Education Matters

Michael Asten
Associate Editor for Education
michael.asten@monash.edu

This month we continue our series on science education in schools, with an article from Ofa Fitzgibbons of the CSIRO Education and Outreach group. This group aims to encourage science technology engineering and mathematics (STEM) education by linking practising scientists with class-room teachers in secondary schools. Such an education initiative complements programmes discussed in past issues of *Preview*, such as the ESWA field programmes (*Preview* February 2016) and TESEP workshops for science teachers (*Preview* December 2015).

We also bring news of a new initiative in marine geosciences – the CAPSTAN project, which will stir the imagination of budding scientists with an interest in all that swims, floats or sinks.

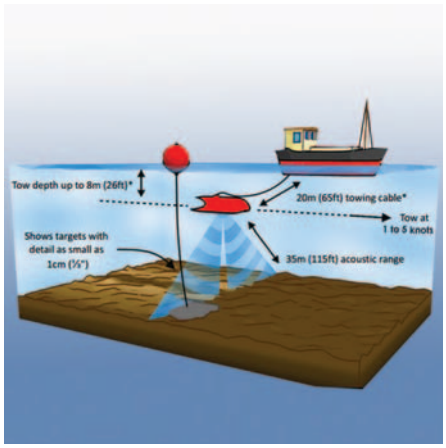
Doug Roberts brings us good news of strong interest in the ASEG Research Foundation, and lastly, supplementing our list of thesis abstracts as published last December, we have six abstracts from Western Australia, including from three ASEG Student Award winners. Special congratulations to Jacob Jackson who won the ASEG WA student night Best Presentation Award for his talk on long offset refraction tomography.

Bringing real life science into the classroom fosters STEM education

For a small group of year 4 and 6 girls at St Mary's Anglican Girls School, Karrinyup (north of Perth, WA), an introduction to engineering, mathematics and science experiments have taken a new spin thanks to Roger Fletcher. Roger is a geophysicist who worked with the school's science teacher Dencker Morrison to bring science to life in the classroom. Doing these experiments in the classrooms is a chance for Roger to share his enthusiasm for engineering, mathematics and science related subjects with the next generation. For Dencker, the experience of working closely with Roger to develop activities gave her an insight in to an area of science that she will now be able to bring to her teaching practice.

Roger Fletcher.

For a number of sessions during one school term, Roger shared some stories of his professional experience with the students, from his schooling to a degree in Material Sciences, to various jobs including doing hydrographic surveys around the world using instruments like side scan sonars.



An example of a sea sonar similar to what was used by Roger during his professional career. Image source: http://seafloorsystems.com/images/com_hikashop/upload/tritech-starfish-990f-diagram.png.

Roger's background in geophysical surveying and large engineering projects enabled him to provide real life examples of how mathematics and engineering can be used for tasks like profiling the ocean floor and dredging seabeds. He ran a number of 'show and tell' sessions with the classroom, which involved sharing visuals and images of his work experience out at sea (see pictures). These sessions offered students a practical insight into the area of surveying and geophysics.

An example of a weather station on a lake representative of Roger's work with the Centre for Water Research. Image source: Google.

Science, Technology, Engineering and Mathematics (STEM) subjects and skills are now considered essential to driving industry innovation in Australia. Yet there is increasingly more public discussion around the critical shortage of STEM skills and the declining participation rates of school students undertaking STEM subjects in school. The Scientists and

Mathematicians in Schools (SMiS) helps address this challenge.

As Australia's largest skilled volunteering programme for STEM professionals and STEM educators, SMiS offers participants the opportunity to make a positive difference to the education of Australian students from kindergarten to senior secondary. Managed by CSIRO, the programme creates flexible partnerships by matching professionals and educators and providing ongoing support to build a collaborative partnership. This means partnerships leverage the expertise of each person to create classroom experiences not otherwise possible if each participant was acting alone.

At St Mary's Anglican Girls School, Roger was able to help demystify complex mathematical themes by doing experiments with rulers and protractors to triangulate a position on a marine map of Perth. The activity also highlighted aspects of geodesy, to account for time zones and curvature of the Earth. This is one of the many ways in which a STEM professional and teacher can showcase real-world, contemporary science experiences for students.

For teachers, the programme really gives educators a chance to build on the natural curiosity the students have about how the world works. Creating modern science experiences also helps to foster their critical thinking and problem solving skills, while at the same time, allowing them to have a lot of fun with science.

For professionals and scientists, the benefits are many. 'Seeing the fascination and awe in the face of the students as they get hands on experience of building a model rocket for the school's open day is a real highlight for me', said scientist Roger Fletcher. 'I am passionate about my vocation and experience, and enjoy being able to inspire young students about science.'

Ofa Fitzgibbons

CAPSTAN: a new initiative in marine geosciences

A new programme, the Collaborative Australian Sea Training Alliance Network (CAPSTAN) is under development by ten universities and government bodies. It is the first of its kind as a sea-based training programme for postgraduate students on-board Australia's principal research vessel, RV Investigator.

In 2017–2019, three pilot voyages will be run with up to 30 postgraduate students along with research active academics and trainers. A series of stake-holder surveys is currently in progress in order to define the scope of the programme, and enrolments for master-level students on the first pilot mission in mid-late 2017, will open in 2017. Current partners include:

Macquarie University • Marine National Facility – CSIRO • Geoscience Australia • Integrated Marine Observing System • Sydney Institute of Marine Science • Department of the Environment – Australian Antarctic • University of Tasmania • Australian Maritime College • University of Canberra • Australian National University • University of Sydney • University of New South Wales • University of Technology Sydney • University of Western Australia • Western Sydney University.

The intention is to gain additional funding and collaboration from industry partners.

Up to date information is available from the project website at http://research.science.mq.edu.au/capstan/, and from the Chief Investigator, Dr Leanne Armand at Macquarie University, leanne.armand@mq.edu.au.

A record number of applications to the ASEG Research Foundation

Our Research Foundation is now in its 27th year of operation (see its history described in *Preview* December 2014, available online on our website at http://www.publish.csiro.au/?act=view_file&file_id=PVv2014n173p44.pdf). This year the ASEG RF reports a record number of applications for grants – eighteen from seven universities in total, compared with about eight per year in the past. Three sub-committees are currently assessing the documents.

Project proposals cover the full spectrum of applied geophysics, with seven in mining geophysics, eight in petroleum and two in engineering geophysics. The RF expects to distribute about $100 000, spread over three years, to support a selection of these projects.

Student geophysical projects at Curtin University and University of WA (2015)

Postgraduate Student Projects

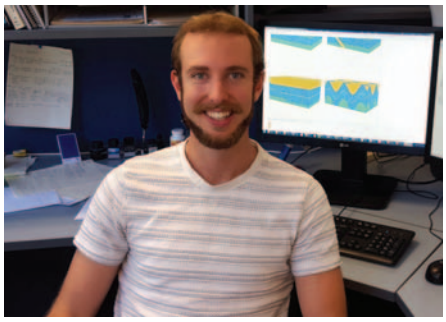
Jacob Jackson, Curtin University: *The application of long offset refraction tomography to improve seismic reflection imaging in the Perth Basin.*

Refraction tomography methods have long been applied to near surface applications including groundwater exploration. The velocity models they produce can provide information useful for static corrections and migration processing of reflection data. Typically refraction tomography is only undertaken for small offsets to create velocity models for the top 10 m of the subsurface. This investigation demonstrates that velocity information for depths of up to 450 m can be obtained when refraction tomography is undertaken using super long offsets of 7.5 km.

It is also shown that significant improvements in the imaging of seismic reflectors are observed if the tomographic model is used for reprocessing and depth conversion. The ability of refraction tomography to resolve a shallow low velocity layer and accurate high-resolution velocity variations contributes to the improved imaging. The lateral velocity changes were also found to correlate well with the seismic data and sedimentary packages delineated from log data and other velocity studies in the area. Of significant advantage is the robust depth conversion translating to improvements in depth to key formations. This provides better constraint when building large scale accurate hydro dynamic models particularly for hydro stratigraphic units below the depth of existing boreholes.

Jacob Jackson recently graduated from Curtin University with an MSc in Geophysics and previously received a BSc in Geology from the University of Western Australia. He is currently working as a contractor at Santos and is looking forward to pursuing a career that allows him to use and refine both his geology and geophysics skills. Jacob received the ASEG WA prize for Best Student Presentation and an ASEG WA 2015 Student Award.

Tom Horrocks, University of Western Australia: *Machine Learning Methods for Three-dimensional Lithology Classification from Inverted Mine-Scale Geophysical Surveys and Downhole Data.*



A robust three-dimensional lithology model is vital for mine planning and efficiency. A simple model can be entirely based on downhole lithology logs, but the interpolation required between holes introduces error. A more accurate but complicated lithology model, which suffers less from spatial interpolation error, can be built using rock properties from wireline logs and inverted 3D geophysical surveys,. However, there are common issues that arise with the latter type of modelling, namely: (i) rock properties from wireline logs must be upscaled to the voxel's scale; (ii) rock unit boundaries are difficult to extract from the inversions due to smoothness constraints in the inversion algorithms; and (iii) the final 3D lithology models often provide single 'representative' lithology estimates per-voxel, rather than estimated lithology proportions with uncertainty.

My thesis aims to design algorithms that create 3D lithology models based on lithology logs, wireline logs, and 3D inversions, while addressing the issues mentioned above. Currently, a kernel density estimation-based clustering method (written in Java) is being evaluated for boundary extraction from the inversions, and in the future machine learning pattern recognition techniques will be evaluated for unbiased prediction of both 'representative' lithology and the proportions of each lithology per voxel. The Kevitsa Ni-Cu-PGE deposit (Lapland, Finland) is used as the case study, with First Quantum Minerals Ltd providing lithology logs, inverted voxets of density, magnetic susceptibility, conductivity, and the associated wireline logs.

Tom Horrocks was awarded the 2015 ASEG WA Branch Student Award, and is a second year PhD student from the University of Western Australia, supported by the Robert and Maude Gledden Postgraduate Scholarship and by First Quantum Minerals.

Baichun SUN, Curtin University: *Seismic while drilling imaging in hard rock environment.*

Drill-bit Seismic-While-Drilling (SWD) is a passive seismic-imaging method, which is implemented by utilising the drill-bit vibration as a seismic source. A receiver array is generally deployed on the surface of the earth or in boreholes to capture the drill-bit signals. In an ideal situation, the passive signals are converted into a seismogram similar to Reverse Vertical Seismic-Profiling (RVSP) using cross correlation. This seismic method requires no additional rig time, but provides one of the benefits of acquiring the real-time seismic data used for imaging around the bore hole.

For the application of the SWD method, the energy of the drill-bit vibration is an important factor to success, so it is understood that most successful drill-bit SWD experiments were completed with a rock-crushing roller-cone bit in petroleum industry. However, there are few successful SWD experiments performed in the mining industry, even in hard-rock applications. One of the main reasons is because of the dominant use of the diamond impregnated drill-bit, which is generally quiet while drilling.

The study of this thesis focuses on application of SWD in hard-rock environments and investigates the feasibility of acquiring and utilising weak diamond drill-bit emitted signals. To study the SWD applications in hard-rock environments, three main subjects of the research are investigated and presented in the thesis. They include:

- Investigating methods that suppress strong coherent noises generated from the rig site;
- Comparing coherent signal detection methods in terms of detectability and imaging resolution, then performing velocity analysis and imaging using the acquired drill-bit signal;
- Comparing radiated energy from different drilling methods in hard-rock environments: diamond-impregnated drilling and Reverse-Circulation drilling.

Both synthetic and field data are exploited in the studies. For the field data example, there were two experiments conducted at Brukunga and Hillside in South Australia. For the purpose of drilling signal characterisations, rig coherent noise suppression and the drill-bit imaging, the data from the Brukunga experiment were investigated. Firstly, to extract the drill-bit signal from strong rig-site noise, I demonstrate the use of Karhunen-Loéve (KL) transform to separate the possible drill-bit wavefields. I show that this method is effective and has little or no contamination from the desired drill-bit wavefield when it is

applied in a SWD common receiver gather. This method is compared with f-k filter, and its advantage is demonstrated in an SWD application. Secondly, to image a diamond drill-bit with high spatial resolution using its weak wavefields, I compare different coherent signal detection methods including: semblance and Multiple Signal Classification (MUSIC). Synthetic examples are used to demonstrate the differences between the two methods. The MUSIC-coherency method manifests higher spatial resolution compared to semblance when imaging a buried unknown source. The resolution and signal detectability by MUSIC can be controlled by the signal space dimension. I show that with added coherent noise and large wavefront time-shift errors, MUSIC method still shows comparable measurement to semblance. Therefore, the MUSIC coherency method can be utilised as a good complement to semblance in terms of improved image resolution.

To understand the different level of energy radiation from different drilling techniques, I compare and analyse the energy emitted from hard-rock drilling between diamond impregnated and Reverse-Circulation (RC) drilling from the Brukunga experiment. The two drilling mechanisms generate very different seismic wavefields. From the field data, by investigating the raw data energy, frequency analysis and cross correlation test from the field data, the seismic responses from percussive RC drilling provide a strong indication that the drill-bit energy can be suitable for drill-bit seismic imaging purposes. It may also provide high-resolution images with bore hole seismic acquisition. In contrast, at comparable drilling conditions, the diamond bit drilling is quiet; its energy is difficult to detect by a surface receiver array.

The techniques studied in the thesis, such as MUSIC and KL transform, can be applied to other similar SWD experiments. Some other research topics, such as correlation of the narrow-band drilling signal and drill-bit interferometry migration, are also investigated in the thesis. All these studies highlight the importance of future research for applications of SWD in mineral exploration.

Dr Baichun Sun is currently working with Halliburton in Singapore as senior scientist. He received a PhD degree in geophysics from Curtin University, Western Australia, and previously a BSc in Physics from China. His main interest is in acoustic logging, borehole acoustic modelling and borehole seismic. He is author of four journal papers, multiple conference/workshop papers and two patents pending.

Lee Tasker, University of Western Australia: *4D Monitoring of Civil Infrastructure using Multichannel 3D Ground Penetrating Radar.*

The aim of the PhD project is to develop a 4D-monitoring tool using multichannel 3D GPR technology to scan and image infrastructure over calendar time to enhance and improve the ability to accurately identify, interpret and monitor structural defects: (1) cracking and/or voiding present within infrastructure; and (2) volumetric changes of regions experiencing structural deformation. As a result of this research geophysicists will be able to provide Civil and Asset Management Engineers with more accurate infrastructure-monitoring tool and geophysical data to better understand the material behaviour of their infrastructure over calendar time. These near-surface geophysical tools would prove most useful in the planning and prioritising of long-term maintenance of an infrastructure, saving time, money and improving the overall safety management of the infrastructure.

Lee Tasker is a PhD student at the University of Western Australia (UWA) and a Geophysics Consultant with Draig Geoscience. He specialises in near-surface geophysics, with a focus on geophysical solutions to engineering problems. Lee has a Master of Physics (MPhys) from Cardiff University, UK and a Graduate Diploma in Science (GradDipSci) in Geophysics from Victoria University of Wellington (VUW), NZ. With over eight years of professional geophysical consulting experience, he has worked both nationally and internationally on projects in the engineering geophysics, environmental, heritage and exploration fields in Australia, Mongolia, New Zealand, Pakistan and Papua New Guinea. Lee also serves as the Western Australian Members Representative for the ASEG Near-Surface Geophysics Group. He received an ASEG WA Student Award in December 2015.

Honours projects

Joshua Meertens, Curtin University: *Generation of a 1D velocity model through inversion of earthquake arrival times, Kalgoorlie, WA.*

The cause and nature of the anomalously high levels of seismic activity within the Yilgarn Craton of Western Australia is not fully understood. Earthquake monitoring in WA is sparse, and the use of inadequate Earth models impedes the ability to analyse seismic activity accurately. Current models used for routine hypocentre locations leave the near surface under-represented, an issue that needs to be further investigated since seismicity in the region is typically very shallow (<5 km depth).

A new 1-D Earth model has been generated from inversion of the first arriving P- wave and S- wave phases sourced from the 2010 ML 5.0 Kalgoorlie earthquake and aftershock sequence. The model describes two layers; a near surface layer of 0.75 km thickness with VP = 5.90 km/s and VS = 3.50 km/s above the upper crust with VP = 6.10 km/s and VS = 3.59 km/s, applicable to approximately 10 km depth. Analysis of the travel-time data provides an average VP/VS ratio of 1.70 for the region.

The new model reduces the RMS travel-time residual for this dataset by ~25% in comparison to the next best solved 1 layer case, confirming that inclusion of a lower velocity surface layer does improve earthquake hypocentre locations and more detailed crustal models are valid on large scales. Re-location of the events measured with a sparse network (a maximum of 12 stations up to 70 km away from the epicentre zone) improved focal depths significantly. With respect to the most accurate model (WA2) currently used for routine locations, events were pushed up to 1 km deeper into the focal zone identified with constrained data. It is expected that the new 'KLG' model will

improve analysis of earthquakes within the Eastern Goldfields region.

Interpretation of this period of activity supports previous conclusions that the N–NNW trending Boulder-Lefroy Fault was the major control over stress-release during this time. This structure is the likely candidate for the main earthquake rupture, although it is possible that smaller, more complex, linkage or en echelon faults may have also been activated. Observation of the focal depths is consistent with the shallow nature of seismicity seen elsewhere in the Yilgarn Craton.

Joshua Meertens completed his Honours degree in Geophysics in 2015 at Curtin University. He also received the Chevron Geology/Geoscience Honours Scholarship in 2015 and was twice a member of the 2014 Vice Chancellor's List for achieving in the top 1% of Curtin undergraduates.

Bryce TEO, Curtin University:
Permeability and electrical resistivity changes in Leederville aquifer core induced by transient physicochemical conditions.

Permeability reduction in aquifers caused by the release and deposition of in-situ colloidal particles can impact on the long-term sustainability of groundwater recharge operations. Experiments were performed on a Leederville aquifer core sample to examine the effects of near-well transient physicochemical perturbations on permeability, within the framework of colloid release and deposition processes. The flow rate, ionic strength of the injectant, and flow direction were varied in a stepwise manner. Significant permeability losses during the early injection of highly-treated recycled water indicated that colloids were sensitive to release in low ionic-strength solutions. Permeability reduction during the injection of recycled water was irreversible at low flow rates. Experiments suggest that: when native formation water was restored at each flow rate, the extent of permeability recovery depended on the distribution of pore water velocities; and under constant flow conditions, permeability recovery during the injection of saline solutions was controlled by diffusive processes in stagnant flow locations. When the direction of injection was reversed, the permeability of the sample improved, however, this improvement was not reflected when the initial direction of injection was restored – a conceptual model was described to account for this behaviour.

Bryce Teo completed his Geophysics Honours Degree in 2015, supported by Water Corporation of Western Australia. He is now a PhD student at Curtin University. His research will focus on further developing the seismoelectric method for hydrogeological applications. Bryce has been awarded an Australian Postgraduate Award (APA) Scholarship to support his PhD studies.

Editor's postscript: All postgraduate and honours students (and their supervisors) are reminded that the December 2016 issue of *Preview* will feature summaries of students projects completed in 2016. Please submit a summary of your project together with a short bio and photo by 11 November 2016. As in previous years, the best student photo (you carrying out your research) will be selected for the cover – so start thinking about how to construct that evocative image now!