Survey name	Client	Project management	Contractor	Start survey	Line km/ no. of stations	Line spacing/ station spacing	Area (km²)	End survey	Final data to GA	Locality diagram (*Preview*)	GADDS release
Kidson Sub-basin	GSWA	GA	CGG Aviation	14 Jul 2017	72 933	2500 m	155 000	3 May 2018	15 Oct 2018	The survey area covers the Anketell, Joanna Spring, Dummer, Paterson Range, Sahara, Percival, Helena, Rudall, Tabletop, Ural, Wilson, Runton, Morris and Ryan 1:250 k standard map sheet areas	TBA
Little Sandy Desert W and E Blocks	GSWA	GA	Sander Geophysics	W Block: 27 Apr 2018 E Block: 18 Jul 2018	52 090	2500 m	129 400	W Block: 3 Jun 2018 E Block: 2 Sep 2018	TBA	195: Aug 2018 p. 17	TBA
Kimberley Basin	GSWA	GA	Sander Geophysics	4 Jun 2018	61 960	2500 m	153 400	15 Jul 2018	TBA	195: Aug 2018 p. 17	TBA
Warburton-Great Victoria Desert	GSWA	GA	Sander Geophysics	Warb: 14 Jul 2018 GVD: 27 Jul 2018	62 500	2500 m	153 300	Warb: 31 Jul 2018 GVD: 3 Oct 2018	TBA	195: Aug 2018 p. 17	TBA
Pilbara	GSWA	GA	Sander Geophysics	23 Apr 2019	69 019	2500 m	170 041	TBA	TBA	The survey area is in the Pilbara region in the northwest of Western Australia.	TBA
SE Lachlan	GSNSW/ GSV	GA	ATLAS Geophysics	20 May 2019	3560	200/400 m	52 600	Jun 2019	Jul 2019	TBA	TBA

TBA, to be advised

Table 3. AEM surveys

Survey name	Client	Project management	Contractor	Start flying	Line km	Spacing AGL Dir	Area (km²)	End flying	Final data to GA	Locality diagram (*Preview*)	GADDS release
East Kimberley	GA	GA	SkyTEM Australia	26 May 2017	13 723	Variable	N/A	24 Aug 2017	Nov 2017	TBA	TBA
Surat-Galilee Basins QLD	GA	GA	SkyTEM Australia	2 Jul 2017	4627	Variable	Traverses	23 Jul 2017	Nov 2017	188: Jun 2017 p. 21	TBA
Stuart Corridor, NT	GA	GA	SkyTEM Australia	6 Jul 2017	9832	Variable	Traverses	12 Aug 2017	Nov 2017	188: Jun 2017 p. 22	TBA
AusAEM2, NT-WA	GA	GA	CGG Tempest	20 May 2019	71 646	20 km	1.5 million	Dec 2019	Mar 2020	TBA	TBA

TBA, to be advised

Table 4. Magnetotelluric (MT) surveys

Location	State	Survey name	Total number of MT stations deployed	Spacing	Technique	Comments
Northern Australia	Qld/NT	Exploring for the Future – AusLAMP	300 stations deployed in 2017–18	50 km	Long period MT	The survey covers the area between Tennant Creek and Mount Isa. The 2018 field season commenced in May 2018.
AusLAMP NSW	NSW	AusLAMP NSW	180 stations deployed to date	50 km	Long period MT	Covering the state of NSW with long period MT stations at approximately 50 km spacing.
Olympic Domain	SA	Olympic Domain	320 total	Varied 1.5 to 10 km	AMT and BBMT	The survey area extends west of Lake Torrens and covers mineral prospects such as Carrapateena, Fremantle Doctor, Red Lake, Punt Hill, Emmie Blu- and Mount Gunson. The data was released in Dec 2018.

TBA, to be advised

Table 5. Seismic reflection surveys

Location	State	Survey name	Line km	Geophone interval	VP/SP interval	Record length	Technique	Comments
South East Lachlan	Vic/NSW	SE Lachlan	Approx 630	10 m	40 m	20 s	2D – Deep crustal seismic reection	The survey covers the South East Lachlan Orogen crossing the Victorian–New South Wales border. The data acquisition phase of the survey commenced on 5 Mar 2018 near Benalla in Victoria. The survey completed data acquisition south of Eden in NSW on 29 Apr 2018. Data will be released late 2019.
Kidson	WA	Kidson Sub-basin	Approx 860	20 m	40 m	20 s	2D – Deep crustal seismic reection	Within the Kidson Sub-basin of the Canning Basin extending across the Paterson Orogen and onto the eastern margin of the Pilbara Craton. The data was released in May 2019.

Mineral Resources Tasmania: A Clayton's helicopter-supported gravity survey

Figure 1. *Looking south at gravity reading being taken beside the road (spot the high-vis jacket) following vehicle rendezvous (photo taken by Peter Harding).*

Earlier this year Mineral Resources Tasmania took advantage of an opportunity to share logistics with its regional geological mapping crews to acquire a little gravity data in one of the remotest parts of the State (Figures 1 and 2). A Lacoste & Romberg G-meter, differential GNSS receiver and operator were delivered to the top of a mountain in an area with no extant gravity coverage, by a helicopter that would otherwise have been empty *en route* to picking up a mapping team from their field camp. Gravity readings were then taken at 500 m spacing while proceeding back to the nearest road (Figure 3). Following rendezvous with a waiting vehicle (Figure 1), some further readings were taken at 1–2 km spacing while returning to a base established to the north, near Balfour. These were placed 500 m away from the road, previously traversed by a gravity crew in 2013, in order to better define the local gradient.

Though less than a dozen stations were acquired and the logistical challenges were significant, the exercise was considered worthwhile as the cost of helicopter access (without which any gravity infill in this region is impractical) was effectively zero. The data are being processed with full terrain correction and will be available along with the rest of the state-wide gravity database from Mineral Resources Tasmania http://www.mrt.tas.gov.au/portal/home

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Figure 2. *Location of new gravity acquisition in northwest Tasmania (green box).*

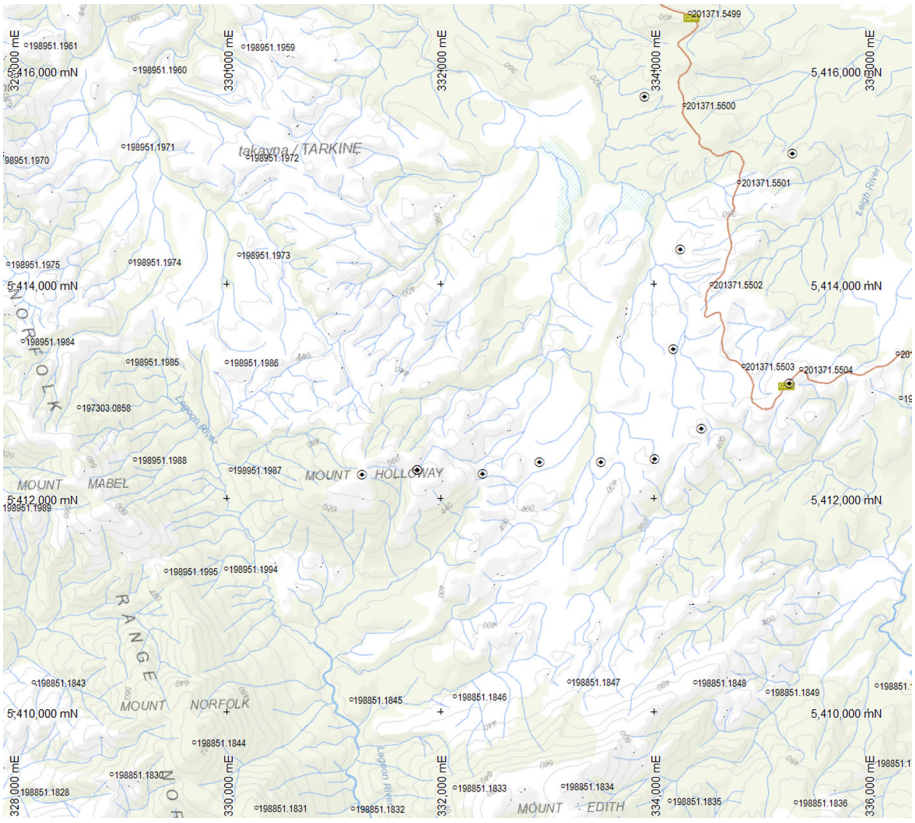

Figure 3. *New gravity stations indicated by larger part-filled circles, older ones by labelled small circles. See Figure 1 for location.*

Geological Survey of South Australia: An update on South Australia's gravity calibration ranges

An *absolute* gravity meter measures the acceleration due to gravity at one place. Typically, this value is approximately 9.8 ms^{-2} (equivalent to 980 000 mGals, or 9 800 000 μms^{-2}). A *relative* gravity meter measures a number in (say) mGals, but it is not an absolute value. For example, a Scintrex CG5 gravity meter measures values between 1000 and 9000 mGals, which need to be tied to an absolute measurement to recover the absolute values. However, the values also need scaling. A range of (say) 100 mGals as measured by an absolute gravity meter might be measured as a range of (say) 101 mGals by a relative gravity meter.

This can be seen by taking two measurements with a gravity meter, one at the bottom of a hill and one at the top of the hill, where the absolute gravity is known at each point. The difference in values should be the same but will typically be out by a very small amount. Even though it is a small amount, the effect of not applying a scale factor to gravity measurements is noticeable and can ultimately affect geological interpretation (Heath 2018). It is therefore important to calculate this scale factor prior to gravity surveys.

Two gravity calibration ranges exist in South Australia to calculate scale factors for relative gravity meters. One is in Adelaide, and the other a short distance southeast of Port Augusta.

The Adelaide Gravity Calibration range has recently suffered a minor setback. The Norton Summit Cemetery Australian Fundamental Gravity Network (AFGN) site (code 2012999208) has been destroyed. The site was near a sheltered park bench and served as the upper half of the Adelaide Gravity Calibration range. The blue plug has gone, and the bench and small shelter are in a new location a short distance away. The ground underneath them is not suitable for a new AFGN site.

Norton Summit Hotel AFGN site

However, the AFGN site at the Norton Summit Hotel (1960910208) is still available for use. It is very close to a couple of roads and so is not ideal for gravity readings, but will suffice until a new, quieter site is established. If any readers have suggestions for new AFGN sites in the Adelaide Hills – preferably a short distance from the established sites at Kensington Park – they would be very welcome.

The established sites at Kensington Oval (2001910108) and the Burnside Rugby Club (2015909408) are still in good condition, although you may have to weave between some parked motorcycles and/or scooters at the Kensington Oval site. Transit from the Burnside Rugby Club to Norton Summit is slightly quicker than from the Kensington Oval site.

Absolute gravity values at these three sites are:

Norton Summit Hotel absolute gravity: 9796300.22 μms^{-2} (AAGD07)

Kensington Oval absolute gravity: 9796985.05 μms^{-2} (AAGD07)

Burnside Rugby Club absolute gravity: 9796927.08 μms^{-2} (AAGD07)

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Reference

Heath, P. 2018. Quantifying the differences between gravity reduction techniques. *Exploration Geophysics* 49: 735–43. doi:10.1071/EG17094.

Geological Survey of South Australia: An overview of the Gawler Craton Airborne Survey – new data and products

The Gawler Craton Airborne Survey

The 1.66 million line km Gawler Craton Airborne Survey (GCAS) is now moving into its final stage, with 99% of its magnetic, radiometric and elevation data acquisition now complete (Figure 1). There has been a recent pause in acquisition due to shared access arrangements within the Woomera Prohibited Area (WPA), however that has not stopped the continued processing, quality control and data enhancements being applied to the currently acquired data, as the GCAS team endeavour to release one of the most comprehensive, high quality airborne surveys in South Australia's history. The survey has captured magnetics, radiometrics and elevation data at 200 m line spacing with a 60 m ground clearance, improving the resolution of existing grids based on existing 400 m line spaced data by a factor of 4.

Data QC

Contractors employed on the GCAS were required to adhere to comprehensive technical specifications set out by Geoscience Australia (GA). Geophysicists from GA and the Geological Survey of South Australia (GSSA) performed data QC and employed several new QC techniques for the GCAS. GSSA developed a method of communicating QC results between the contractors, GA and GSSA simultaneously through

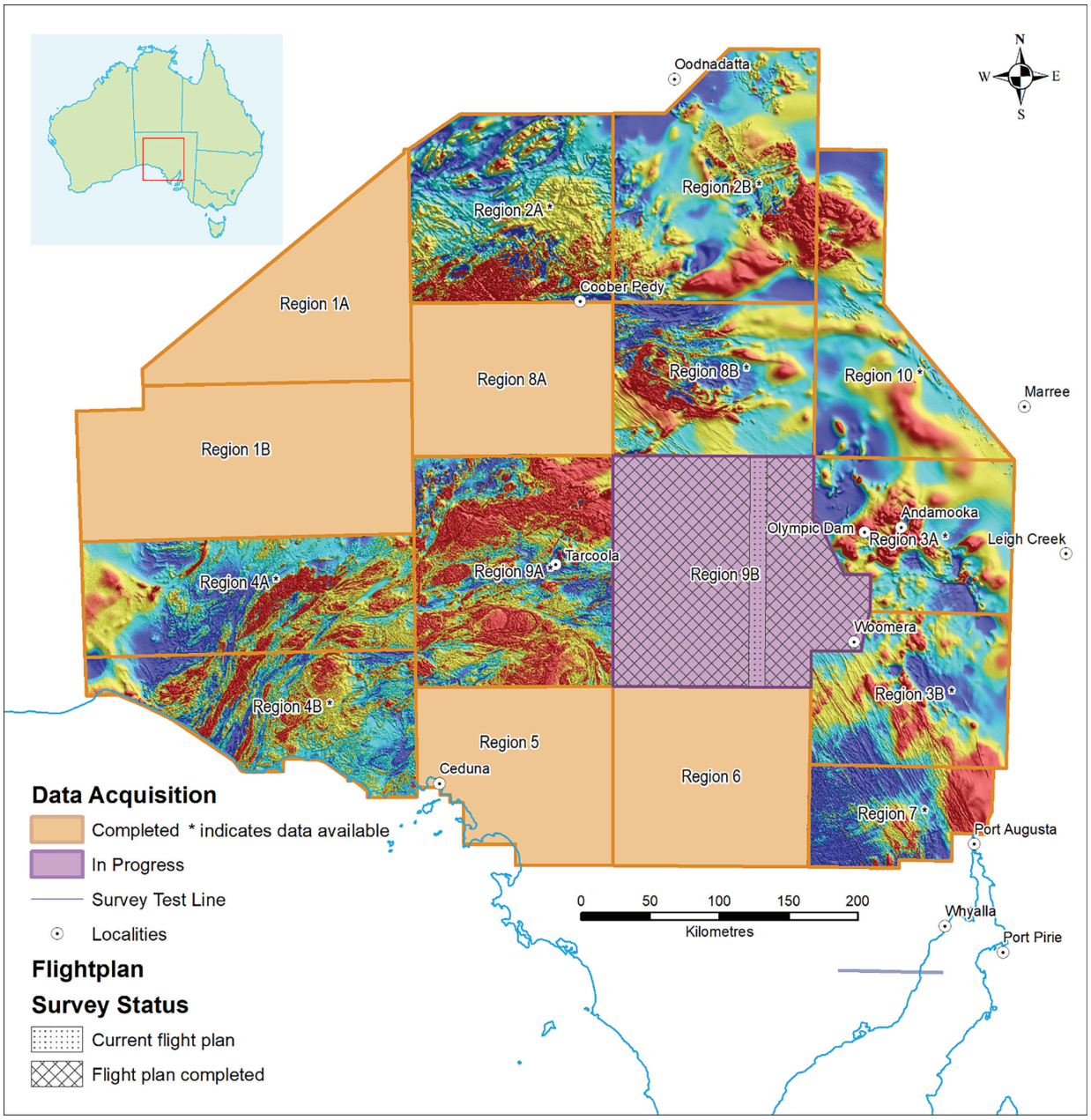

Figure 1. *The GCAS acquisition is 99% complete. Magnetic images on the map show areas for which data has been released.*

online spreadsheets. These spreadsheets contain all the QC communication, can be edited by all approved personnel and retain revision history.

The GCAS employed laser altimeters as part of the survey equipment for the first time in a South Australian regional dataset. Laser altimeter data needed to be assessed carefully, mainly because of the intensely directional nature of the laser when compared to conventional radar altimeters that have a cone shaped detection zone. Contractors were required to fly a set of pre-survey test lines near Whyalla in South Australia (The Whyalla Test Lines), which allowed direct comparison of each system employed by the contractors on the GCAS. The Whyalla Test Lines extended over Spencer Gulf, with the over water sections of the test lines used to check aircraft and cosmic gamma ray backgrounds. The final digital elevation models, magnetic field and equivalent ground concentrations calculated by the contractors under the Whyalla Test Lines were compared, allowing evaluation of system calibration and corrections.

Enhancements and analytic products

GSSA encouraged and facilitated uptake of the GCAS data in geological mapping and exploration programmes by releasing a suite of data enhancements and depth analysis products for each survey block. These enhancements were provided in consistent industry formats for each block, making the data much more easily accessible. A major focus of the enhancements was the integration of the new magnetic data with the state-wide gravity coverage. Integration of gravity and magnetics is crucial for geological interpretation, particularly over the Gawler Craton where the combined data sets are essential for IOGC studies. However, selection and processing of gravity data can be time-consuming.

We learnt two key lessons in this process. The first is that we should recover additional information from the gravity field in any area where there are closer spaced stations. Even in areas with a gravity station spacing of 400 m, it is clear that even closer spaced stations could reveal even more information. Secondly, we have found that combined gravity and magnetic vectors are more easily evaluated than side-by-side gravity and magnetic images, or a single complex image. We derived a suite of edge enhancement contours ("worms") from the gravity data, and selected the level carrying the most coherent information. We then derived a suite of magnetic worms, from which we selected the level with strongest correlation to the gravity worm. These two worms, colour coded, are then combined and can be overlain on any images. In some cases the two worms are coincident, in other cases individual worms may trace separate segments of a feature not continuous in either data set, or one worm may highlight cross-cutting structures evident as terminations of the other. An example area is shown in Figure 2. We are confident that this data product will prove useful for structural interpretation.

Those who have proprietary methods of data analysis can, of course, derive their own enhancements from the primary data. We supply our enhancements in a variety of formats suitable for import to ESRI ARCGIS, Geosoft, MapInfo/Discover, QGIS or Google Earth, and also supply PA sessions that can be viewed in PA or PA Viewer. There is also a brief report on derivation of the enhancement products and source depth solutions for each block.

Magnetic source solutions

Magnetic field data is collected at great cost and considerable care, but often source depth information is derived from that data using an automated "shot-gun" approach. Information about the depth to magnetisation is only available at select locations, and recovery of that information requires exact focus to derive the most reliable estimates. Unfortunately, this inverse problem is

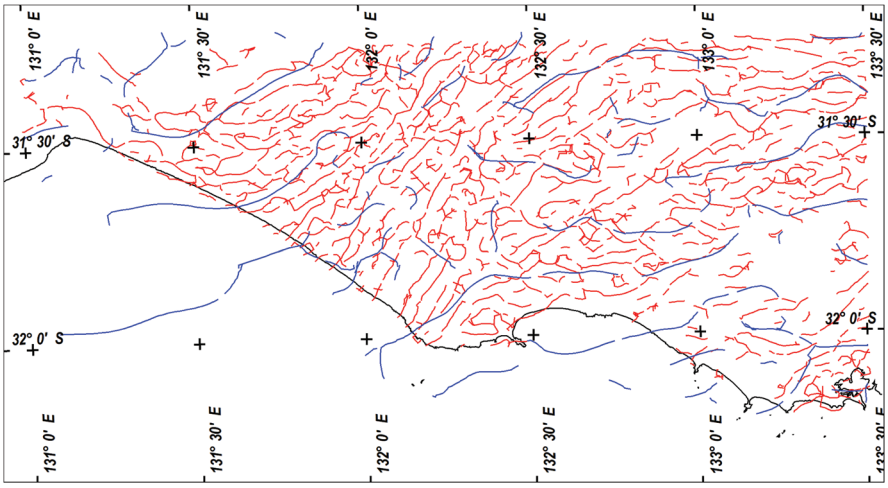

Figure 2. *Magnetic (red) and gravity (blue) worms for area 4B (Fowler). Most other areas have higher density of gravity coverage and show greater detail.*

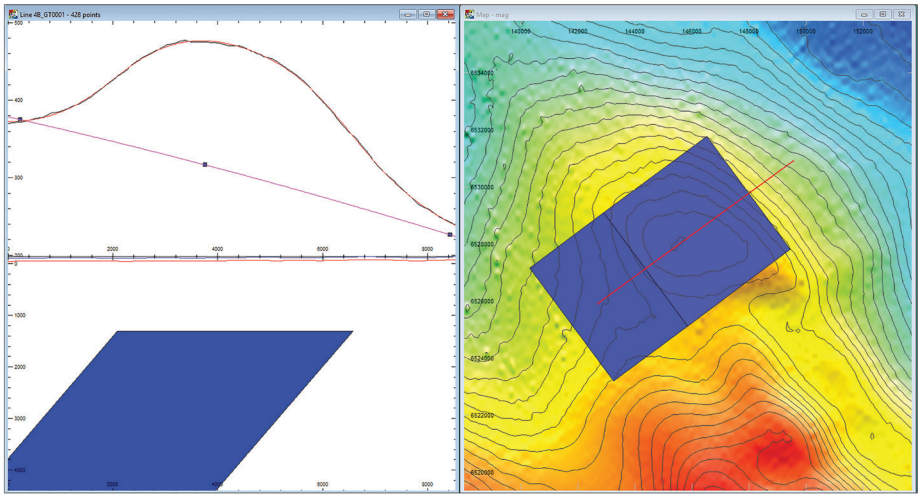

Figure 3. *Example "sweet-spot" magnetic depth section of a selected grid traverse. Left: purple = regional field, black = measured TMI, red = model computed, right: section over TMI image).*

inherently non-unique, which precludes assigning true uncertainty measures to solutions. The merits and limitations of any depth estimation method can therefore only be evaluated empirically. We have used the "sweet-spot" method where locations for depth estimates are hand-selected, and that optimal data is inverted in a computationally intensive process. The resulting solutions are not proven correct, but are qualified as having been conscientiously generated as suitable for inclusion in regional and national data sets. An example depth estimate is shown in Figure 3.

We provide the depth models in point format, as 3D models, in cross-section and map images, and in their individual ModelVision session files for any further development or testing. Where feasible we have also produced depth surfaces from an automated ("non-intelligent") gridding, in some cases incorporating borehole basement intersection depths. These surfaces are far more interpretive and speculative than the individual solutions from which they are derived, and issues in assigning depth solutions vary considerably from block to block as discussed in the reports.

Some of the GCAS blocks do provide a special opportunity for application of an automated magnetic source depth estimator due to the peculiar suitability of the Gairdner Dolerite dykes to analysis using AutoMag, a Naudy-based depth estimator. The dykes are well represented as thin, homogeneous magnetic sheets of large depth and strike extent, and their analysis can be applied through a profile-based vertical derivative filter to increase sensitivity to their tops and reduce influences of other sources. Most importantly, the analysis of each anomaly is individually performed in a moving window and the resulting solutions can be converted to bodies for testing by forward modelling (and subsequent inversion if required). An example AutoMag analysis of a section of profile is shown in Figure 4 and a set of model solutions is shown in Figure 5. Each profile/dyke intersection provides an anomaly opportunity, and this automated procedure generates many more solutions than can be evaluated by a manual method.

Data, enhancements, source depth solutions and reports can be downloaded from the Gawler Craton Airborne Survey community information page: www.energymining.sa.gov.au/minerals/gcas

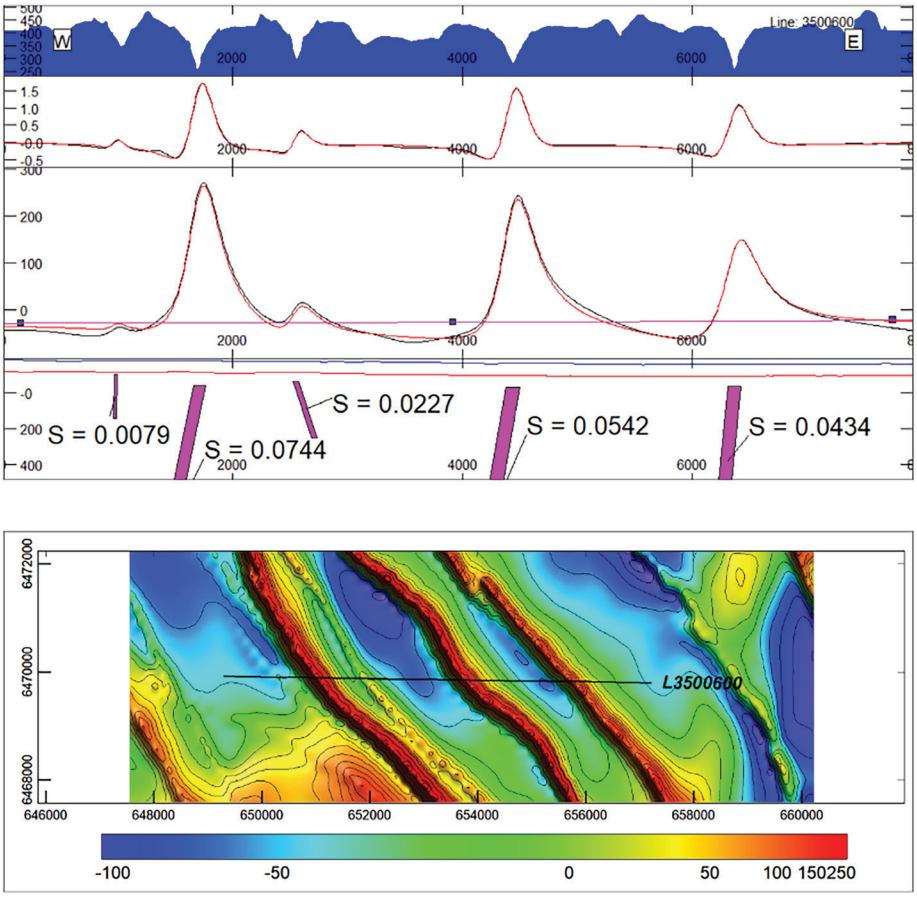

Figure 4. *Example AutoMag depth section. Top: similarity coefficient (inverted), middle: vertical derivative (black from measured, red from model computed), bottom: TMI (black from measured, red from model computed, purple = regional).*

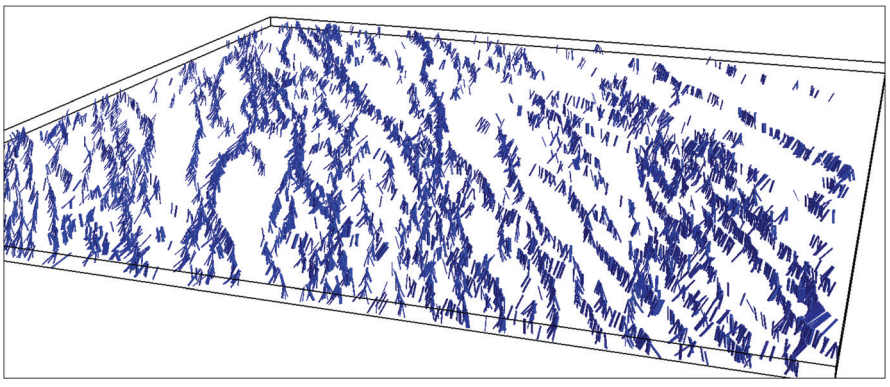

Figure 5. *Perspective view of depth models automatically generated from AutoMag depth solutions.*

with a "data available" link accessed by a mouse click in the selected map block. For blocks with data already released this opens further links to the data package and its report and, for those blocks with enhancements and depth solutions released, links to the appropriate digital package and report.

The Gawler Craton Airborne Survey is one of the most comprehensive, high quality airborne surveys in South Australia's history. The data that has been recovered will support the next generation of resource industry growth.

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Geological Survey of Western Australia: Seismic survey completed and airborne gravity survey commences

Acquisition completed on GSWA's Eastern Goldfields seismic survey

The acquisition phase of the Geological Survey of Western Australia's (GSWA) Eastern Goldfields seismic survey was completed on 6 April 2019, with data recorded for an aggregate 305 km on seven traverses along roads and tracks in the area between Broad Arrow and Kambalda (Figure 1).

Velseis Integrated Seismic Technologies began recording data on 13 March 2019, after the conclusion of a comprehensive planning and stakeholder liaison phase undertaken between July and December 2018.

A single AHV-IV 380 Renegade 80 000 lb peak force Vibroseis unit provided the seismic source at 20 m spaced vibration points, shooting into a ±6000 m spread of 10 m spaced receivers to provide nominal full-fold of 300. The target depth of interest was from 300 to 5000 m, although the 5 s "listen time" will provide data to greater (nominal) depths.

GSWA will release both raw and final data products as soon as practicable after processing and preliminary interpretation is complete, estimated to occur by September 2019. A list of the acquisition equipment and parameters, the proposed processing stream, and the expected data delivery products are available at www.dmp.wa.gov.au/geophysics.

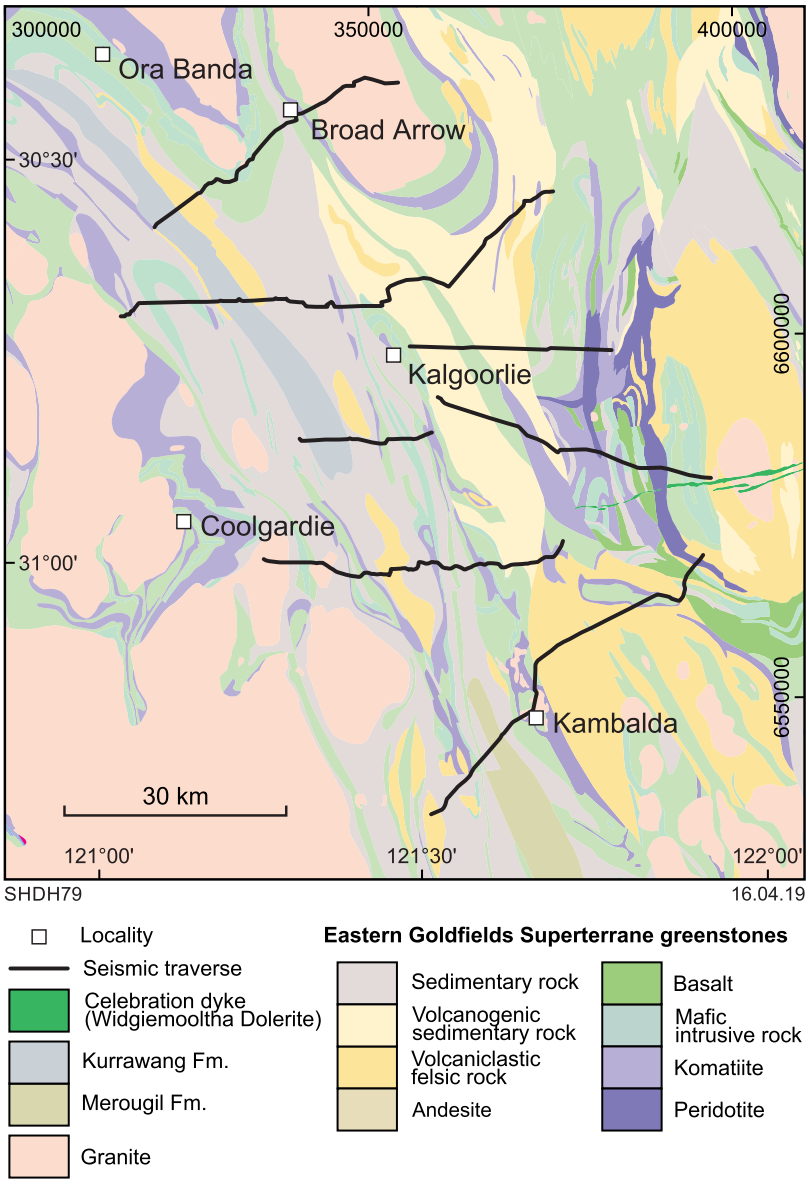

Figure 1. *GSWA Eastern Goldfields seismic survey. Location of traverses on regional geology. Projection GDA94–MGA51.*

These high-resolution 2D seismic data complement GSWA's 100 m line spacing Eastern Goldfields aeromagnetic and radiometric surveys flown in 2013, the regional ground gravity surveys, and the existing Geoscience Australia (GA) deep 2D seismic traverses. As well as delineating areas that might be suitable for more detailed 3D seismic exploration surveys, we expect that integration of these data with GSWA's field mapping, and data from recent passive seismic and magnetotelluric surveys, will provide a substantially improved understanding of the geological framework in this region.

Acquisition commences on the Pilbara airborne gravity survey

As the Velseis crew was demobilising from Kalgoorlie, Sander Geophysics' (SGL) airborne survey crews and aircraft began mobilising for a new airborne gravity survey over an area of 170 000 km^2 in the Pilbara region in northwest Western Australia (Figure 2). Data acquisition with the SGL AIRGrav system of a planned 69 000 line-km along 2.5 km spaced lines began on 23 April 2019; it is expected to be complete by the end of June. Survey progress updates are posted weekly at www.dmp.wa.gov.au/geophysics.

The Pilbara survey is the final piece of a long-running collaborative programme between GSWA and GA to bring to completion a new generation of regional gravity coverage of Western Australia, with up to 16 times higher resolution than the first generation coverage of the Australian continent by GA's predecessor, the Bureau of Mineral Resources, between 1959 and 1975.

After covering much of the southwestern half of the state with a series of ground surveys at 2.5 km station spacing, GSWA and GA began acquiring airborne gravity data in 2016 with a 38 000 line km survey in the East Kimberley, also flown

by SGL. More and larger surveys were flown in 2017 by Thomson Aviation/CMGO with a GT-2A gravimeter in the Tanami and northeast Canning Basin and by CGG Aviation with a Falcon gravity gradiometer over the Kidson Basin; and in 2018 by SGL over large tracts of the Kimberley Basin, and the Little Sandy and Great Victoria Desert areas.

All the airborne surveys were flown with 2.5 km line spacing with a nominal along-line full-wavelength resolution of 5 km or better. Consequently, the release of the Pilbara survey data later this year will see the northeastern half of Western Australia covered with airborne gravity data at an equivalent resolution to the ground surveys in the southwest.

All the new data will be compiled into an update of GSWA's gravity anomaly map of Western Australia.

Funding for both surveys was provided by the Western Australian Government's Exploration Incentive Scheme.

For more information, contact geophysics@dmirs.wa.gov.au or visit www.dmp.wa.gov.au/geophysics.

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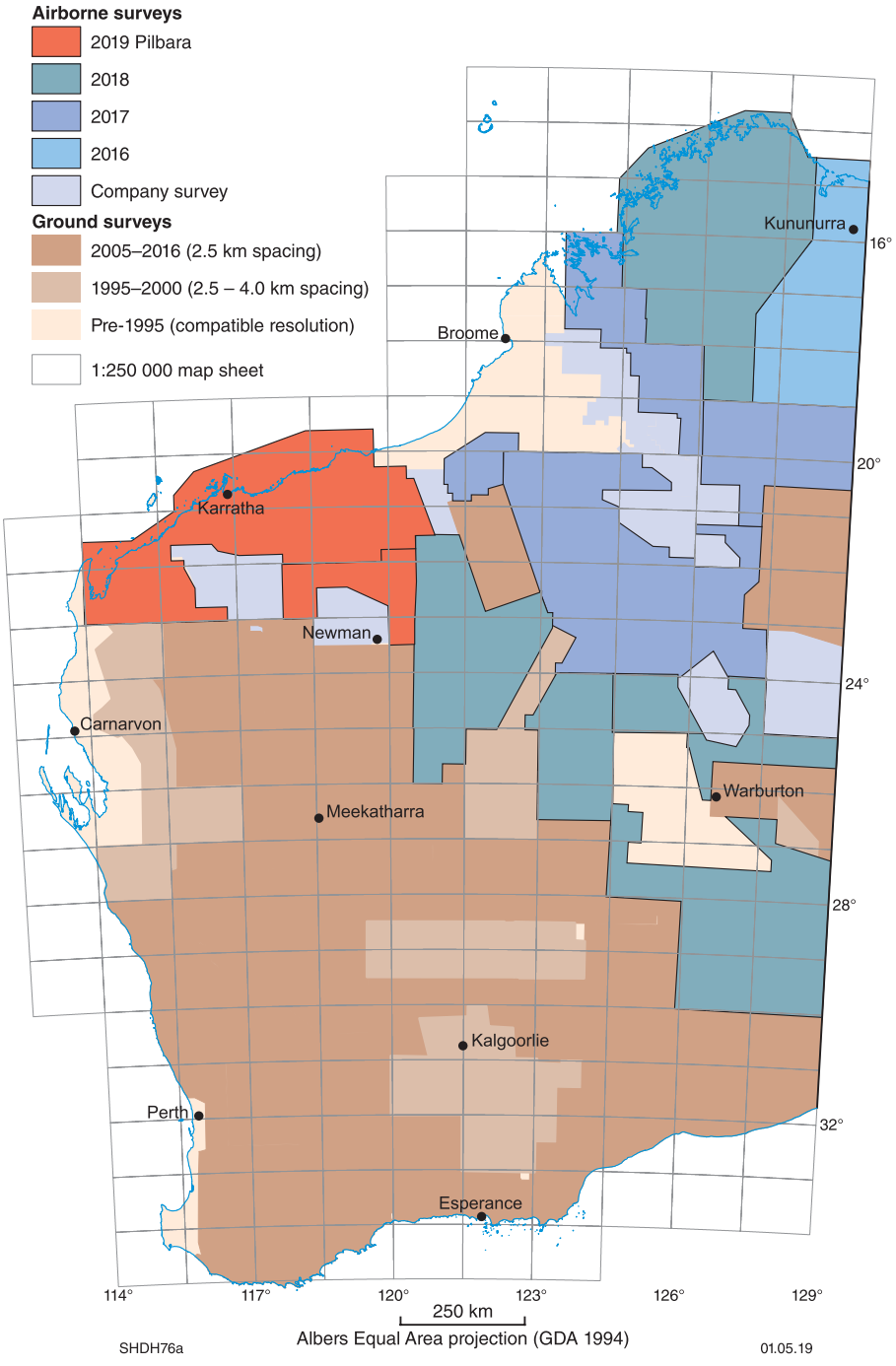

Figure 2. *Western Australia "second generation" gravity coverage.*

Canberra observed

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The election and the budget 2019

The election

By the time this issue of *Preview* is published, the results of the 2019 Federal Election will be known. This election must rank as one of the most boring elections ever. The campaign for votes has been on-going since the last sitting day of Parliament in 2018, with the electorate being bombarded non-stop by crass slogans and vague promises.

Instead of governing the country from the Parliament, all the energies have been focused on getting a seat or seats in the bubble. It's ironic that ScoMo decries what he calls the Canberra bubble and yet desperately wants to be at its centre. As a Canberran, I have on occasion had to point out that only four (soon to be five) of the 226 elected politicians come from Canberra. The vast majority come from elsewhere. If there is a bubble, it must include all states and territories.

The workload in the Parliament is noteworthy. From the start of December in 2018 until Parliament was prorogued on 11 April 2019, the Senate sat for only nine days and the House of Representatives eleven (https://www.aph.gov.au/News_and_Events/Events_Calendar), not very impressive!

Anyway, back to the Election. The campaigns mainly seemed to focus on "what's in it for me", particularly in the marginal seats where "pork barrelling" was rampant. If you want top-class infrastructure, then move to a marginal electorate.

Both the major parties were promising huge spending programmes and claiming that they were the best economic managers. However, when you examine what has been achieved on tackling debt, the record is not good for either of them. For example, the External Debt has increased enormously over the last few years (see Figure 1).

According to Trading Economics (https://tradingeconomics.com/australia/external-debt) the External Debt in Australia increased to a record A$2.1 trillion in the fourth quarter of 2018 from a record low of A$147 billion in the third quarter of 1988."

As the External Debit has increased the Gross Domestic Product has stagnated (see Figure 2).

According to Trading Economics (https://tradingeconomics.com/australia/gdp-constant-prices), the quarterly GDP in Australia increased to a record A$462 billion in the fourth quarter of 2018, marginally higher than the A$461 billion in the third quarter of 2018. Notice that the External Debt is now larger than the annual GDP. A$2.1 trillion v A$1.8 trillion. Not a pretty set of numbers.

Meanwhile, the Federal Government debt increased to a record 41.90% of the country's annual GDP in 2017, much higher than the low of 9.70 percent in 2007 (https://tradingeconomics.com/australia/government-debt-to-gdp). In dollar terms this amounts to about A$770 billion or $31 000 for every Australian. The 2018 numbers were not available at the time of writing, but the rate of increase in government debt appears to be decreasing.

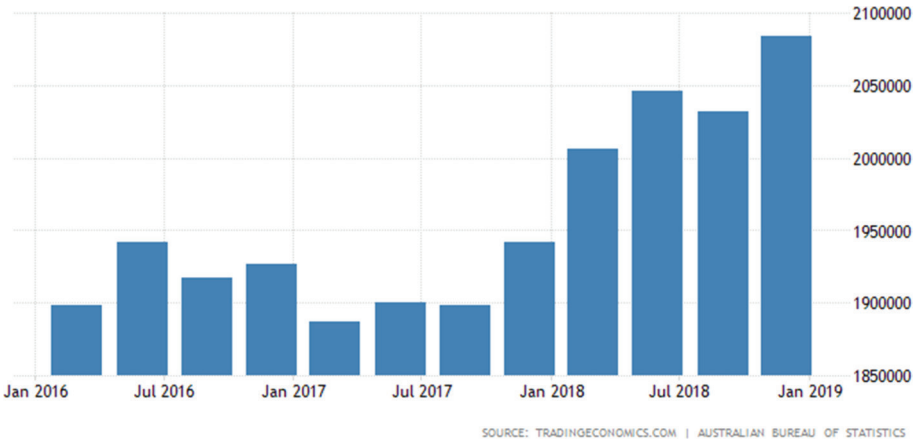

Figure 1. *Australia's External Debt from 2016 to 2019 in A$ million. The debt has steadily increased during the last two years.*

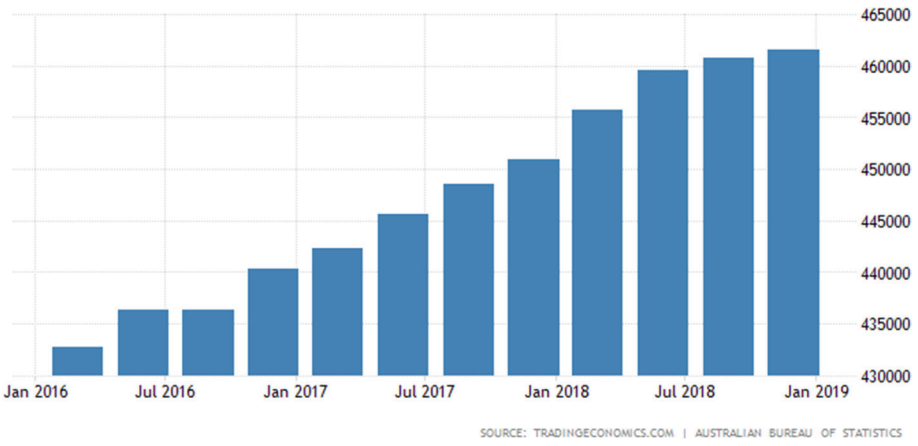

Figure 2. *Quarterly GDP for Australia in A$ million from January 2016 to January 2019.*

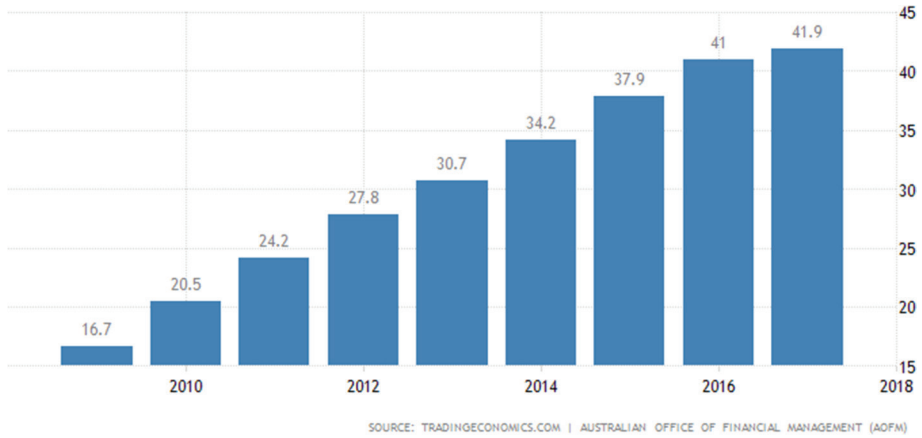

Figure 3. *Annual Government debt as a ratio of GDP from 2009 to 2017.*

Election promises

Both the major parties made a huge list of promises. I had a quick look at both the Liberal Party and the ALP's, particularly those relevant to the resource industries and Australia's research capabilities.

The Liberals

The Liberal Party election policies announced during the campaign were based on 15 plans on a range of issues, including "Strengthening Australia's World Class Health System", 'Lower taxes for Small Business" and "Delivering High Quality Skills and Vocational Education" (https://www.liberal.org.au/our-policies).

I could find nothing in this list about higher education or our national research capability and the only reference to the resource sector was:

"Support for new resource development in Queensland, having completed Commonwealth environment approvalsrequired to start the Adani Carmichael project, with conditions to ensure protection of the environment."

The Establishment of the National Water Grid: "a statutory authority responsible for national strategic planning and management of water policy and infrastructure" and the opening up of the Beetaloo Basin "for gas exploration and development, delivering more jobs for the NT and more reliable and affordable gas supply for Australia."

The Coalition also endorsed the 2030 Resource Task Force report discussed in the April *Preview*.

The Australian Labour party

In contrast to the Liberal's 25 plans, the ALP produced a massive 309 page tome "A Fair Go for Australia" (https://www.alp.org.au/media/1539/2018_alp_national_platform_constitution.pdf).

The detail in the document is very impressive, but in the context of an election it really should have identified the more important objectives. There are eleven chapters including:

1. A strong economy for all Australians, encompassing, Science and Research, Australia's Research institutions, Science for Australia's Future, Industry, and Science and Research Collaboration.
2. Building Australia's future; encompassing, Minerals & resources: to develop Australia's natural resources through a competitive minerals, resources and energy industry, backed by quality infrastructure links, which grow export-oriented jobs for our modern economy.
3. Tackling climate change, securing our energy future & addressing our environmental challenges.

All good stuff, but how do you sell it to the electorate?

The 2019 budget

The Treasurer, Josh Frydenberg, had both eyes on the Election when he gave his budget speech on 2 April 2019. References to resources and research were minimal and mostly referred to medical research. All I could find was:

"We're investing $9 billion this year in science, research and technology, including its commercialisation. And we established the $20 billion Medical Research Future Fund (MRFF), with dividends going to new clinical trials and research. There is also more than $400 million in this budget for genomics research to unlock the secrets of our DNA. And $160 million for research to improve the health of Indigenous Australians. We're establishing a Heart Kids Project for new research to treat and prevent heart disease which affects thousands of Australian children."

His words on the Environment were equally succinct:

"We all have an important responsibility to protect our environment and address climate change. This budget includes a $3.5 billion Climate Solutions Package — $2 billion of which will go to practical emission reduction activities, working with farmers and Indigenous communities."

He announced a $100 million Environment Restoration Fund to deliver large-scale environmental projects protecting the habitats of our threatened species, our coasts, our waterways and cleaning up waste. This would also support practical community action on waste recovery and recycling.

The Table 1 below shows how the main science focused agencies fared. The numbers are taken from Appropriation Bill No 1 (mainly operating funds) and the numbers in brackets are the 'average staffing levels', where these are provided.

Most agencies are operating on what was included in the forward estimates last year. Geoscience Australia, ANSTO and CSIRO receive small increases, but their allocations are then cut the following year.

Medical research continues to do well. ARC, which covers all disciplines, gets less than the NHMRC, which is just restricted to Medicine. And there is also the MRFF which was established by the Abbott Government for cancer research.

I still do not understand why the government continues to attack the ABS. If we are to successfully survive in this very competitive world, it is essential that we have available to us a platform of information covering a wide range to issues. Cutting back on basic statistical information makes no sense. Finally, when we learn that the rate of extinctions is increasing at a rapid why rate, one must question why the funding for our National Parks remains stagnant. The next government should do better.

Table 1. Science agency funding 2015–2022

Agency*	Government appropriation in $m & (*average staff numbers*)						
Financial year	**2015/16**	**2016/17**	**2017/18**	**2018/19**	**2019/20**	**2020/21**	**2021/22**
AIMS	40 (*208*)	42 (*221*)	42 (*223*)	47	44	45	46
ANSTO	181 (*1257*)	183 (*1277*)	198 (*1303*)	214 (*1275*)	235 (*1356*)	220	226
ARC	821 (*128*)	778 (*128*)	789 (*136*)	793 (*133*)	818 (*136*)	833	849
Bureau of Meteorology	315 (*1581*)	300 (*1602*)	250 (*1565*)	296	315	294	265
Antarctic Division	158	179 (*383*)	176 (*378*)	188 (*384*)	185 (*392*)	225	233
Geoscience Australia	121 (*584*)	193 (*590*)	208 (*600*)	238	232	226	228
CSIRO	750 (*5056*)	787 (*4995*)	794 (*5063*)	834	839	834	844
NHMRC	934 (*185*)	927 (*179*)	938 (*177*)	946	926	943	943
ABS	489 (*2871*)	622 (*2894*)	431 (*2486*)	401	413	187	192
CRCs	141	150	161	167	184	187	192
DSTG	464	438	435	436	447	455	432
National Parks	41	43	47	47	46	44	44

**AIMS (Australian Institute of Marine Science), ANSTO (Australian Nuclear Science and Technology Organisation), ARC (Australian research Council), NHMRC (National Health and Medical Research Council), ABS (Australian Bureau of Statistics), CRCs (Cooperative Research Centres), DSTG (Defence Science and Technology Group).*

Postscript

The 2019 Election Campaign may have been boring, but the results on polling day were anything but. All the main pre-poll forecasts were wrong, and the unexpected outcome was a surprise to most observers. Maybe a good result for anyone doing research on sampling techniques, but not very helpful for people using the current methods to predict results.

My take is that the Election came down to a Morrison v Shorten contest. Morrison said very little of policy substance, but delivered his words well. Shorten's words were usually good, but the way he delivered them was anything but persuasive.

As with many previous elections it came down to the perceived outcome for the voter's back pocket. The retirees in Queensland did not want anyone touching their franking credits and they killed any chance of a Labor victory – slam dunk, game over!

As John Hewson found in 1993, with his 650 page comprehensive economic *Fight Back* package, logical arguments and sound evidence do not win elections. It's all about whom you trust.

This is a pity, because if Australia is going to continue to prosper, we need rational debates about big issues such as the environment. It doesn't matter very much if the GDP rises, but we don't have enough water and we are still polluting the atmosphere. We need a sustainable healthy environment, but the leaders said very little about water resources and the Murray-Darling Basin, Climate Change, or pollution in the rivers, the oceans and in the air.

In the health sector there was talk of huge investments to treat diseases, but nothing much about preventing them. Maybe no votes in cutting back on sugar and alcohol?

Nothing about improving our higher education system, boosting research funding or (to get down to just one detail) about our woeful internet connections.

The latest Ookla Speedtest Global Index came out at the end of April and Australia is continuing to fall down the international table. It is now ranked 59th at 38 Mb/s, putting us far behind many other developed economies. For example, Russia's download speed is 52 Mb/s and, of course, Singapore and South Korea are at the top with 198 and 145 Mb/s respectively. We should be able to do better.

There is a lot of work to be done by the new government and hopefully ScoMo will be able to heal the rifts and deliver good policies that achieve national benefits.

Education matters

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Next generations of earth scientists IV: Mentoring and inspiring students and early career geophysicists

This month we have news of four programmes aimed at mentoring and inspiring ASEG-PESA Members as students, and then early in their careers.

Dave Pratt reminds us about past successes in the Frank Arnott Award, and brings news about the next 2020 competition. This is an international competition that challenges students to devise innovative ways to process and interpret potential-field data sets.

Daniel Thompson tells us about his personal experience of the Victorian PESA-ASEG mentoring programme and, in particular, about the short course led by Rob Kirk and sponsored by Karoon Energy and 3D Oil Limited.

We congratulate one of our Australian faculty members, Professor Boris Gurevich, on being selected by the International Society of Exploration Geophysicists to be an Honorary Lecturer for Australia and the Pacific, teaching on the theme "Seismic attenuation, dispersion and anisotropy in porous rocks". We include an overview of Boris' lectures in these pages, illustrating the huge advances from seismic interpretation to rock property analysis that have been achieved in past decades.

And, in breaking news, we are able to announce an SEG DISC course coming to Australia in August-September. The Distinguished Instructor is Professor Monika Prasad of the Colorado School of Mines. The opportunities in these lectures for inspiring our students and providing further education for our professional Members are outstanding.

The Frank Arnott Award – encouraging students

Through its "Innovation in data integration and visualisation" competition, the Frank Arnott Award is focused on motivating the next generation of young geoscientists to become leaders in mineral exploration. Following the success of the first competition, the Award committee wants to encourage our societies, universities, industry and geoscience students to participate in this ongoing programme.

The Frank Arnott Award was established to honour Frank Arnott (1951 – 2009), an exceptional exploration leader who championed innovative techniques through multi-disciplinary dataset integration and visualisation across a range of global exploration programmes. The Award focuses on innovation with modern world class datasets, teamwork and collaboration across disciplines.

The Award objectives fit well with the ASEG's aims as set down almost 50 years ago to;

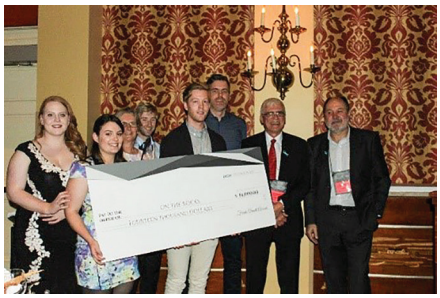
- to promote the science of geophysics, and specifically exploration geophysics, throughout Australia,
- to foster fellowship and co-operation between geophysicists,
- to encourage closer understanding and co-operation with other earth scientists,
- to assist in design and teaching of courses in geophysics and to sponsor student sections where appropriate.

Undergraduate and post-graduate research students are entitled to participate in the Award and they are encouraged to form their collaborative teams early in the Award cycle.

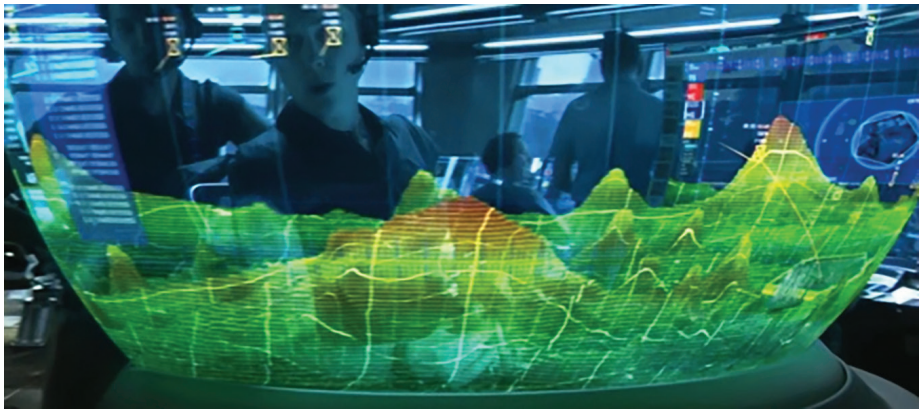
We see an opportunity for universities to integrate the Award processes into their undergraduate and post-graduate programmes, and to take advantage of support from our societies, industry and industry mentors. Participation in the Award provides access to modern and diverse geoscience datasets suited to collaborative exploration projects. The submission dates and preparation process are designed to slot into the long December-February session breaks to ensure that the participants have sufficient time available outside normal university programmes.

Past successes for Australian students – the 2017 Award competition

Team "On the Rocks" from the University of Adelaide were the winners of the 2017 Apprentice Category. The award ceremony took place at Exploration '17 during the Gala Dinner. The team's project on "Innovation in 3D projections and presentation of geoscientific data" was an excellent example of collaboration across many disciplines.



The University of Adelaide Team "On the Rocks" accepting their Award cheque from the Award Committee members, Tim Dobush and Theo Aravanis.



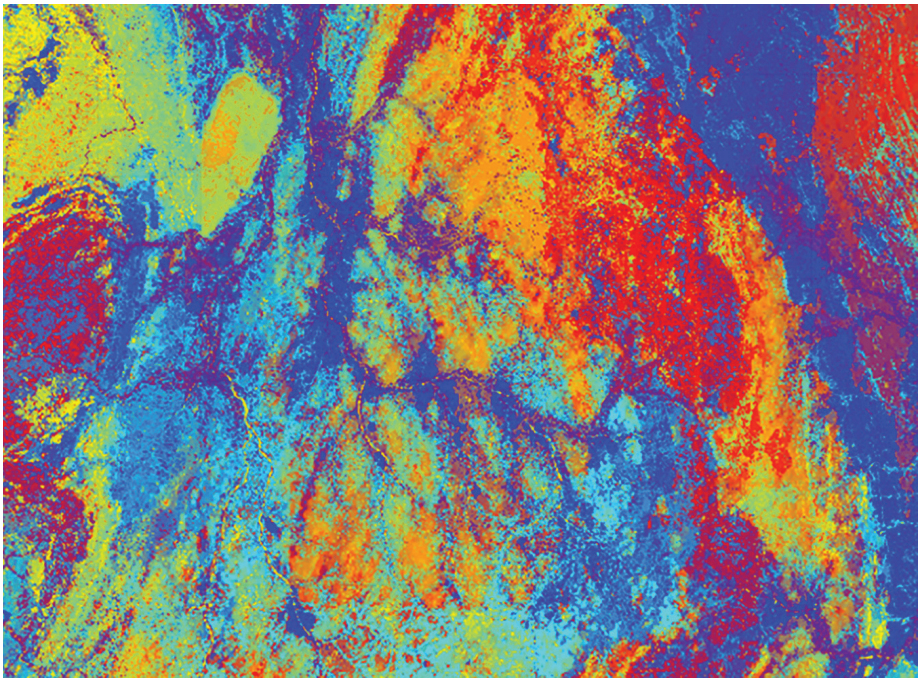
One of the rear-projection models developed by team "On the Rocks".

The "On the Rocks" project integrated 3D processing of magnetic data into a form that could be visualised in a low cost, portable 3D light box. The model was rear-projected onto a translucent 3D model of the topography created using a 3D printer. The team developed models for the Gawler Craton and Broken Hill datasets.

"Team Macquarie" was awarded 3rd place in the international competition for their submission on "Self-Organising maps". While there was no monetary award for 3rd place, Macquarie University found some travel funds for the team to travel to Canada to attend the Exploration '17 Conference and to participate in the Frank Arnott Award ceremony. Attendance at Exploration '17 provided an opportunity for the students to meet the judges, Committee members, sponsors and industry leaders.

The "Team Macquarie" project was designed to extract anomalous relationships in a high-resolution, multi-layered dataset from the Broken Hill district. A rapid expansion of their software application skills and some software engineering was required to put together their final project.

"Team Macquarie" members Luke Smith and Tasman Gilfeather-Clark being congratulated by David Pratt (at left) at the Exploration '17 Gala dinner.



An image of SOM classes extracted from the multitude of different datasets used by "Team Macquarie".

Tasman and Luke became so enthusiastic about the SOM project, they kept exploring the data and methodology and went on to present their results at the 2018 AEGC Conference and Exhibition, where they won the Best Student Paper Award.

Tasman and Luke also presented their results at the local ASEG Sydney Branch meeting. Later on, Tasman had the opportunity to present their results in Japan. They were both very happy with the concepts, processes and outcomes of the Frank Arnott Award competition as it gave them insights into our exciting industry. Tasman was invited to join the UWA PhD programme on the application of AI to geophysics and has now settled into Perth and is working on his first research project. He will be presenting some of this new work at the 2019 AEGC conference in Perth.

Mentoring – the key to success in 2017

Mentors do not participate in the project, but they can provide guidance, perspective, access to industry experts, advice, encouragement and opportunities to review progress and outcomes. The discipline of regular meetings during the research period is also important for maintaining perspective and setting achievable goals for the available time.

Tasman Gilfeather-Clark (centre) being presented with the 2018 AEGC – Best Student Paper Award by Keith Leslie (CSIRO – at left)) and Chris Wijns (First Quantum Minerals).

ASEG Members David Pratt from Tensor Research and Bruce Dickson CSIRO (retired) acted as mentors to "Team Macquarie" and helped them with the daunting task of finding a practical theme that could be applied to the high quality, detailed dataset compiled by the NSW Geological Survey. This rich, multi-layered dataset was an ideal candidate for SOM analysis where looking for anomalous geological relationships in a well-endowed mineral terrane is a time-consuming task. Bruce's background in SOM research at CSIRO provided an appropriate perspective to help the team focus on an achievable goal with a finite time budget.

Preparing for the next round in 2020–21 – the Frank Arnott Award process

The process begins by organising interested students into collaborative teams with a good spread of expertise. A team leader with good communications skills should be selected early on in the process so that they can liaise with university supervisors, societies, mentors and the Frank Arnott Award organisers. It is important for team members to assess their level of commitment at an early stage, because, for some, the time requirements may conflict with other university obligations. The major effort should focus on the December – February university break, with the remaining time devoted to refinement of the project outcomes.

When the competition opens, teams should register their interest and request access to the available datasets. Teams are likely to spend some time selecting their preferred project dataset(s) and identifying objectives that satisfy the judging criteria relating to "innovation in data integration and visualisation". This is the time when mentors can help simplify the range of options as their industry experience will save teams from proceeding down endless dead-end paths. Mentors will also be able to advise on the degree of innovation from an exploration industry context.

Once the team has settled on a dataset and concept, they can start working on the data, acquiring the various tools that they will need and then learning how to use them on real-world problems. Most software vendors are likely to provide free access to software for the duration of the contest.

At this stage, the concepts should start to mature and create a new focus as problems emerge and are resolved. It may be necessary to reach out beyond the skills of the existing team to resolve some tricky problems and again, this is where mentors can provide valuable assistance. Collaboration is regarded as a very important component of the judging criteria.

It is a good idea to prepare a preliminary team presentation on the prototype results to help focus the team on the important issues and boost their enthusiasm for the final stage prior to submission. The preliminary presentation will be submitted for judging by September 2020, with the judges releasing their results and identifying a short-list of teams for participation in the final round at PDAC in March 2021.

Invitations to short-listed participants will be sent in October 2020, providing ample time for teams to refine their work and tailor their final presentations. Financial assistance with travel and accommodation will be made available from a pool of funds contributed by sponsoring organisations. A special session will be set aside by the PDAC conference organisers to host the finalist presentations. The winning teams will be chosen on the basis of these presentations, and will receive their awards at the PDAC 2021 Student Luncheon.

Benefits to for students

There are many benefits for students participating in the Frank Arnott Award. These benefits extend well beyond their university education and into their future careers. Students will:

- Develop an understanding of team work, collaboration and leadership as a valuable skill,
- Acquire new software skills that are focused on future employment,
- Gain new exploration geoscience skills that are focused on future employment,
- Expand their industry network,
- Get to know industry representatives,
- Learn from the judging panel,
- Gain recognition for work on global datasets,
- Present at society meetings,
- Work with a local geoscience mentor to guide project development.

Summary

The rewards for the undergraduate and post graduate students, universities, our societies, explorers and mentors are significant. The students gain insights, encouragement, exposure and motivation. Universities have access to a range of data and people resources that enable their course development and industry recognition. As previously cited, the goals of the Frank Arnott Award are well aligned with the goals of our Society. Exploration companies get a chance to see future leaders well before they have entered the competitive employment market. David Pratt and Bruce Dickson both found the process of mentoring Team Macquarie immensely rewarding. Not only did they see the "lights turn on" but, they had the chance to see the team grow and take their own ideas beyond the Award.

The Frank Arnott Award key dates

Feb 2019	University contact initiated.
Mar 2019	Student and sponsor events at PDAC Toronto.
Jun 2019	Competition opens
Sep 2019	Promotion to students, educators and sponsors at AEGC 2019 in Perth
Oct 2019	Promotion at SAGA Durban promotion
Mar 2020	PDAC Toronto team reps, sponsor and judges meet and engage with universities
Sep 2020	Competition submission deadline.
Oct 2020	First round of judging and short listing of teams
Mar 2021	PDAC Toronto. Presentations by short listed teams. Final judging and award ceremony.

For more information go to https://www.pdac.ca/members/students/faa/background or contact David Pratt at David.Pratt@tensor-research.com.au.

Training the next generation of petroleum explorationists

As a young professional geoscientist who has worked with small oil and gas operators through the recent downturn, Daniel Thompson says formal training opportunities have been few. Many small operators are under-resourced, and do not prioritise professional development. Looming on the horizon is a significant gap in experience and technical expertise within the industry, which will ultimately result in unnecessary dry wells at a time when new and creative play concepts are required to replace diminishing reserves.

Daniel Thompson

In 2018 Daniel applied to join the PESA-ASEG Young Professionals (YP) mentor programme in Melbourne, organised by Jarrod Dunne of Karoon Energy, and designed to provide access to industry professionals, career advice and training opportunities to help bridge gaps in technical knowledge. Daniel tells us his story.

To close the knowledge gap for young professionals, PESA-ASEG has been running after-hours seminars to address a wide variety of technical and non-technical skills. We recently reached out to Rob Kirk (robkirkconsultants@bigpond.com) in Adelaide, a specialist consultant in sequence stratigraphy with 40 years of industry experience with companies such as BHP, Woodside, Occidental and SA Oil & Gas Corp. Rob generously volunteered his time and expertise in the form of a highly practical three-day short course on "Operational Seismic and Sequence Stratigraphy", expertly delivered in Melbourne on 15–17 April 2019.

For many of us the course was highly motivating, as well as transformative in the way we approach the geological interrogation of seismic data. We now view seismic through a new lens, which focuses on stratal packages and stacking orders, geometries, seismic facies and depositional settings. We now have the ability to be predictive in our hunt for new prospects, plays and petroleum systems, especially stratigraphic plays which will become increasingly important exploration targets in years to come.

Our first and highly successful short course has highlighted that training technical staff through external means need not be cost prohibitive if companies and consultants/industry specialists continue to support such low-cost training events. As an industry we need to take responsibility for the development of our future leaders in this new post-downturn environment. Otherwise, who will be the sequence stratigraphers etc. of tomorrow?

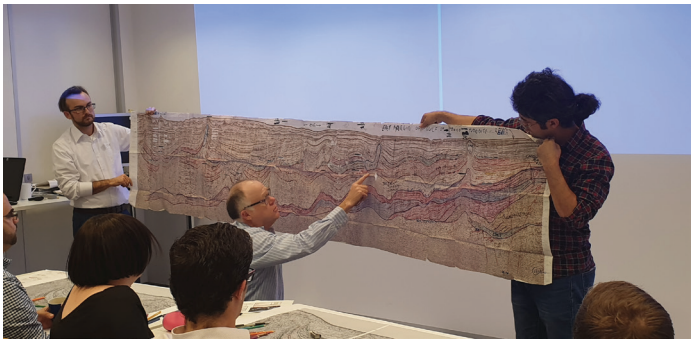
The PESA-ASEG YP group hold regular technical and non-technical seminars, as well as social events, and will be aiming to grow participation through 2019. If you are a YP and interested in attending future events then please contact either myself (dthompson@3doil.com.au) or Jarrod Dunne (jdunne@karoonenergy.com.au) for further information.

Similarly, if you are consultant/industry professional interested in helping to bridge the knowledge gap, or mentoring, then please also reach out to us. This includes any retired professionals. It would be a shame to lose the value of your experience. If you are interested in sponsoring upcoming events then we would also love to hear from you.

On behalf of the YPs that attended the course I would like to sincerely thank Rob for providing a highly informative and practical course for the benefit of our YP group. The course would not have been possible without industry support and sponsorship from Karoon Energy and 3D Oil Limited, as well as PESA and ASEG. Thank you to our sponsors for supporting your future leaders.

We have additional upcoming short courses planned so please watch this space. And remember, the more participants we have, the greater the opportunities for all of us.

Knowledge is power; young professional geoscientists acquire a wealth of insight and information working with their mentors in the after-hour sessions (from right to left, Rob Kirk, Hannah Booth, Yakufu Niyazi and Mitchell O'Mara).



Rob Kirk provides expert guidance on methods of seismic and sequence stratigraphy.

Boris Gurevich is an SEG Honorary Lecturer for Pacific South in 2019

Boris Gurevich

This year, geophysics Professor Boris Gurevich of Curtin University and CSIRO has been appointed Society of Exploration Geophysicists (SEG) Honorary Lecturer for Pacific South. The SEG Honorary Lecture programme, funded by Royal Dutch Shell through SEG Foundation, sponsors up to six lecturer tours each year, available on location in major regions around the globe or online.

Each year Honorary Lecturers are nominated by the vote of the SEG Distinguished Lecture Committee. Quoting from the SEG procedures, "The Honorary Lecture program focuses on transfer of knowledge within a region and/or topic, recognizing prominent geophysicists and strengthening the services that SEG provides to an expanding global membership". In her nomination letter to Prof Gurevich, SEG President Nancy J. House says that he had been chosen for this special honour because he is an outstanding communicator of ideas and an individual noted for quality in his contributions to geophysics.

Boris's lecture tour is taking place in March-June 2019. He toured Australia from 13 to 28 March, giving lectures to ASEG state branches in Perth Canberra, Brisbane, Sydney, Melbourne, Adelaide and Hobart. His lecture tour is also taking Boris to Singapore, Taiwan, China, Japan, Indonesia and Malaysia. The Australian leg of the tour was co-sponsored by ASEG, as well as by kind donations from CGG and DUG, and organised by Dr Marina Pervukhina, the ASEG's Professional Development and Branch Liaison coordinator.

Boris Gurevich has an MSc in geophysics from Moscow State University (1976) and PhD from Institute of Geosystems, Moscow, Russia (1988), where he began his research career (1981–1994). Between 1995 and 2000 he was a research scientist at the Geophysical Institute of Israel, where he focused mainly on seismic diffraction imaging problems. Since 2001 he has been a Professor of geophysics at Curtin University and advisor to CSIRO (Perth, Western Australia). At Curtin he has served as Head of Department of Exploration Geophysics (2010–2015) and, since 2004, as Director of the Curtin Reservoir Geophysics Consortium. He has served on editorial boards of a number of scientific journals, is a Fellow of the Institute of Physics and has over 100 journal publications in the areas of rock physics, poro-elasticity, seismic theory, modelling, imaging and monitoring of CO_2 geo-sequestration.

The SEG/ASEG Honorary Lecture tour highlights Boris's Australian career. Boris has worked with Curtin and CSIRO for the last 19 years, during which he has built a world leading rock physics team. He continues to inspire new generations of geophysicists down under. Boris is available for professional discussions and mentoring opportunities. He can be reached at B.Gurevich@curtin.edu.au

Seismic attenuation, dispersion and anisotropy in porous rocks – an overview

The topic of Boris Gurevich's Honorary Lecture is "Seismic attenuation, dispersion and anisotropy in porous rocks: Mechanisms and models". Understanding and modelling of attenuation and dispersion of elastic waves in fluid-saturated rocks is important for a range of geophysical technologies that utilise seismic, acoustic or ultrasonic waveforms and amplitudes. In particular, in seismic oil and gas exploration, lateral variations of the attenuation in the overburden can distort seismic reflection amplitudes from exploration targets, leading to errors in reservoir characterisation. Conversely, seismic attenuation is ultimately controlled by subsurface properties and is thus increasingly used as an attribute for subsurface characterisation. Understanding the nature of seismic attenuation and its dependence on rock properties can make this characterisation more quantitative and robust.

A key mechanism of seismic wave attenuation and dispersion in fluid-saturated rocks is viscous dissipation due to the flow of the pore fluid (relative to the solid frame) induced by the passing wave. Such fluid flow (or pressure relaxation), known by an acronym WIFF (Wave-Induced Fluid Flow) can take place on various length scales. Wavelength-scale fluid pressure relaxation between peaks and troughs of a passing wave is known as global or macroscopic flow and is described by Biot's theory of poro-elasticity. WIFF caused by spatial variations of matrix or fluid properties on a scale much smaller than the wavelength but much larger than individual pore size is known as mesoscopic flow. Pore-scale WIFF is known as local or squirt flow.

WIFF caused by pressure relaxation between peaks and troughs of a passing wave in a porous rock, occurs due to density differences between solid matrix and the pore fluid. When the fluid is inviscid, application of the same pressure to the porous material will result in different particle velocities in the solid and fluid, and separate longitudinal waves propagating in the solid matrix and fluid (known as fast and slow waves, respectively) with no dissipation. When the fluid is viscous, the solid and fluid motions are coupled, but there are still fast and slow waves. In the fast wave, the fluid and solid motions are almost in-phase, and in the slow wave, out-of-phase. Thus the attenuation is vast in the slow wave and relatively small in the fast wave – but non-zero due to some small lag of the fluid relative to the solid.

To visualise this phenomenon, consider a solid pipe filled with a viscous fluid and being shaken back and force in the axial direction. Were the fluid inviscid, it would have remained stationary. But if the fluid is very viscous, it will be dragged along by viscous forces, but will

lag behind the solid pipe, creating relative motion, and hence energy dissipation. The same phenomenon occurs in a porous medium, although the tortuous pore space results in additional inertial coupling between the solid matrix and fluid motion.

Mesoscopic flow occurs when the wave passes through a porous medium with spatial variation of material (frame or fluid) properties on meso-scale (much larger than pore size but much smaller than wavelength). For instance, when the frame bulk modulus is spatially variable, the more compliant regions will deform to a greater extent than stiffer ones, resulting in fluid pressure gradients and hence WIFF from more compliant into stiffer areas, and, consequently, viscous dissipation. Mesoscopic dissipation factor scales with the variance (squared contrast) in material properties, and hence is only significant when the contrast is large. Two such situations are of particular interest: liquid- saturated rock with mesoscopic fractures and with meso-scale gas-saturated patches.

Consider a rock saturated with a mixture of a liquid and gas. At low frequencies, there is enough time for fluid pressure to equalise between liquid and fluid saturated regions, and hence the bulk modulus of the saturated rock is given by Gassmann's equation with the fluid modulus equal to the modulus of the fluid mixture given by the weighted harmonic average of the bulk moduli of liquid and gas. This mixture modulus is entirely controlled by the modulus of gas, and hence the rock modulus is constant almost in the entire saturation range. In contrast, at ultrasonic frequencies, there isn't enough time for pressure to equalise, and the overall rock is effectively a mixture of two elastic constituents saturated with liquid and gas. According to the Gassmann theory, these constituents have the same shear moduli and only somewhat different bulk moduli, and hence the overall bulk modulus is a very gradual (near-linear) function of the volume fractions.

Local (pore or grain scale) WIFF, also known as squirt, occurs between more compliant voids (cracks, grain-to-grain contacts) and relatively stiff pores. When the rock is compressed, much greater pressure builds up in compliant than stiff pores, resulting in the fluid pressure gradient, pore scale WIFF and dissipation. Similarly to the case in mesoscopic WIFF, when the frequency is low, fluid pressure has enough time to equalise within one half-period of the wave, and hence the compliant pores remain compliant, while at high frequencies, there is not enough time for the pressure to equalise, and hence the pores that are compliant in dry state become much stiffer. Hence materials with binary pore structure exhibit moduli and velocity dispersion. At the same time, presence of compliant pores is responsible for strong pressure dependency of elastic wave velocities. Thus substantial reduction of pore compliance at high (e.g., ultrasonic) frequencies results in much weaker pressure dependency. This effect can be demonstrated by much stronger pressure dependency of the rock bulk modulus at seismic than ultrasonic frequencies, with the difference (dispersion) decreasing with increasing effective pressure. At intermediate frequencies, the dispersion is accompanied by significant attenuation.

Attenuation is even stronger in rocks saturated with viscoelastic substances such as heavy oil/bitumen. At low frequencies (and/or high temperatures), the pore fill is in liquid state, the pressure is equalised between compliant and stiff pores, and the rock is relatively soft. But at high frequencies (or low temperature) the pore fill is near-solid, and won't flow, making previously compliant pores very stiff, and causing strong dispersion.

SEG DISC Lecturer Manika Prasad presents in Australia, August – September 2019

Breaking news from Marina Pervukhina and the ASEG's Education Committee is that the SEG has just announced an SEG Distinguished Instructor Short Course (DISC) to be offered in Australia over the next 3 months.

Physics and mechanics of rocks: a practical approach

This one-day short course will be presented by Professor Manika Prasad of the Colorado School of Mines. It will provide the earth scientist and engineer with a foundation in rock physics to describe the physical processes that govern the response of rocks to the external stresses essential for reservoir characterisation. The course will also offer practical guidance to help better analyse existing data. A major goal of this course is to offer practical instruction and provide working knowledge in the areas of rock physics and rock mechanics for rock characterisation (Table 1).

Table 1. DISC lecture dates.

Branch	Date	Time	Venue
QLD	20 August	09:00	XXXX Brewery (Alehouse), Black Street, Milton
VIC	22 August	09:00	Kelvin Club TBC
SA	27 August	09:00	128 Rundle Mall, Adelaide, SA, 5000
ACT	29 August	09:00	Geoscience Australia
WA	6 September	09:00	AEGC Conference

More information about the course and the speaker can be found at https://seg.org/Education/Courses/DISC#sort:path~type~order=startdate~datetime~desc|paging:number=10|paging:currentPage=0

Minerals geophysics

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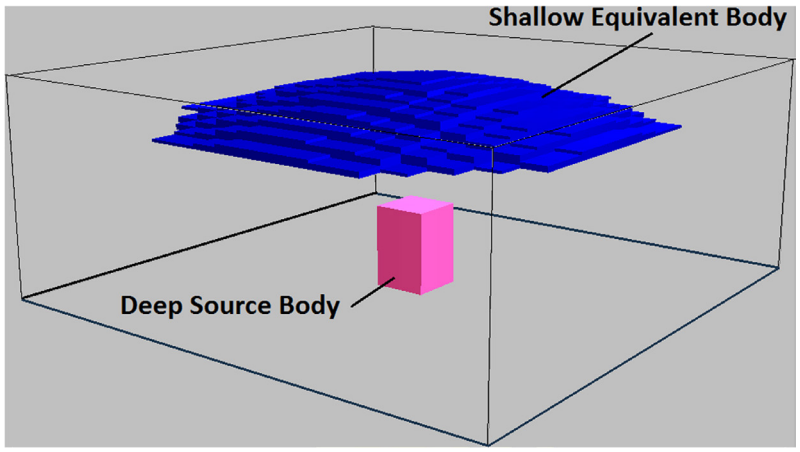

Figure 1. *Equivalent gravity anomaly source bodies.*

Shallow or deep?

Gravity and magnetic potential field anomalies have a maximum theoretical source body depth. However, a plethora of other source body configurations is possible at shallower depths. That is, a sharply defined anomaly must have its source body near surface, but a broader anomaly, although conventionally attributed to a deeper source body, may actually have its source at shallower depths. In mineral geophysics, such source body properties and configurations will be constrained by mineralogically appropriate density contrasts and magnetic susceptibility values, and geologically realistic geometric distributions.

To see how equivalent source body configuration might change with depth, I first calculated the gravity response at surface for a prismatic source body topped at 50 m depth, then inverted the resulting gravity anomaly but constrained the modelled source body to be within the first 20 m below surface. The two bodies are shown in Figure 1. Not surprisingly, the domed shape of the shallow modelled body somewhat mimicked that of the gravity anomaly itself. Is this shape geologically reasonable? Absolutely. We're dealing with density contrasts not absolute densities here, so this shape could easily represent a localised palaeotopographic basement high beneath younger less dense transported cover, or the localised shallowing of a base-of-weathering profile (weathered material is less dense). So, if you're drilling a gravity target and encounter bedrock/basement much shallower than expected, you might have already explained your anomaly. However, unless you have a good understanding on the surrounding depths to bedrock/basement and a localised shallowing is indicated, I wouldn't abandon the drilling.

In contrast to positive gravity anomalism, consider the response of a localised deepening of the weathering profile, or of a depression in the palaeotopographic profile, i.e. negative gravity anomalism. In strongly weathered environments, primary sulphide mineralisation is often characterised by associated enhanced weathering and by a localised deepening of the weathering profile, both of which would create localised negative gravity anomalism. Superimposing this weathering-related gravity low over the expected positive gravity anomaly from deeper massive primary sulphides will seriously downgrade, distort or even obliterate the positive gravity response (see Figure 2). Perhaps this explains why some primary sulphide mineralisation

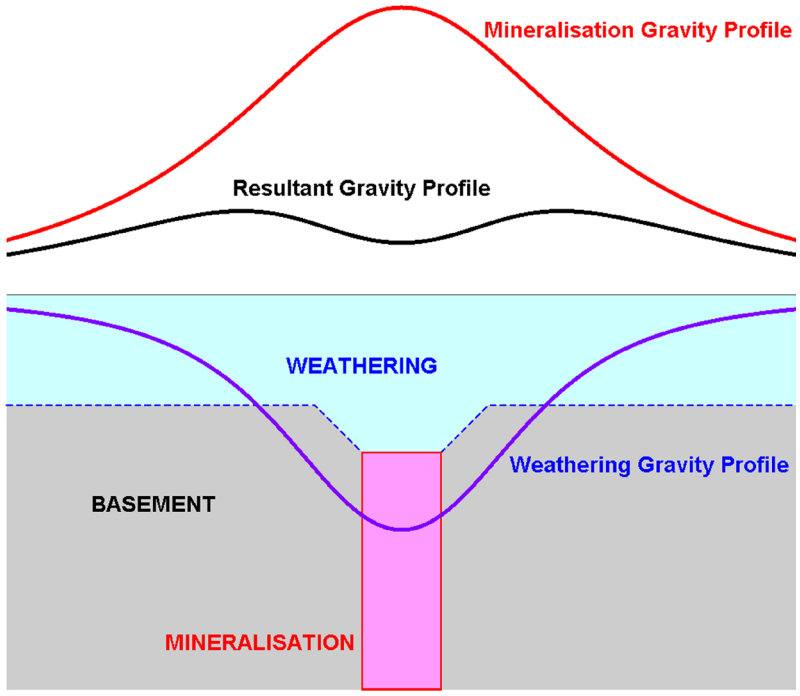

Figure 2. *Weathered mineralisation gravity anomalies.*

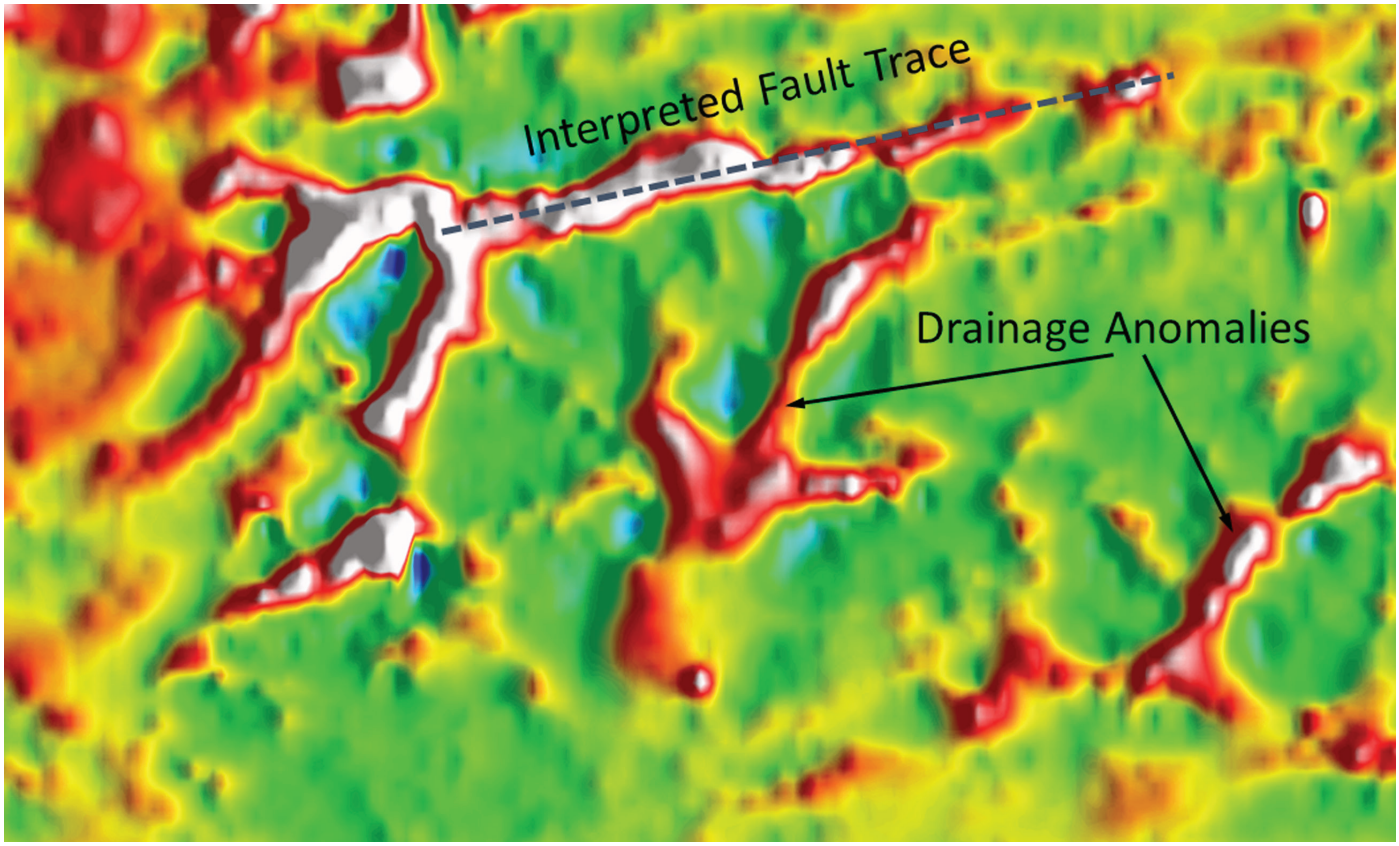

Figure 3. *RTP magnetics surficial anomalies.*

lacks the expected positive gravity anomaly?

Although sourced at shallow depths, sharp potential field anomalies can sometimes inform us about geology at depth. Figure 3 shows portion of the residual RTP image from a detailed airborne magnetics survey in Northern Australia. Rock types in the area comprise a series of sedimentary units, some of which are strongly pyritic; no magnetic pyrrhotite or magnetite is present in these units. The ground surface is rubble and alluvium covered. The residual RTP image is characterised by a pattern of sharply defined low order (5-15 nT) magnetics anomalies of obviously shallow origin, most of which are associated with drainage features. However, the highlighted magnetic lineament is not drainage-related. One interpretation might be that this response outlines a fault, where iron mobilised to the surface from pyritic sediments at depth has focussed the distribution of surficially developed maghaemite along the fault trace. There is support for this fault at depth from drill-hole results.

So, with real world potential field responses, appearances may be deceiving and a bit of lateral thinking rather than a conventional interpretation can sometimes be called for.

The ASEG in social media

The ASEG has just joined Instagram https://www.instagram.com/aseg_news/ – so go on, give us a follow! We'd love to share your photos too, so please email Kate Robertson at communications@aseg.org.au if you have any images you would like featured.

We know not everyone is on Instagram, but you can also find us on a variety of other social media platforms too! We share relevant geoscience articles, events, opportunities and lots more.

Facebook: https://www.facebook.com/AustralianSocietyOfExplorationGeophysicists

LinkedIn company page: https://www.linkedin.com/company/australian-society-of-exploration-geophysicists/

LinkedIn group: https://www.linkedin.com/groups/4337055/

Twitter: https://twitter.com/ASEG_news

Youtube: https://www.youtube.com/channel/UC-dAJx8bXrX5BEudOQp4ThA

Seismic window

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Pitfalls revisited

On my bookshelf is a small 20 page booklet with the title "Pitfalls Revisited". It was published in 1982 and is a follow up to the original 1971 SEG Monograph "Pitfalls in Seismic Interpretation". How relevant are the topics discussed in these books nearly 50 years ago? It seems the problems in seismic interpretation have not really changed over the intervening years because most of the 16 pitfalls described are still applicable today.

Pitfall 1 – Assuming the marine subsurface needs no low velocity correction. In fact the shallow section has numerous channels, reefs and faults which can lower signal – noise and introduce lateral velocity variations that distort the reflections at the target horizon. Today we can model velocity variations with full waveform inversion, and pre-stack depth migration aims to locate reflectors accurately in depth, but these are relatively recent additions to the seismic processing sequence.

Pitfall 2 – Assuming a sonic log gives true velocity and a VSP is a continuous recording. Well ties still require some editing, stretching, squeezing and bulk shifting of the sonic log to match the seismic. Today we can record sonic while drilling, and a wireline sonic log is often not included in the evaluation programme. While this may be good enough for P wave velocity, we often need S wave velocities to solve rock physics problems. In practice an estimate, rather than a true S wave velocity, is produced by sonic while drilling and the tool has no way of recording variations caused by azimuthal anisotropy.

Pitfall 3 is about Fresnell zones which are now well understood, but still largely ignored by many interpreters.

Pitfall 4 – Neglecting the use of the diffraction overlay. Not even I am old enough to remember whatever that is, but I guess it is no longer needed now migration is standard.

Pitfall 5 – Flattening to restore geological history. Ideally this should be done using depth migrated sections but it is regularly applied to time sections. Even on today's workstations, flattening across a fault is not handled well and the area beneath a fault plane is distorted and not very useful.

Pitfall 6 – Over-migrating. In the past it was expensive to migrate data and 2D strike lines contained side swipe reflectors which could not be migrated. With the advent of 3D seismic it seems this pitfall is no longer an issue.

Pitfall 7 – Undocumented changes in acquisition and recording parameters. This will always be a pitfall. Only last month I had a problem with an unrecorded change in shot delay.

Pitfall 8 – Using only a variable area display on cheap paper to interpret. Luckily this is a thing of the past and interpreters can almost instantly adjust scales and colours to suit their requirements.

Pitfall 9 – not including a data processor in the team is still common.

Pitfall 10 – Overlooking the need to coordinate stratigraphic and structural mapping. Today's interpreters should have a sound knowledge of structural geology and sequence stratigraphy as well as geophysics. Some exposure to reservoir engineering also helps. Many of us do, but not everyone tries to put geology into their interpretation. This is still an issue, especially as many of the experienced interpreters are heading for retirement.

Pitfall 11 – Not using or misusing seismic velocities. There should be no excuse for ignoring seismic velocities today. The trick, however, is to figure out which velocity to use (e.g. average velocity, interval velocity, migration velocity to name a few). A modern 3D seismic survey will often be delivered with about a dozen different velocity files including some anisotropy measures like epsilon and delta. Which one should be used for depth conversion? Velocity can also be used as an attribute to determine geological characteristics such as channel fill or the lithology of a shallow prograding sequence.

Pitfall 12 – Using only one scale ratio – this is another problem of the paper section era, though it is still difficult to display long, regional lines on a workstation screen.

Pitfall 13 – Ignoring pitfalls. Nothing has changed on this one!

Pitfall 14 – Paying lip service to coordinated geological and geophysical evaluation. A team approach is required, even more so than 50 years ago as prospects get more subtle. Sure, some geopeople call themselves geoscientists (usually these are geologists trying to progress themselves☺), but nobody knows everything.

Pitfall 15 – Job switching for temporary advantage is not a problem these days. In the last four years there has been no word from the plethora of head hunters that invaded our industry from overseas when the oil price was over $100/barrel.

Pitfall 16 – Emphasis on drilling expenditure compared to interpretation costs. Ill- conceived wells will still be drilled because spending on pre-drill interpretations has been slashed as companies down size or try to maximise the number of projects assigned to geophysicists and geologists. Good prospects still need good ideas, and people with enough time to think of them.

This quick analysis indicates about half the pitfalls identified 40 to 50 years ago in interpretation are still valid today, especially where velocities and the makeup team members are concerned. Velocities can be dealt with easily, but building and keeping good exploration teams together requires a high priority corporate commitment, which is often lacking.

References

Tucker, P. M. 1982. Pitfalls Revisited, SEG Geophysical Monograph Series 3.

Tucker, P. M., and H. J. Yorston. 1973. Pitfalls in Seismic Interpretation. SEG Geophysical Monograph Series 2.

Data trends

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Open data formats for the post DOS world

The universally readable ASCII formats of ASEG GDF2, ESF or simple text files are still the preferred, official data exchange format for geophysics surveys in Australia. But, after 40 years, the Hierarchical Data Format (HDF) originally designed for supercomputers is growing in recognition as an efficient usage format [1]. Whether you collect large surveys, need simplified storage for many surveys, or a more efficient network and distributed computing solution, HDF5 offers an open format for the post DOS standalone world.

Passive seismic and lithospheric scale electrical surveys mirror astronomy's need for very large, portable storage. Ideally multiple surveys of multiple types should be combined into a monolithic standalone file without proprietary restraints or crashing because the file is too big. The ASEG Technical Standards Committee has met with petroleum consultants who report that converting a selection of SEG-Y data sets into a HDF5 store has meant that access to their data is faster, and the datasets are more stable and easier to move around their network.

HDF5 and its variants offer a database that acts as single file with binary file speed but with text-like headers. Include the relevant package or header file and it is almost as simple to interrogate the resultant database as it is to interrogate a text file. The example below, from the website of the National Ecological Observatory Network (NEON) [2], shows how the opened object echoes the properties of a dictionary object with keys, values and items. The example enumerates keys to display the column names.

```
f=h5py.File("NEON-DS-Imaging-Spectrometer-Data.h5","r")
datasetNames=[n for n in f.keys()]
for n in datasetNames:
    print(n)
```

HDF5 and its variants may be of value to archivists and companies trying to analyse enormous data stores where tracking the files and not crashing the network is half the battle. Similarly, the format may assist with web distribution of data for use in apps, machine learning, and distributed number crunching in the cloud. The promise of running tenements from a mobile phone using data stored in the cloud rather than on workstations is not restricted by the supply of data, but how the data is being supplied.

For more on these file formats, Alex Ip from Geoscience Australia (GA), with special guest Carina Kemp from AARNet, is running a workshop on how GA uses the NetCDF variant of HDF at the upcoming AEGC [3].

Notes

[1] https://www.hdfgroup.org/
[2] https://www.neonscience.org/hdf5-intro-python
[3] https://2019.aegc.com.au/workshops/

Webwaves

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A new Webmaster

After four years as Webmaster, David Annetts has stepped up to become the ASEG President Elect, and I now fill the role of Webmaster for aseg.org.au. As always, email webmaster@aseg.org.au or complete the contact form on the website if you have any queries about the website. As Dave is also moving on from the Web Committee, please get in touch if you are interested in volunteering and helping out with the website.

The next planned addition to the website is a facility for non-members to sign up to receive email alerts about new editions of *Preview*. This functionality (the CSIRO Publications email alert) disappeared during the transition to Taylor & Francis at the start of this year, and we aim to recreate it on the ASEG website at www.aseg.org.au/publications/PVCurrent. Members of ASEG will continue to get email notifications from the ASEG about the release of each edition of *Preview* and *Exploration Geophysics*.

Since the current iteration of the website was released, we have tracked metrics of user activity in order to provide better content, based on what users want to consume. This has resulted in the closure of the forum, which was inactive, but the expansion of professional content. In 2019, so far, the most popular page on the website has been www.aseg.org.au/publications/geological-interpretation-aeromagnetic-data where users find the Isles & Rankin book free to download. At times this page has had more visits than the website home page. Other pages that see a high number of visits include:

- AEGC2019
- ASEG publications (*Exploration Geophysics* and *Preview*)
- The monthly ASEG Newsletter
- Workshop proceedings (in particular the workshop on passive seismic)
- The events pages
- The contractor database
- The Research Foundation (over 1% of total website page views this year have been on the how-to-apply page)
- History pages (where there are regular contributions from the History Committee)
- The open source geophysical software page

Access to the website globally (Figure 1) is dominated by Australian users (46%), with the USA (12%), Canada and India (each 4%), and the United Kingdom (2.5%) filling out the top 5 countries by sessions. Notably, we have several gaps in world readership, so if you find yourself on a survey in one of the following locations, please visit the ASEG website:

- Bhutan
- Burundi
- Central African Republic
- Costa Rica
- Equatorial Guinea
- French Guiana
- Greenland
- Guinea-Bissau
- North Korea
- Paraguay
- Svalbard
- Turkmenistan
- Western Sahara

Some of these missing countries are interesting. Turkmenistan has the sixth largest reserves of natural gas https://en.wikipedia.org/wiki/Turkmenistan, while Equatorial Guinea also has an economy dominated by crude oil. North Korea, meanwhile, is the world's 21st largest producer of iron ore and 17th of zinc https://www.indexmundi.com/minerals/ (latest North Korean data from 2012).

This year has also seen change for ASEG in social media, with Kate Robertson setting up an Instagram account (@aseg_news). We work in an industry where we often get to appreciate beautiful vistas, so please contribute material to the account and help raise the awareness of geophysics in the wider community. Some great pictures have already been posted, so go and check it out! ASEG is also present on Facebook, YouTube, Twitter, LinkedIn, as well as the website of course.

So, when you next find yourself at a North Korean iron ore mine, in addition to visiting the ASEG website, make sure to take a selfie and share it with ASEG on social media!

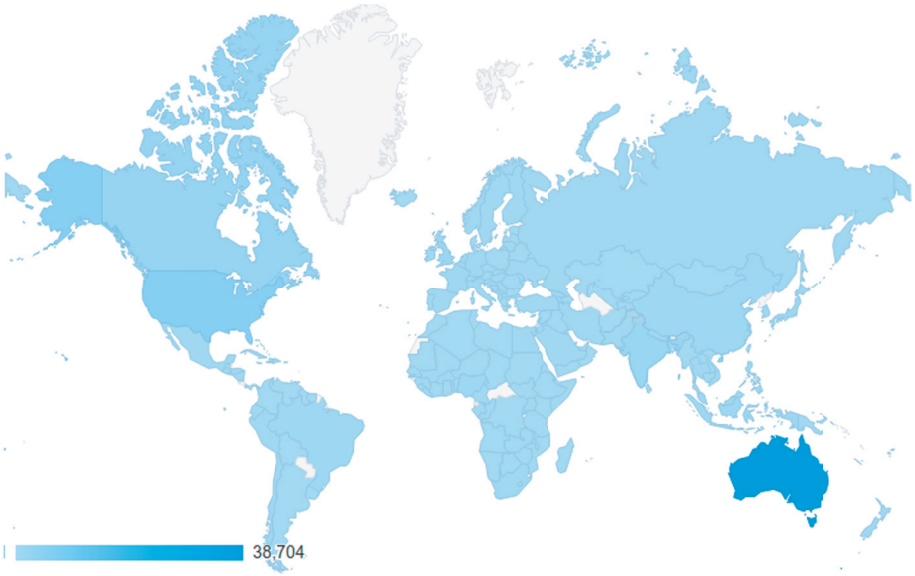

Figure 1. *Global access to the ASEG website.*

Mining geophysics: A Canadian story

By Norman Reed Paterson

Published by the Canadian Institute of Mining, Metallurgy and Petroleum, 2019, 188 pp.

RRP CAN$39.95.

ISBN: 978-1-926872-42-1.

This book is a personalized history of many of the entrepreneurial technocrats who created a new geophysical technical service industry in the three decades after World War II. Decades during which Canada became, arguably, the world leader in mining exploration technology. The author introduces readers to most of the key participants in the exciting 1945-75 period of initial growth in mining geophysics in Canada.

Norm Paterson was a central participant in this growth era as a consequence of his early career with Hunting Survey Corporation and, subsequently, as President of Huntec Ltd. in Toronto. He is well known to many older members of the mining geophysical community and, during his long career, he met and/or worked with many of the people described in his book. He emphasises that his book is not an attempt at a comprehensive history of geophysics in Canada, but rather a subjective, personal recollection of people and developments. It serves admirably in this regard.

The book comprises four main sections:

(1) *The Birth of Exploration Geophysics*, which describes how Canadians and Canadian universities were early leaders in R&D.
(2) *Developments and Projects 1945–1959*, which highlights some of the equipment developments, including ground and airborne electromagnetics, together with brief, personalized "case histories" of some of the discoveries in which the author was involved.
(3) *The Pioneers*, in which the author presents "snapshots" of many of the individuals who initiated mining geophysics in Canada (most of whom the author knew personally), including Tony Barringer, Fraser Grant, Norman Keevil Sr, Vaino Ronka, Harry Seigel and Gordon West.
(4) *Developments and Projects, 1960–1975*, which describes significant instrument developments, particularly in IP and ground and airborne electromagnetics. Several typical Canadian exploration "rushes" are also described in this section, including the classic Pine Point where a number of Pb-Zn ore bodies were found with less than a couple of weeks of IP surveying, and the late '60s uranium rush in the Athabasca Basin. All the descriptions have numerous interesting, and often amusing, anecdotes and interpretive comments by the author.

In addition, there is a short section on the author's perspective of the Canadian ground geophysics industry and the principals involved, with particular emphasis on his experience in forming Huntec Ltd. and some of the in-house equipment developments. An appendix by William J. Scott documents very early magnetic and gravity surveys in Canada (from the 1820s) and also some early exploration geophysics done by the Geological Survey of Canada (GSC) up to the late 1930s. Another useful addition is a list of "Key Players", which is cross-referenced to page numbers in the text.

I particularly appreciated the custom drawn Deposit Location Maps at the front of the book, where all the deposits and mine discoveries mentioned in the text are clearly shown. There are six maps, covering different parts of Canada.

At times the text exhibits "stream of consciousness" tendencies and, overall, it sometimes appears disjointed and lacking structure. The book contains numerous black/white photos of people and survey equipment. Unfortunately, the quality of these photos is sometimes poor, presumably because of the need to limit printing costs.

However, despite these shortcomings, I would recommend the book to anyone interested in the history of exploration geophysics in Canada.

Reviewed by
Richard Irvine
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Mining to mud: a multidisciplinary approach to understanding Victoria's riverine landscape as a product of historical gold mining

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Introduction

The Victorian gold rush began in 1851, resulting in massive demographic, land use, and social changes (Serle 1968). Rivers, during much of the gold mining history of Victoria, were used as a "free" resource, both to extract and process sediment. The effect on river systems around the state was catastrophic. A quarter of the length of the main streams was damaged. Even though the devastating environmental impact of Victorian gold mining was recognised at the time, it appears to have been forgotten today (Figure 1). This is despite extensive documentation of the number of mining operations, methods used, resultant environmental impacts and consequent legislation. The ARC discovery project "Rivers of gold" set up a multi-disciplinary team to try and reconstruct the historical development of mining across the state of Victoria, and to determine the legacy of this mining.

One of the main consequences of gold mining was the production of alluvium that was known as "sludge".

' Sludge' shall mean water holding in suspension particles of mineral matter derived from mines or particles of debris or other waste matter derived from mineral or metallic ores or matrices whilst under treatment or particles of soil earth clay sand quartz rock gravel or other material delivered into the water in consequence of the operations of any mine, but shall not include water holding in suspension particles of soil only or of vegetable organic or other matter not connected with mining operations. (Shakespear, Walker, and Rowan 1887, xxviii)

The sludge filled up channels and meant that stock couldn't be watered, it also blanketed floodplains killing vegetation. Davies et al. (2018a), using a combination of approaches, estimate that around 650 million m^3 of sediment was likely mined and input into river system from 1851–1900. The amount of gold won by miners decreased over this time period, and this decrease was accompanied by a decline in the numbers employed in the industry (Figure 2). These numbers bely the fact that in order to get payable amounts of gold more and more sediment needed to be mined, and that new technology had supplanted manpower. From 1851–58 20 million m^3 of sediment was mobilised (2.5 million m^3 a^{-1}), whilst 492 million m^3 were processed from 1859–1891 (15.4 million m^3 a^{-1}).

The approach taken to understand the fate of the mined sediment, and whether there are any legacy impacts, is one that has combined the skills of archaeologists, historians, geochemists and geomorphologists. The evidence that these disciplines has provided is presented in eight different chronological stages. The project used state-wide data, where available, and more detailed data on three catchments: Ovens River, Loddon River and the Leigh-Yarrowee (Figure 3). The goal was to show what data can be collated across different research areas, and how it could be combined to provide multiple lines of evidence.

Stage 1: Pre-European settlement (pre 1803)

A baseline dataset needed to be created to understand the environment that miners modified. These data are not readily available across Victoria, and conditions were only reconstructed for the focus catchments.

Evidence

Whilst the pre-European vegetation across Victoria has been described using Ecological Vegetation Classifications, and

Figure 1. *Mining at Guildford, near Castlemaine, during the gold rush (left), and the same scene in 2018 (right).*

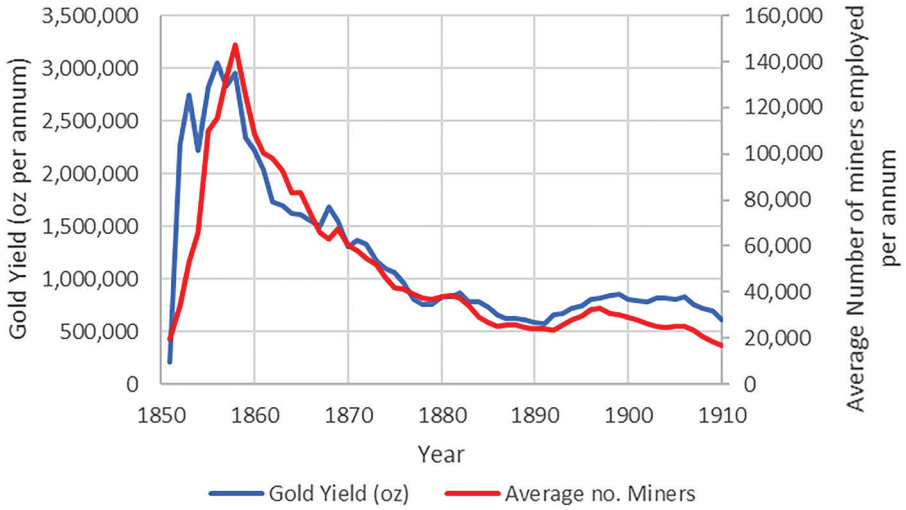

Figure 2. *The annual gold yield and average number of employed miners across Victoria between 1850 and 1910 (Department of Mines 1910, 16).*

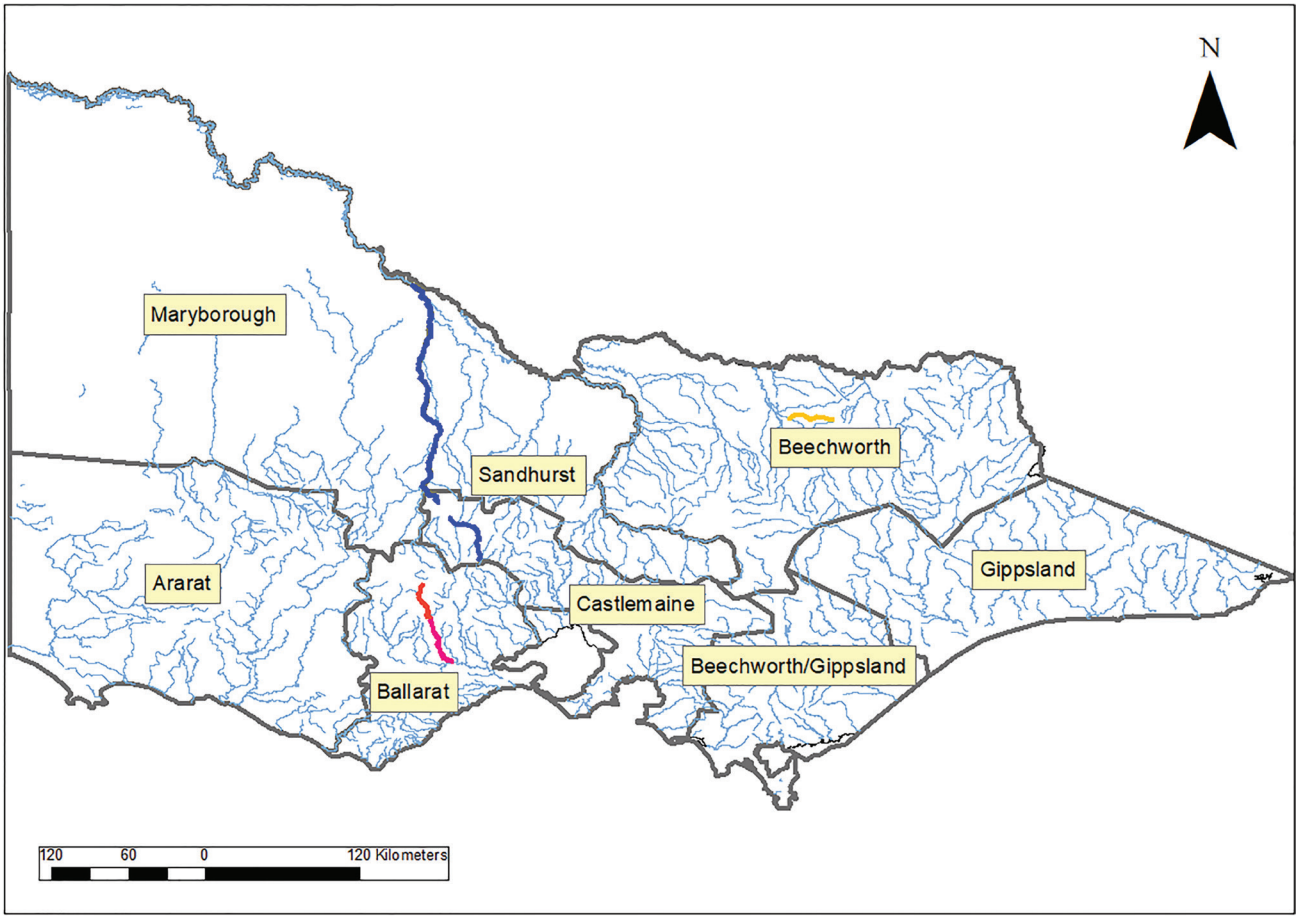

Figure 3. *Mining districts of Victoria with the study catchments of Hodgsons Creek (orange trace) in the Beechworth district, Loddon River in Sandhurst and Castlemaine districts (blue trace), and Leigh/Yarrowee in the Ballarat district (red trace).*

bioregions have been mapped, there is only a patchwork of information about the geomorphology and geochemistry of pre-European settlement river systems. One source of information is early explorer reports. The River Loddon, for example, was crossed by Major Mitchell on 1 July 1836.

Mitchell describes camping near a chain of ponds, which may be on Serpentine Creek. Further on, near Fernihurst, he crossed a river that had steep banks that were twenty feet high (~6 m). The current bank-full height in this region is on average 3.6 m, with a maximum of 6.2 m. The banks seen by Mitchell were thickly covered in grass, with trees at the stream edge but not on the top of the banks. The water had a brown colour and was about nine feet (~2.7 m) deep. Flow was 1.5 miles an hour (0.7 m s^{-1}) and there were no large wood debris in stream.

Joseph Hawdon also crossed the river near Fernihurst in 1838 (Hawdon 1840). It was a drier year and he reports that,

as he travelled downstream, every 7–10 miles a little water was observed in the bed. Twenty three miles downstream of Fernihurst the channel was barely perceptible.

Another source within the Loddon catchment, Morrison (2002), recounts aboriginal descriptions of the pre-European environment. Water was mentioned as being scarce at times, as evidenced by the practice of using banksia flowers to filter the water from waterholes that were drying out.

Interpretation

Whilst it is difficult to generalise across the whole of the state, it appears from our focus catchments that smaller streams were originally dominated by waterholes and had less well-defined channels. The lower Loddon River had a fairly similar morphology with a deep well-defined channel, again with significant bed variability in terms of pools. This evidence aids in understanding the receiving waters into which the sludge was poured.

Stage 2: Pre-mining (1803–1851)

Evidence

Maps and surveyors' notebooks provide information on the Victorian landscape as it was settled. Many early maps have been digitised and are available online from different sources, such as the State Library of Victoria. In our study areas we have geo-rectified the maps so that historic river channel locations can be viewed against the current river channel locations (Figure 4). The surveyor's notebooks were more difficult to access, and many are not digitised so that physical copies had to be requested from the Public Record Office Victoria.

It has long been understood that European settlement, and the associated land clearance, resulted in reduced evapotranspiration and increased surface runoff and, as a consequence, increased soil erosion and gullying. These changes have been modelled across Australia by CSIRO using SEDNET (Prosser et al. 2001). Much of the landscape clearing was coincident with mining activities. However, the modelled yields do not include sediment directly produced by mining. The SEDNET yields have been compared to estimates of yields from mining (Figure 5), revealing that yields from mining can be up to 600 times the "natural" annual sediment loads.

Interpretation

The relatively limited amount of data available on the intervening period between European settlement and the gold rush suggests that minimal disturbance had occurred in upstream mining areas. In recent times layers of modern sediment found deposited on floodplain surfaces, or exposed on riverbanks, have been ascribed to land clearance. These deposits have been called "Post European Settlement Alluvium" (PESA). In mining regions sediment yields were well above the natural rates, and care needs to be taken in how these sediments are interpreted.

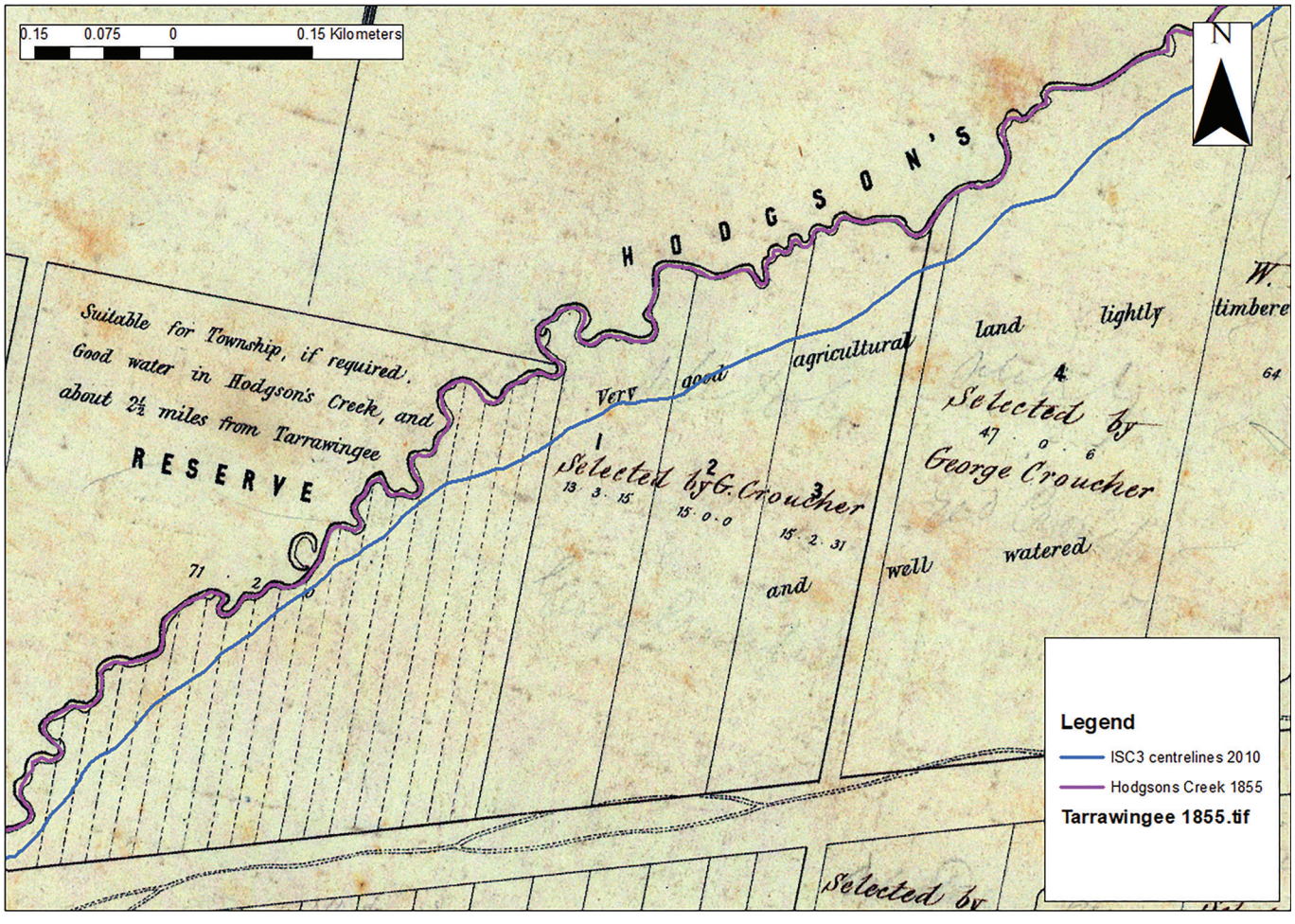

Figure 4. *The 1855 stream position of Hodgsons Creek at Tarrawingee overlain with the 2010 position.*

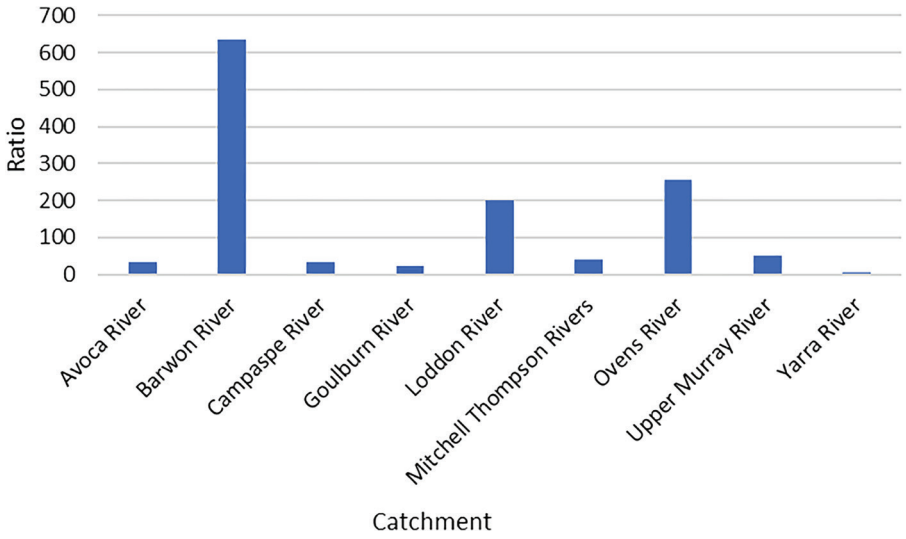

Figure 5. *The ratio of annual sludge volumes to SEDNET natural load estimates from NLWRA (2001).*

Stage 3: Gold rushes (1851–1880)

Evidence

Data on the initial gold rush is limited to anecdotal information in various reports and miners' journals. Regulation of miners' activities, and the issuing of mining leases, meant that data needed to be collected on the number of miners and the location of their activities. Much of this information was recorded so that it could be reported to the Government. From records of different mining districts, such as appear in the *Mineral Statistics of Victoria* (MSV) reports, it is possible to reconstruct the number of miners and the mining techniques that they were using for the period 1859–91. Estimates were then made about the volume of sediment that each different enterprise would produce in order to give an overall sediment yield (Figure 6).

Records were originally compiled for each of the gold mining districts (Figure 1). In order to fully understand the impact of the mining operations on river systems these data needed to be separated into river catchments. The VICPROD and VICMINE datasets (Department of Primary Industries c.2002) provided a compilation of around 16 000 gold mines across the state with approximate mining dates and locations alongside other attributes such as whether the mine was mining primary or placer deposits (Figure 7). These data are undoubtedly an underestimate of mining activities, and will certainly miss the earlier phase of artisanal mining, however they do act as a guide as to where most of the mining activity occurred.

The estimated volumes for each mining district were distributed across the known mines in the region, and this allowed each mine to be allocated a volume of sediment. This has allowed the volume of sediment produced in each river catchment to be estimated and then compared with other data such as the SEDNET yields (Figure 5).

The VICPROD dataset also allowed for the relative position of mines in their river catchments to be determined using the BOM Geofabric. Mined sub-catchments had an average size of 73 km^2 and were most common on Strahler 2nd order streams. This means that mines were on average 12 km from the headwaters, and 714 km from the river outlet. In most cases they were in confined or partly confined valley settings with a limited area of floodplain on which to deposit sediment. This meant that the sludge deposition was greatest once the river debouched onto a floodplain after valley confinement was reduced.

The impacts of increased sediment yield downstream were reported in contemporary newspapers (available on the TROVE archive). The impacts were so great that in 1886 an inquiry was

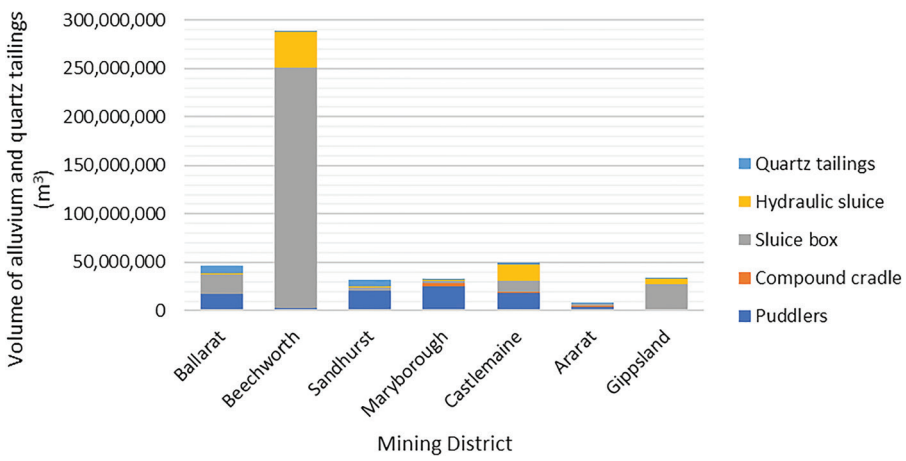

Figure 6. *The volume of alluvium and quartz mine tailings produced by different techniques in each mining district for the period 1859–1891.*

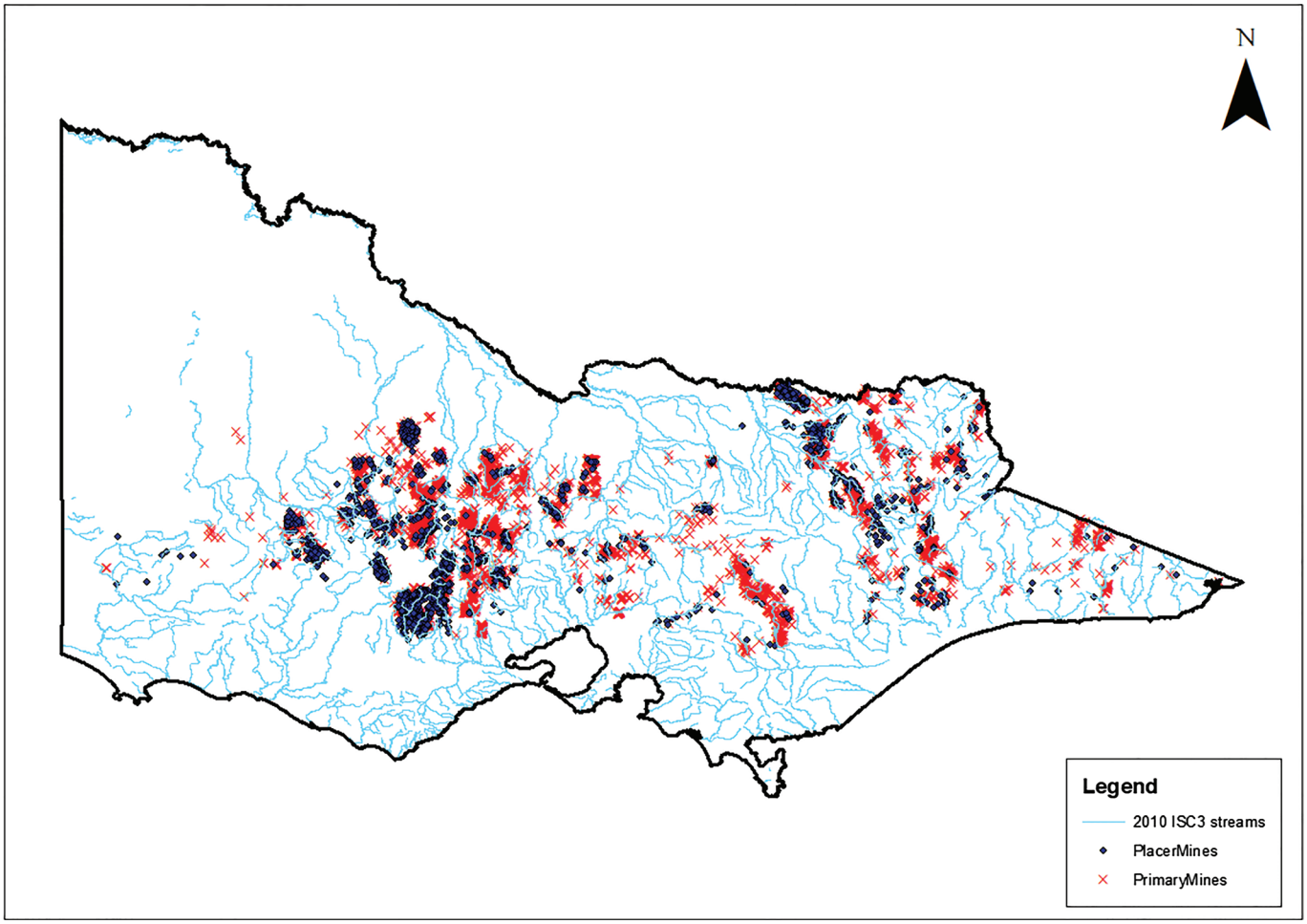

Figure 7. *VICProd and VICMine data of primary and placer gold mines for the period 1864–1960.*

set up to take evidence on the matter (Shakespear, Walker, and Rowan 1887). The descriptions recorded of sludge impacts could be linked to either a property or a general locality and thus could be mapped. Where it was possible to get estimates of depths of sedimentation or erosion from the evidence these were collated and mapped. It was also possible to infer rates of change from these data, which were also mapped.

Interpretation

After the dispersed disturbance from prospectors searching for gold, there was the sudden focus of attention to specific sites where gold had been discovered. Shallow shafts were excavated to the contact with palaeo riverbeds. Coarse sediment was left close to the shafts, and fine sediment, which was more likely to contain placer gold, was removed for processing. Riverbeds and banks were also dug up.

Rivers were employed as an industrial processing stage to winnow away the fines and to leave the gold. Different techniques were used including cradling, puddling, sluice boxes and ground sluicing. These techniques needed water to a greater or lesser extent. Ground and box sluicing predominated in the northeast of Victoria in areas such as the Ovens River. Puddling was more common in the drier more seasonal rivers in the west, (Figure 6). The different techniques influenced both the volume of sediment being delivered into the river and its size distribution. Puddlers supplied a much finer range of sediments, whilst sluicing tended to have slightly coarser sediment delivered to the stream. Our calculations suggest that 58% of the sludge came from ground and box sluicing (Davies et al. 2018a). The cumulative effect of large numbers of small-scale mining operations massively changed both the area of mining and the rivers downstream.

The volume of sediment from mining operations would have, on its own, completely changed the sediment budget of the river systems. An added factor was the change in the size of sediment being delivered during low and medium flows. Sands, silts and clays predominated, rather than the usual mix of fine to coarse sediment. The result of this constant delivery of sediment was that channel beds aggraded. Waterholes that were metres in depth filled up first, and then the channels as a whole started to fill. This loss of channel capacity, sometimes combined with an upstream diversion of water and the loss of vegetation, meant that channels spilled onto their floodplain more frequently.

Floodplains aggraded 1 m a^{-1} on average by 1886, and up to a maximum of 2.4 m (Figure 8). Extensive areas of floodplain were covered, up to 4–5 miles (6–8 km) laterally on the Ovens River. This inundation homogenised the floodplain surface and, in some places, the sludge was enough to kill the surface vegetation. This could be because the rate of deposition was too great, or the sludge baked hard after it was deposited creating a crust that inhibited plant growth. The combination of infilling and reduced vegetation roughness would have resulted

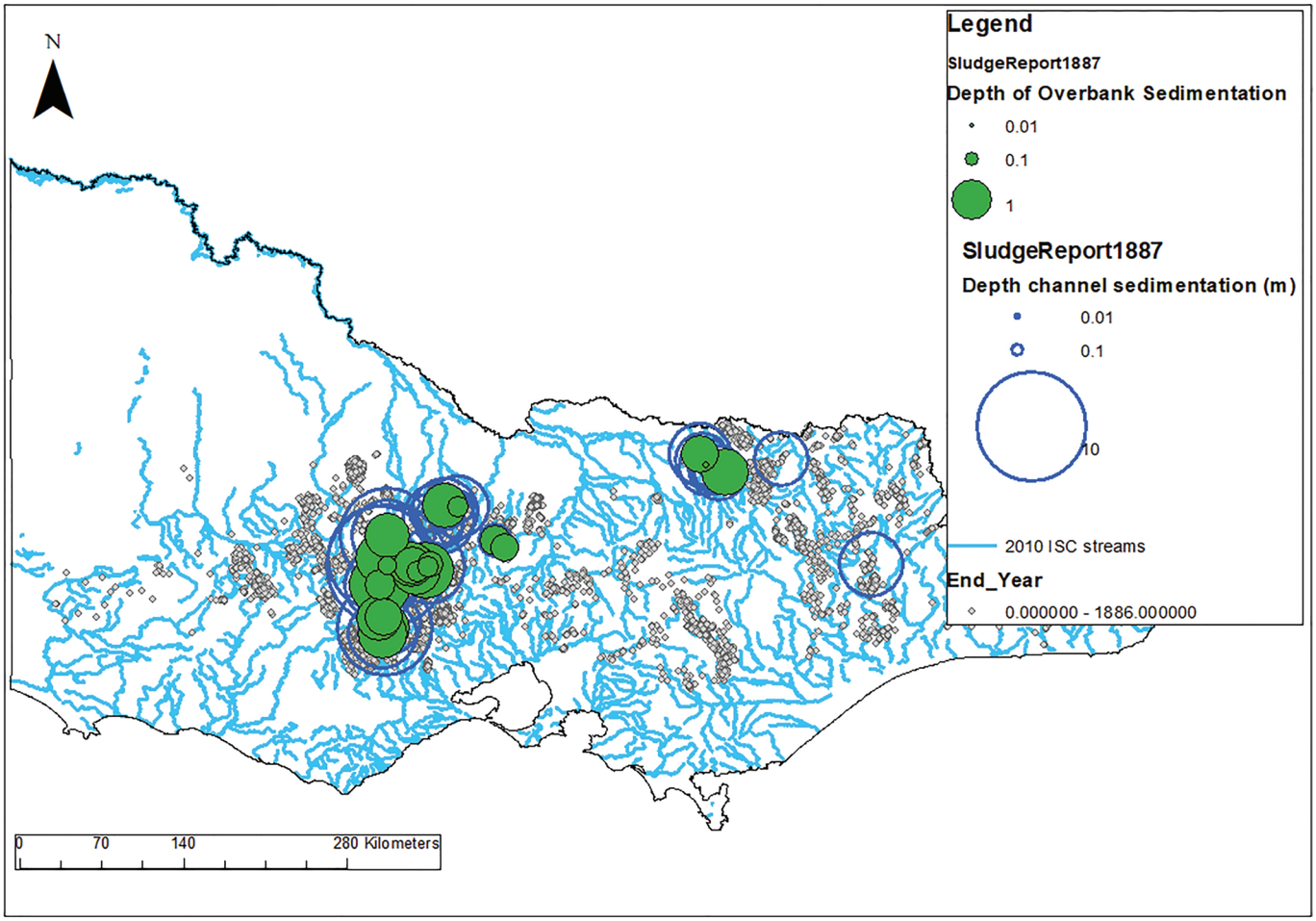

Figure 8. *Depths of overbank and in-channel deposition reported in the 1887 sludge inquiry.*

in a feedback effect, increasing the extent that water, and its associated sediment, could flow over the floodplain.

In some systems the mining of tributaries and the main channel led to aggradation to such an extent that tributaries were blocked and the streams back filled. This was the case in Tullaroop Creek and the Loddon River, where the confinement of the valley sides near the confluence resulting in the river channel being completely choked.

Whilst the fine and dissolved sediment fractions would have been transported all the way down river system, such as into the River Murray, the rest of the sediment appears to have deposited proximal to the mine sites, and was only transported 10's of km. Fans of sediment built up on floodplains downstream of the mines. The stream type and network configuration clearly played a part in determining how far sediment travelled. By 1886 stream avulsions were reported in 11 streams, forming new channels on the floodplain.

Stage 4: High volume mining (1880–1905)

Evidence

In the 1880s there was a gradual transition from a high number of dispersed mining leases with relatively low output operations, to a lower number mining leases in higher production centres. This transition was partly a result of technological advances, and partly a consequence of the reduction in the grade of available ore.

Hydraulic sluicing was a progression from ground sluicing, and was introduced into Victoria in 1860. Water was pumped under pressure through a monitor (nozzle) at the base of mining claims (Figure 9). Undercutting the sediment led to collapses from which the large clasts were extracted and stacked locally. The rest of the sediment was directed into sluice boxes, eventually ending up in the river system.

Giant monitors were introduced in the 1880s and needed large volumes of water. This equipment was mainly used in northeast Victoria particularly around Beechworth, Yackandandah and Mitta Mitta. *Mineral Statistics of Victoria* reveals that that up to 1.5 million m^3 of washdirt was produced per year (MSV, 1888). This resulted in around 13% of the state-wide sediment yield being produced by hydraulic mining between 1859 and 1891 (Davies et al. 2018a). The scars left on the landscape from sluicing can be detected using LiDAR imagery. One distinctive method of sluicing, also found in New Zealand, was herringbone sluicing (Figure 10). This concentrated sluicing approach results in a feather type pattern on the LiDAR. Subsequent revegetation makes this impact harder to distinguish in photographic imagery.

The upper part of one of our study catchments, 3 Mile Creek, a tributary of Hodgsons Creek (Figure 3) had been hydraulically sluiced. Using the LiDAR available from DEWLP we mapped the area of the hole left behind by the sluicing (Figure 11). A 35° slope was used as a mask to help delineate the top of the scarp faces. This produced an area of 1 185 740 m^2. Mining had not

Figure 9. *Hydraulic sluicing on the Mitta Mitta (source: State Library of Victoria).*

occurred uniformly in the hole, and there were some pillars of sediment remaining on the valley floor that showed where the original surface had been. The elevation of these pillars was extracted and modelled using ARCGIS, along with the elevations of the tops of surrounding scar walls, to approximate the old valley surface. The two surfaces were extracted from each other and the volume change was calculated as –5 327 642 m^3.

Mining of primary deposits resulted in adits being blasted along quartz reefs associated with the gold. In order to reach underground deposits, the overburden was removed, and this was often stacked locally. Processed sediment was also stacked in mullock heaps. Some of these heaps are listed in the Heritage Council of Victoria's database. Mullock heaps that were proximal to river systems contributed sediment directly into the river system, especially during high rainfall flood events (Figure 12).

Once the ore rock was extracted it was crushed. Mechanisation of this process increased over time, leading to the development of large stamp batteries. Crushing produced fairly standard sand sized clasts. These sand grains were less rounded than fluvially transported grains, and can be used a physical tracer in some environments. This was the case in the Leigh and Yarrowee Rivers where sand was deposited on the floodplain, blown up the hillsides and, ultimately, into sheep wool causing a reduction in wool value.

Data on the location of mining for primary deposits is in the VICProd/VicMine database (Figure 7). This database also contains attributes relating to shaft dimensions and orientation, alongside estimates of gold production.

Interpretation

Hydraulic sluicing of alluvial deposits was concentrated in northeast of the state and resulted in localised higher rates of deposition on floodplains. It also contributed a broader range of sediment sizes into the river channel. This method has resulted in holes in upland landscapes that now have a very limited capacity for adjustment.

Mining for primary deposits was much more targeted than mining for secondary/alluvial deposits. Mercury and cyanide were also used in processing (Rae, 2003). As a consequence, there are more likely to be higher concentrations of contaminants in the sludge derived from mining for primary deposits. Conversely, the sludge is more likely to contain sand sized grains that are less likely to adsorb contaminants than finer silts and clays.

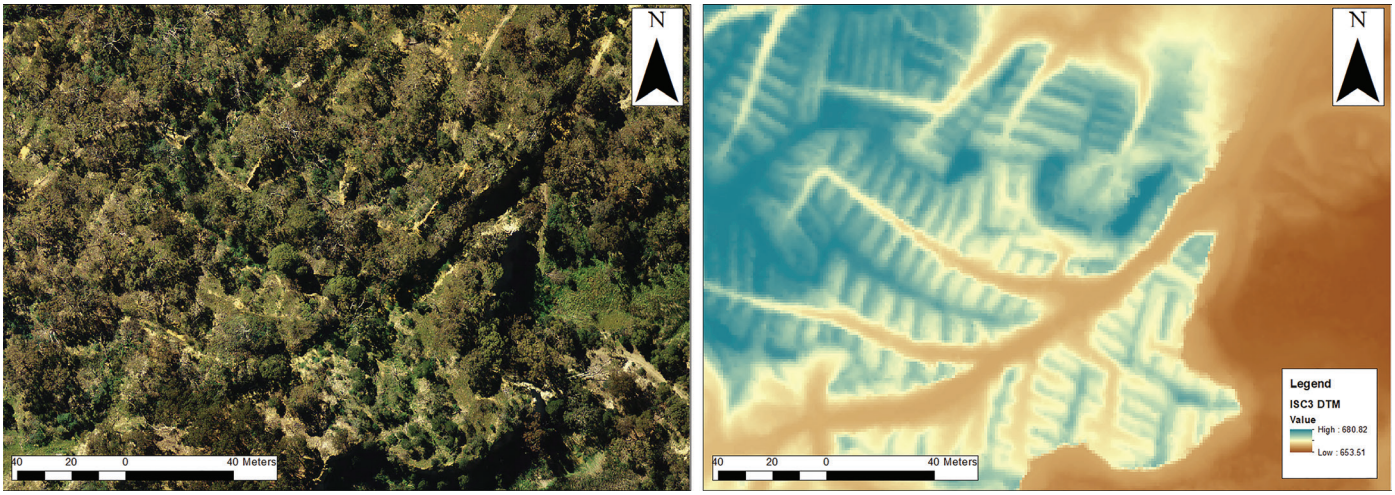

Figure 10. *The impact of herringbone sluicing near Omeo apparent in photographic imagery and (left) and LiDAR (right). (source: Department of Environment, Land, Water and Planning).*

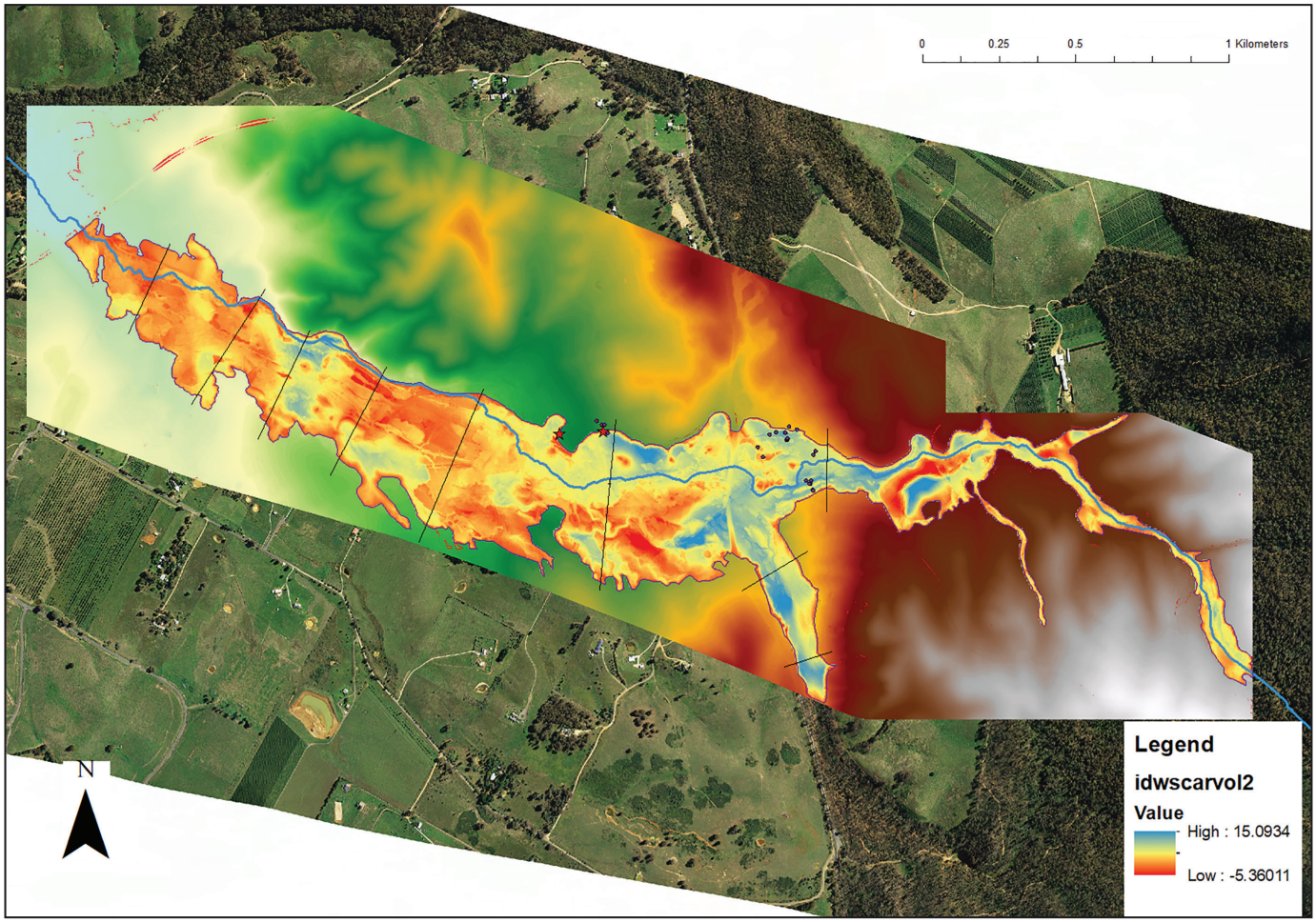

Figure 11. *The estimated surface changes a result of mining in the 3 Mile Creek valley, negative numbers are erosion and positive are deposition. (source: Department of Environment, Land, Water and Planning).*

Figure 12. *An example of primary mining at the Jim-Crow Diggings showing the mullock heaps and the disturbance to the river channel (source: State Library of Victoria)*

Stage 5: Environmental regulation (1905–1950)

Evidence

Parliamentary Acts and inquiries, alongside newspaper reports, reveal that initially the regulatory approach to managing sludge was to move it elsewhere, such as via channels to larger streams. Mining claims were also protected by constructing infrastructure so that the sludge did not halt mining activities. Later legislation attempted to deal with the sludge at source, penalising miners for polluting channels (Lawrence and Davies 2014). The Mines Act of 1904, and its amendment in 1907, led to the creation of the Sludge Abatement Board (SAB). Inspectors from the SAB could impose fines for polluting waterways.

The detention of sludge near to its source and its stacking at mine sites were some of the consequences of this change in legislation. Sludge dams were built around mine sites, changing the landscape of many tributaries and resulting in localised accumulation of fines either in channels or close by. On Hodgsons Creek these sludge dams are recorded in early maps, and can be seen in the current LiDAR imagery. It is easy to see them by using a slope layer derived from the DTM as they are flat surfaces on the landscape (Figure 13). They are estimated to contain up to 0.3 million m^3 of sediment.

Whilst some detention dams were used as a terminal store for sediment, there are records to suggest that some were flushed during high flows, when inspectors would be unable to detect

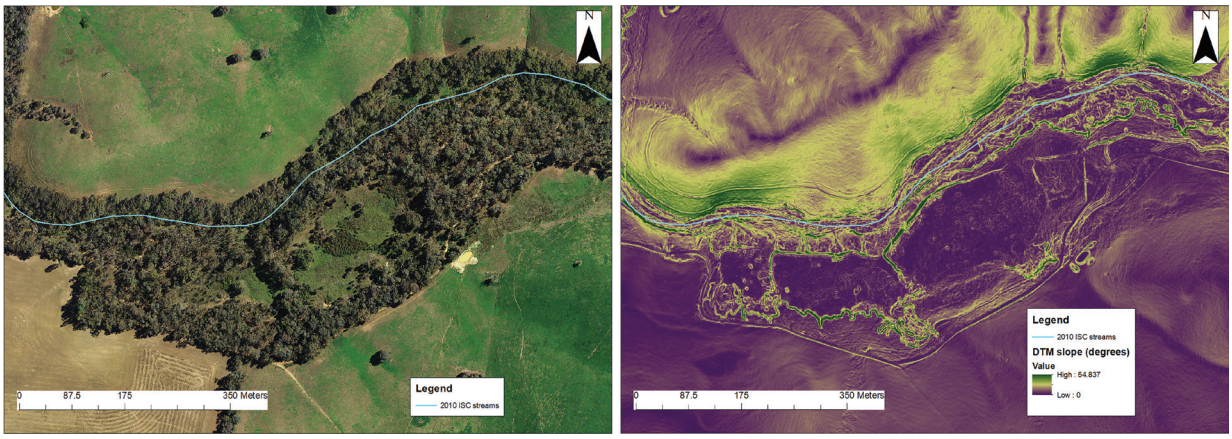

Figure 13. *Sludge dams on Hodgsons Creek imaged using aerial photography and a LiDAR DTM. (source: Department of Environment, Land, Water and Planning).*

the activity. This would explain the relatively small volume of the dams on Hodgsons Creek compared the volume of sediment produced.

Inference

Increased regulation led to much greater storage of sediment proximal to mine sites. Sludge yields would have decreased, although there would still have been sediment accidentally or deliberately discharged during flood events. The result is that there are pockets of fine sediment stored in stream headwaters, and these sediments may include contaminants.

As environmental regulation of sludge was being enforced there was also a decline in gold yields. Fixed gold prices and the First World War meant the end for large scale alluvial and quartz reef mining.

Stage 6: Dredging (1899–1950)

Evidence

"*Since dredging started the sludge had alarmingly increased in volume, and now possessed chemical properties which threatened to gradually convert the flats into waste land. Farmers stated that there was no place within six miles south of Eddington where stock could obtain water at the river, and serious losses must occur during the summer. The capacity of the Laanecoorie Weir had been reduced by fully one half, and the water trusts should know that the weir would be practically useless in a few years. It was estimated that at high' water mark there was an average depth of only four feet*" (The Age 1905, 6)

Dredging commenced at around 1899 and was the last major technological change in gold mining in Victoria (Davies et al. 2018b). Initially steam driven, and later electric powered, dredges minimised the use of manpower and maximised the volumes of sediment that could be excavated (Figure 14). There are various types of dredging. Within the VicProd, VicMine and Mineral tenements "Minten" (DEDJTR 2013) databases dredging data can be extracted, however these data include sluicing as well as dredging. We have extracted bucket dredging from the data as this was extensive across Victoria and had reasonable records. From these data we estimate over 100 000 000 m^3 of sediment was excavated by more than 115 bucket dredgers, mostly in the Ovens and Loddon catchments in northern Victoria.

LiDAR and aerial data from 2009–2010 were used to examine the sites identified using the spatial data. These data were used to look for any evidence of dredging. Features included

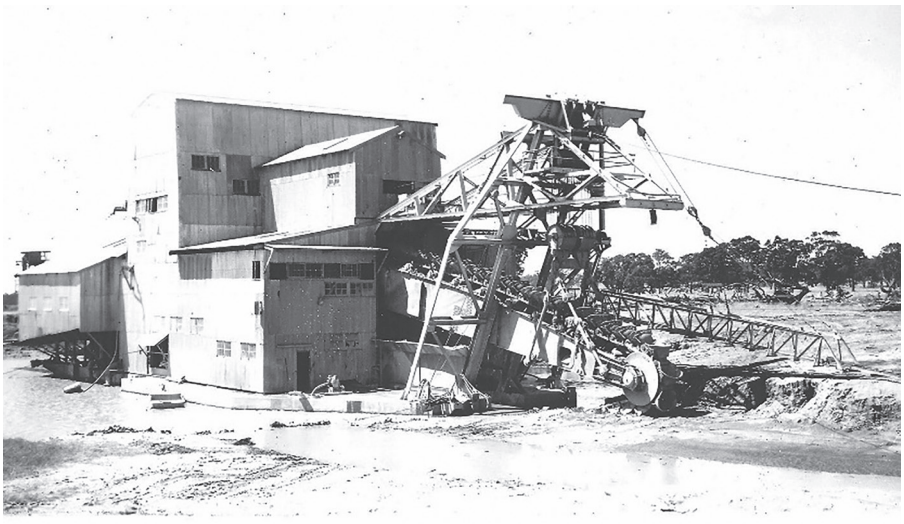

Figure 14. *A photo of the Newstead Dredge on the Avoca River floodplain showing the buckets at the front of the machine. (source: Avoca Historical Society).*

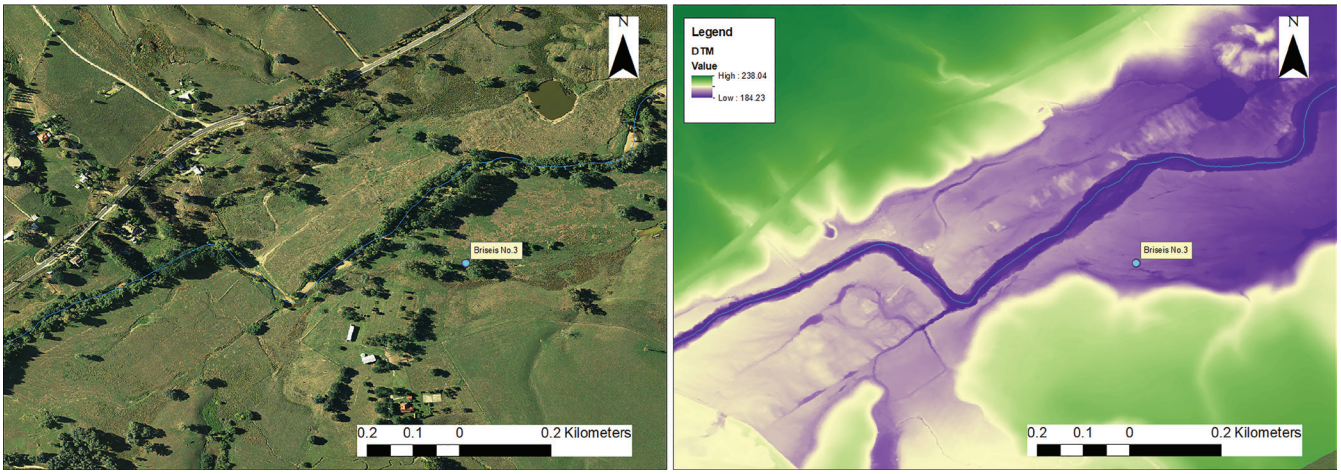

Figure 15. *A linear dredge track, and an associated channel diversion, shown using aerial photography (left) and LiDAR (right). (source: Department of Environment, Land, Water and Planning).*

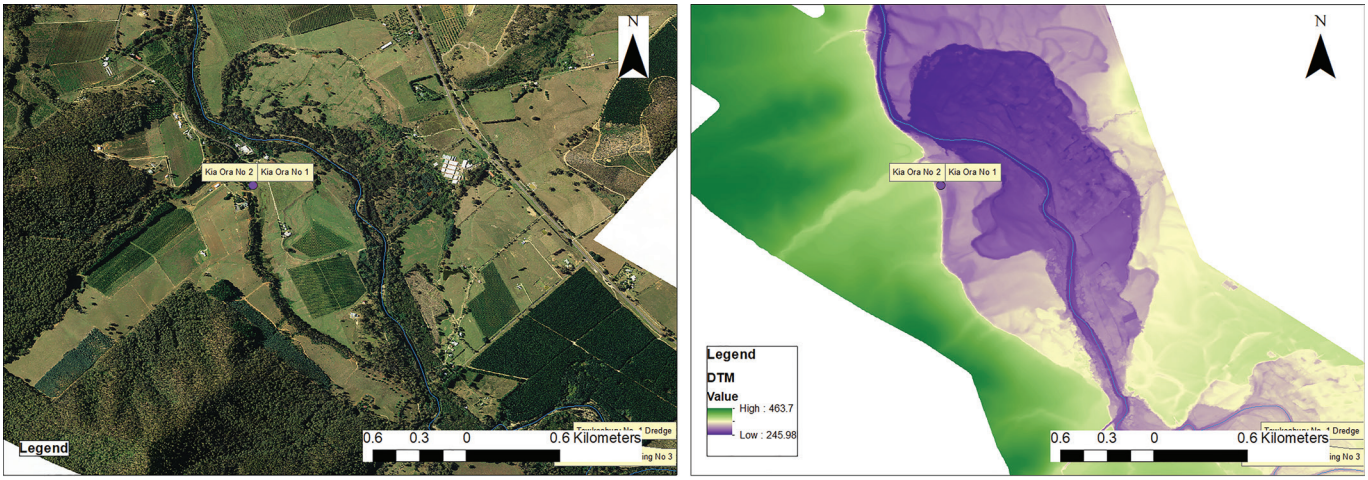

Figure 16. *A dredged floodplain on the Ovens River indicated by the loss of palaeochannels, shown using aerial photography (left) and LiDAR (right). (source: Department of Environment, Land, Water and Planning).*

dredge pools, and depressions or linear marks that indicated a dredge track (Figure 15). The absence of floodplain features such as palaeo-channels was also evidence that dredging had occurred (Figure 16). The 2010 land use present at the dredge sites was identified using high resolution aerial (0.15 m^2 pixels) and satellite imagery, and was manually classified by the vegetation type and the presence of urban features (Figure 17).

Bucket dredges were a floating factory up to 167 m in length. They either sat in the channel or had an artificial lake formed on the floodplain to house them. At the front of the dredge was a chain of steel buckets that could be manoeuvred and raised up and down so that the sediment in front of the machine could be excavated (Figure 14). They did not operate well in stiff clays, but were able to excavate coarse sediment up to the size of cobbles. Clean, reliable and plentiful water was essential for dredging operations, firstly to enable the dredge to float, and secondly for the treatment of alluvium. Water from upstream or from bores was used, and settling ponds both settled fine sediment and provided a clean source of water to be re-used.

The largest dredges could dig down into fluvial gravels to a depth of 40 m. During the excavation the dredge separated out coarse and fine sediment using a rotating cylindrical screen. The fines were passed over undulating riffles allowing the gold to settle out in the hollows. Mercury was sparingly used to amalgamate the gold, however, the full details of its use are unknown (Davies, Lawrence, and Turnbull 2015).

The excavated sediment was deposited out of the back of the dredge, either into the dredge hole or into a settling dam. The result of this was a complete stratigraphic change in the channel margins or the floodplain, often leaving behind layers of fines topped by coarse sediment. Early complaints about the coarse material deposited near the surface led to the use of more advanced redistributors that put fines on the surface. Advance stripping was also undertaken by removing the top layer of soil and storing it nearby. Once the dredging was completed the soil would be replaced over the surface. The stacked sediment, and the dredge pond itself, were exposed to flooding and were a continuing source of sediment.

Interpretation

Whilst we understand the likely volume of sediment that was excavated on floodplains, we do not yet fully understand the impact of the early in-stream dredging, or how much sediment entered waterways from dredge operations on floodplains. Clearly

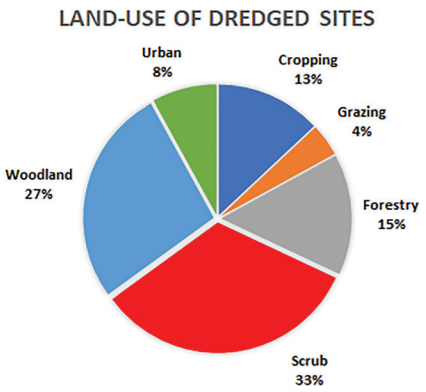

Figure 17. *Land-use on historically dredged sites identified using aerial imagery from 2010 and current satellite imagery.*

there were circumstances where there were releases of sediment into the channel, some of which may have been deliberate and others accidental. Any sludge that was released entered into a channel already modified by previous mining, exacerbating the issues of overbank deposition and reducing water quality.

Dredging activities also included the straightening of river channels, or when the channel itself needed to be mined, the relocation and replacement of a channel – in the same position with the original dimensions. This latter practice makes it difficult to identify where dredging had altered the channel, however, sometimes the channel was "rocked" to limit channel migration into the subsequent mining pond.

Increased numbers of reservoirs for water supply and flood mitigation had been constructed by the time dredging commenced. This suggests that any offsite impacts from sediment mobilisation might be mitigated by storages north of the divide in the west of Victoria, but this was not the case in the rest of the state. In particular in the Ovens River, where the majority of dredges operated, no dams and weirs have been constructed. Thus, any disturbed sediment could have been transported throughout the Ovens River.

The *Bendigo Advertiser* (1906, 2) suggests that Laanecoorie weir was considerably built up with sludge, with about 18 inches (0.45 m) of silt on the bed, and 10 inches (0.25 m) on the sides. More sediment was deposited at the head of the reservoir. When the water level dropped a channel 14 ft (4.2 m) wide and about half a mile (800 m) long was cut through the sludge and the resulting sediment was deposited downstream for about ¾ of a mile (1.2 km) on the riverbed.

The differential deposition of sediment in the dredged area led to unworkable surfaces for agriculture and, even with surface pre-stripping, the lower soil structure was not favourable to plant growth. Sub-surface groundwater flows removed layers of fines leading to sinkhole development. The current land use patterns in these areas (Figure 17) shows that they are not being used for intensive agriculture, and it is likely they will never fully recover because of the depth of disturbance.

Stage 7: Incision and downstream redistribution (non-dredged sites approximately 1890s, dredged sites approximately 1930s – 80s)

Evidence

The reduction in mining activities, mining sludge legislation and its enforcement, removal of in-stream wood, construction of levee banks, bank stabilisation and continued regulation of river systems led to rapid incision of channels. The reduction of sediment yield combined with the increased catchment runoff after vegetation clearance meant that both natural and artificial channel deepening occurred and this reduced flood risks. The current stream network in Victoria has many examples of incised streams; however, the exact timing of their incision is not well documented. We have used historic photos, reports and newspapers to suggest that much incision may have occurred before dredging started. In some cases where dredging occurred there was further aggradation in the channel followed by incision when it stopped. Most of the evidence appears to suggest that incision in mined streams had occurred by the 1930s, or was underway by that point in time (Figure 18).

Channel incision meant that the sludge deposited on the surface was removed and often the erosion continued down into the original pre-sludge floodplain. The riverbanks clearly show a transition between a darker pre-sludge floodplain and a lighter sludge layer. Similar layering results from clearance triggered deposition followed by erosion, but deposition resulting from mining is indicated by finer clast sizes with less evidence of coarse sediment in flood couplets.

To verify the source of the sludge sediment on the Loddon River we used an Olympus Delta XRF gun in the field and in the lab. The stratigraphy of the riverbanks was described, and XRF measurements were taken on the riverbank surface providing

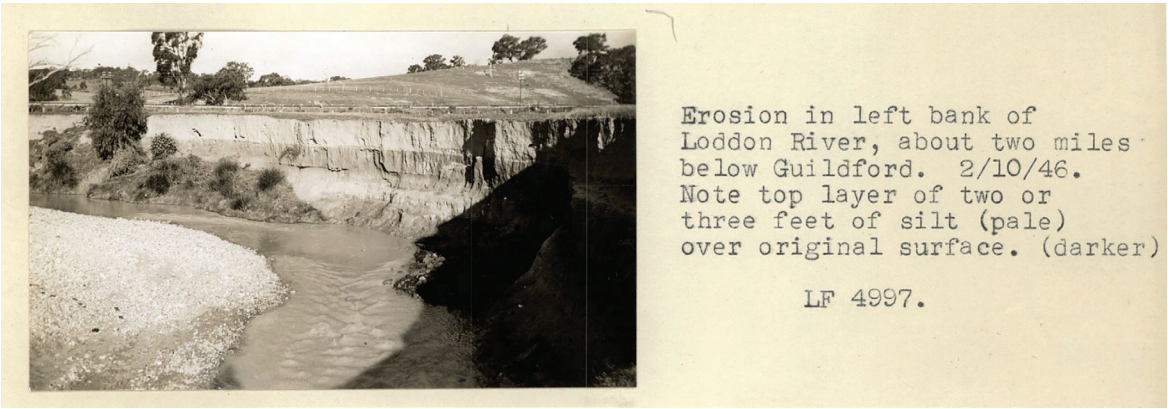

Figure 18. *A photograph taken of the Loddon River near Guildford in 1946 showing the light-coloured sludge layer on top of an older and darker floodplain surface (source: River Basin Management Society).*

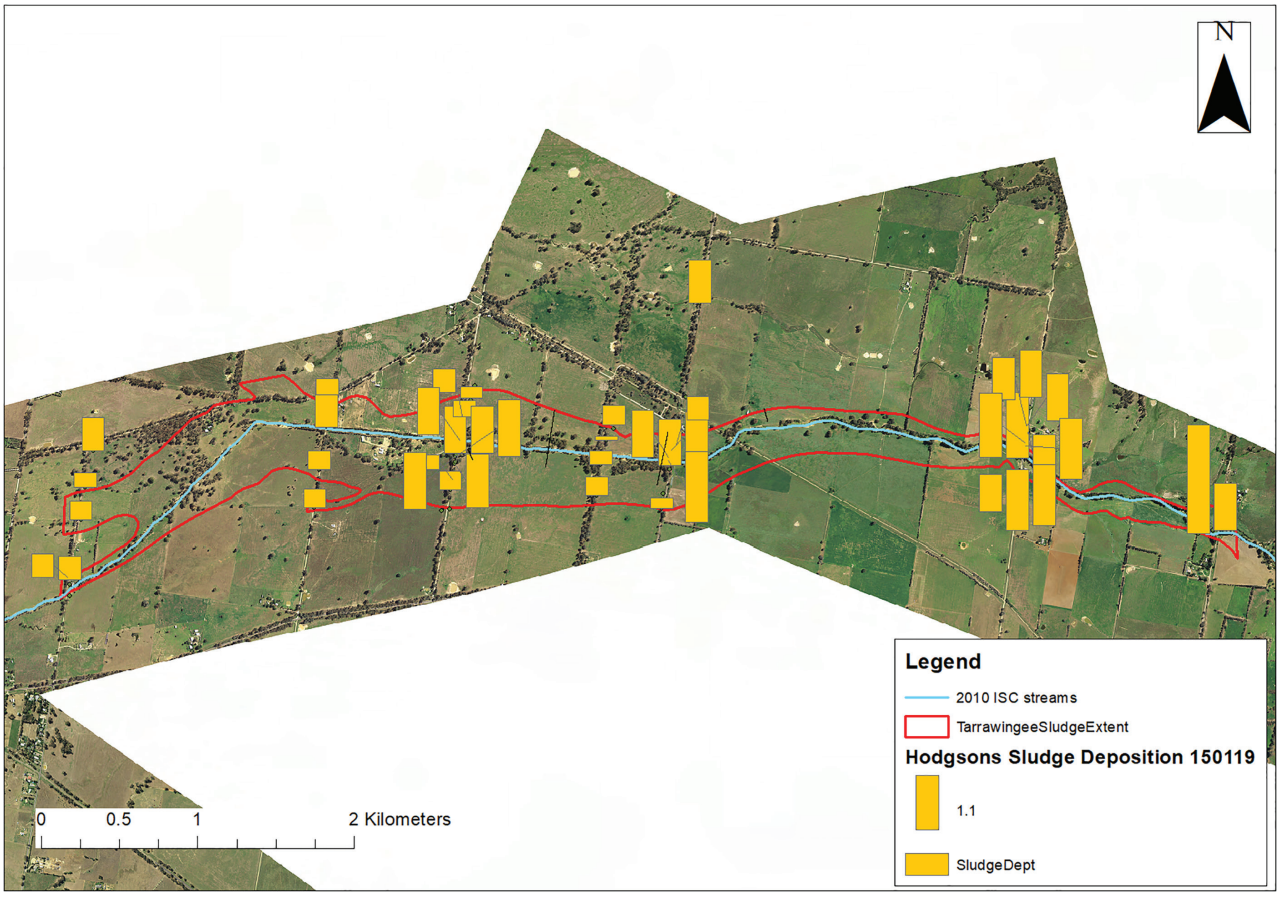

Figure 19. *Depths of sludge (m) across the Hodgson Creek floodplain, shown against a prospector estimate of sludge extent (red outline).*

a range of elemental compositions within 90 seconds. The samples were then removed, sieved and re-analysed using XRF and acid digestion. Source sediment was taken from spoil heaps at the top of the catchment. Arsenic was found to be a good indicator of mined sediment, most likely associated with the primary source of the gold. Manganese and a higher organic content appear to be good indicators of the contact sediment in the pre-sludge floodplain.

An attempt was made to use multispectral satellite imagery to identify sludge extents, following the method of Kotsonis and Joyce (2003), which was used in Bendigo. This was not successful, and we found that we could not repeat the process in the same location or elsewhere.

In the Hodgsons Creek system transects were hand cored across the floodplain looking for a change in colour, sediment size and chemical composition. These cores have been combined with data from prospecting carried out under exploration licenses. (Figure 19). This has allowed an estimate of the deposited sludge volume to be made of 2.5–3.5 million m^3. This means that Hodgson Creek may contain most of the eroded sediment from the upper catchment (Figure. 20).

Inference

Whilst our analyses of the chemical composition of sludge is still ongoing, it is clear there is a downstream reduction of sludge volume and concentration as expected. The incision of the sludge with the cessation of mining meant that there was a secondary pulse of sludge that had the potential to move further down the river system, however, this may have been limited in places by increased regulation.

The depth and appearance of sludge when exposed in an incised riverbank is fairly obvious, especially proximal to mining where it is particularly thick. Further down the system and out onto the floodplain it becomes more difficult to identify visually, and this is where the geochemistry has been extremely useful. Sampling does, however, need to take into account the likely sedimentation processes that have occurred both in-channel

Figure 20. *A 2 m section of sludge above the previous floodplain contact (left) and holes showing where sample were taken for geochemical analyses.*

and on the floodplain. Down the Loddon system there was a geomorphological change from confinement to an open floodplain, and then further confinement before a large slope change as the system becomes anabranching. This means that incised sludge could be found upstream, but not in the confined mid-lower catchment as there were limited surfaces for its deposition. The depositional downstream reaches are not as incised, and the sludge appears to have been laterally accreted within the channel and thus is only found in limited quantities on the floodplain.

Conclusions

The eighth and contemporary stage of channel management is one of stabilisation. Channels are being assessed for their stability and managers are actively strengthening channel margins to reduce "loss of land". This approach is slowly changing, however, with rivers being allowed the freedom to move where infrastructure is not threatened. Knowing the fate of historically mined sediments will become increasingly important in helping to understand how this new management ethos will affect the mobilisation of contaminants stored on the floodplain.

We have calculated that over 25% of the length of major streams in Victoria have been affected by sludge generated by mining. Much of the adjacent floodplain has been able to revegetate and become agriculturally productive. The past damage has been forgotten. The upstream scars produced by hydraulic sluicing and the mining of primary deposits will take an extremely long time to recover, and many now remain as forested regions as their productive use is limited. The same is true of the dredge holes created by bucket dredging.

The multidisciplinary approach described in this paper used historical research to understand the volumes and locations of sediment production. Combining these data with sediment geochemistry has meant we could describe the consequences of the supply of sediment from mining into river systems. The original stream channel geomorphology and current catchment characteristics were paired with historical descriptions of sludge impacts. This allowed the size, location and chemistry of deposited sediments to be budgeted against its original supply characteristics.

This project also provides a stepping stone for a better understanding of where aboriginal artefacts might be found. They will be underneath the sludge rather than on the surface. There are also implications for reconstructing pre-European settlement landscapes and vegetation, and pre-sludge floodplain sediments have the potential to act as seed banks.

The creation of a higher resolution flood record alongside a detailed stratigraphic description of floodplain deposits is currently being undertaken, aided by the use of Optically Stimulated Luminescence. This should help to determine whether the depositional sequences observed are the result of mining operations, flood conditions or a combination of the two. The project is also trying to develop a better understanding the bioavailability of heavy metals in the sludge and the consequences for human health.

Acknowledgement

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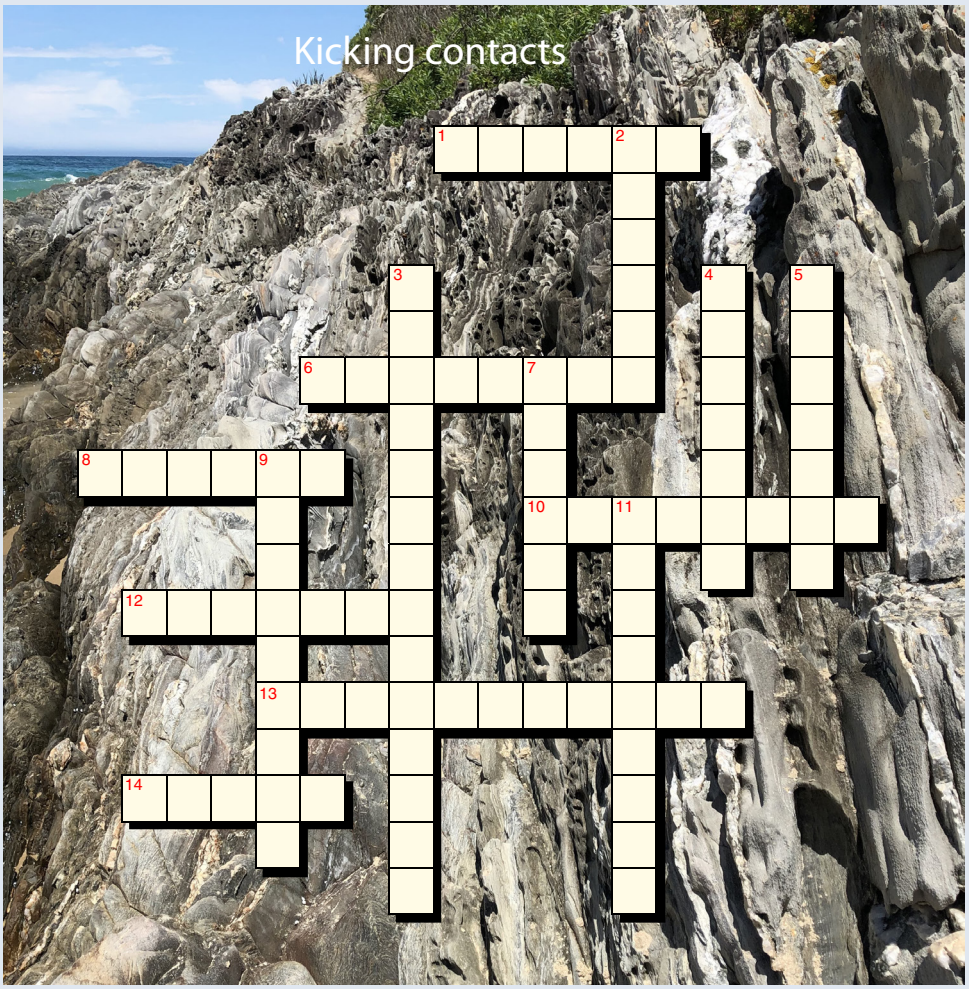
Preview crossword #2



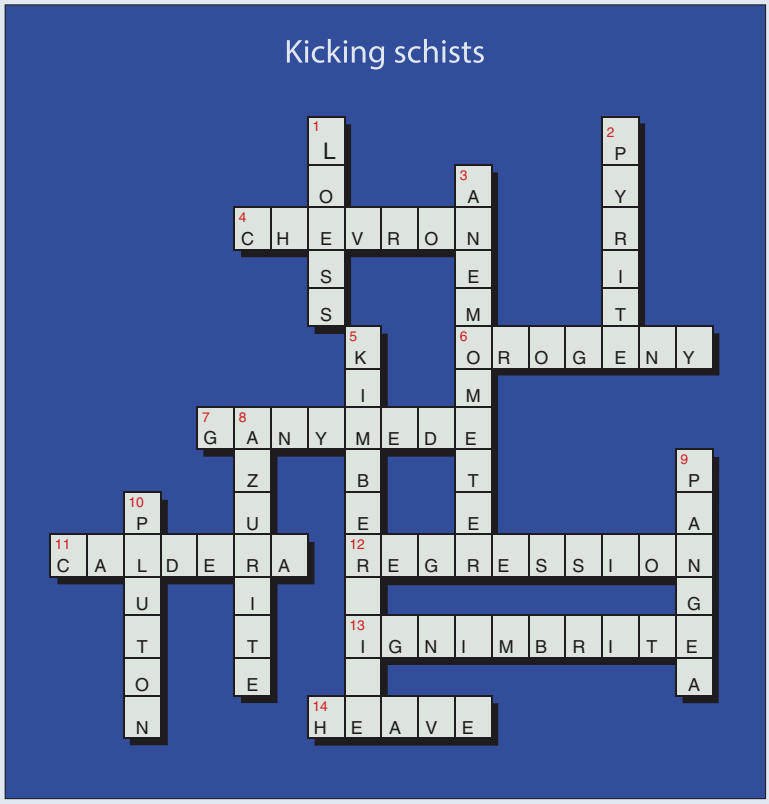
Across	Down
1. For small strains, this law states that a given strain is directly proportional to the stress producing it.	**2.** Hungarian mathematician and physicist who invented the torsion pendulum and for which the unit of gravity gradient is named after.
6. A fine-grained, granoblastic contact metamorphic rock formed by recrystallisation of shales.	**3.** The term describing the property of permanent magnetism in naturally occurring iron.
8. Asymmetric landform consisting of a steep scarp slope and a more gentle dip (or back) slope.	**4.** The zone of greatest ocean depth.
10. The name given to the very first detected and confirmed interstellar object that passed within the orbit of the Earth and therefore through the Solar System in October 2017.	**5.** A narrow strip of land connecting two larger land masses.
12. Location of the test range for benchmarking the capabilities of airborne gravity, airborne gravity gradiometry and other airborne sensing systems in Western Australia.	**7.** The smallest of the Galilean moons.
13. The loss of energy or amplitude of waves as they pass through media.	**9.** The first lecturer in exploration geophysics in Australia (last name only).
14. A method of remote sensing that uses light in the form of a pulsed laser to measure ranges to the Earth.	**11.** Events seen in seismic data that have undergone more than one reflection.

Play to win!!

Send your answers to previeweditor@aseg.org.au. This time, to make the competition a bit more interesting, the **fifth** correct entry received from an ASEG Member will win two Hoyts E- CINEGIFT passes. The solution and the winner will be published in the next edition of *Preview*.

Good luck!

Preview crossword #1 solution

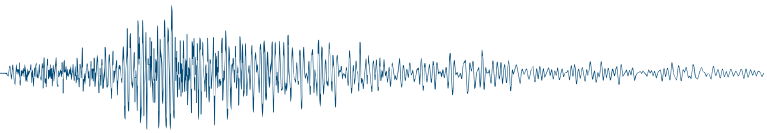


Winner

The winner of the first *Preview* crossword competition was Queensland Member Nicholas Josephs. Nick has won two Hoyts E- CINEGIFT passes. He submitted his correct entry just over an hour after the April issue of *Preview* was published online. Fast work Nick!! A close runner up – but no banana – was West Australian Member Regis Neroni.

To make the competition a bit more interesting for Members who might be a trifle slow to view *Preview* after online publication, the winner of the next crossword competition (Kicking contacts) will be the **fifth** Member to submit a correct entry to *previeweditor@aseg.org.au*

Business directory



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16–20	8th International Geosciences Student Conference	Uppsala	Sweden
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29–31	2019 SEG Geophysics for Smart City Development Workshop https://seg.org/events/smartcitychina	Beijing	China
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22–25	2019 GSA Annual Meeting https://www.geosociety.org/GSA/Events/Annual_Meeting/GSA/Events/gsa2019.aspx	Phoenix	USA
October	**2019**		
6–9	SAGA 16th Biennial South African Geophysical Association Conference and Exhibition http://sagaconference.co.za/	Durban	South Africa
21–24	Fifth International Conference on Engineering Geophysics (ICEG) https://seg.org/Events/ICEG-2019	Al Ain	UAE
29–30	Asia Petroleum Geoscience Conference & Exhibition (APGCE 2019) www.apgce.com	Kuala Lumpur	Malaysia
29–31	OTC Brazil http://www.otcnet.org/Brasil	Rio de Janeiro	Brazil
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14–15	Dorothy Hill Women in Earth Sciences Symposium https://absoluteevents.eventsair.com/dorothy-hill-women-in-earth-sciences-symposium-2019/	Brisbane	Australia
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March	**2020**		
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11–16	SEG International Exposition and 90th Annual Meeting	Houston	USA

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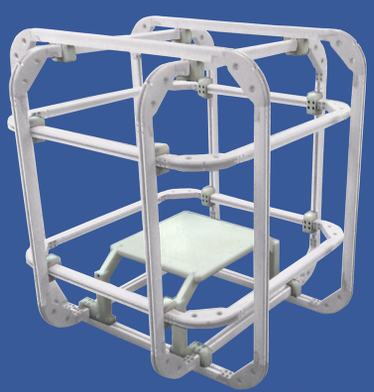

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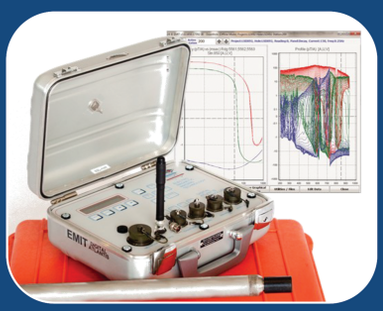

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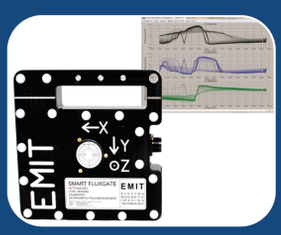

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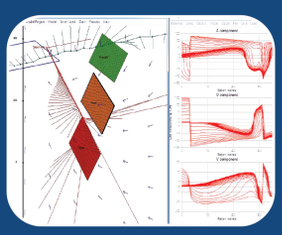

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