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# National search for earth science superstars off and running

The national search conducted by Australian Science Innovations for talented students to represent Australia at the 2015 International Earth Science Olympiads is off to a flying start, with 380 students registering to sit the inaugural Earth and Environmental Science Olympiad (EESO) exam.

Joining the well-established Olympiad competitions in biology, chemistry and physics, the Australian Earth and Environmental Science Olympiad will select and train talented secondary students in preparation to compete at the International Earth Science Olympiad (IESO). The first stage in the process is the national exam, where Year 10 and 11 students test their knowledge of geology, geophysics, meteorology, oceanography, astronomy and environmental sciences. The inaugural exam was held in August, with those who performed well in the exam invited to attend an intensive summer school at ANU where their theory and practical skills will be developed further.

According to the EESO Program Director, Greg McNamara, the exam was a challenge to write:

> *In order to select a cohort of 12 excellent candidates to attend the first EESO summer school the exam needed to identify truly outstanding students from an exceptional group while also asking questions within the framework of the Australian curriculum and the IESO syllabus. In addition we needed to ensure the questions were scientifically and pedagogically sound. I would like to think we were successful and acknowledge the able assistance provided by critical friends, experts in the 'spheres' of geology, atmosphere, hydrosphere and astronomy.*

The Executive Director of Australian Science Innovations, Lillian Lesueur, reported that:

> *all students who sat the exam should be proud of their efforts as it is clear they all put in a great effort to succeed. The most outstanding candidates, who have now been invited to summer school, come from a variety of city and rural backgrounds and we are looking forward to working with this group over January.*

The exam has provided a number of learnings that will inform future exams as well as the content and structure of the 2015 summer school. It is clear from the variety of questions successfully attempted by students that not all students have the same underpinning content knowledge and that the variations are both school and state based. Whilst not a surprise, it has provided the EESO program staff with an empirical benchmark from which to plan their training.

Generally, students demonstrated a good understanding of contemporary environmental issues but tended to interpret all environmental processes through an anthropogenic lens rather than considering the possibility of overarching natural processes. The exam also revealed widespread misconceptions in the areas of stellar evolution and the formation of solar systems with students frequently confusing these processes with those operating during the Big Bang. There was also a general lack of depth in basic content knowledge pertaining to solid Earth geology, mapping and stratigraphic relationships.

The experience that Greg McNamara and the program's Deputy Program Director, Dr Bronte Nicholls, recently had at the 2014 IESO in Spain confirms that the Earth Systems Science approach adopted in formulating the EESO exam and summer school plans are well aligned with the IESO and will provide a good basis for taking a team of four students to the 2015 IESO. The inaugural Australian Earth and Environmental Science Olympiad is sponsored in part by the Australian Geoscience Council (AGC) and the ASEG is a member of the AGC.

*Ruth Carr*
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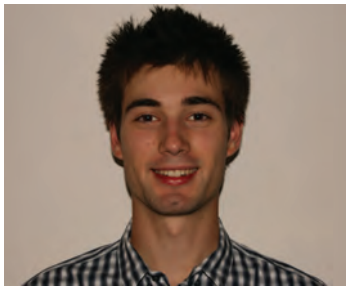
# Student projects in geophysics completed in 2014

## Honours projects

**Michael Dello-Iacovo:** *Heat flow in southern Australia: source and implications for geothermal energy.* University of Adelaide.



The South Australian Heat Flow Anomaly is a broad region (>400 km wide) in Proterozoic South Australia defined by drill holes with anomalously high heat flow estimates yielding a mean of 92 ± 10 mW $m^{-2}$, compared to a global Proterozoic mean of 49-54 mW $m^{-2}$.This study conclusively determined the primary source of this anomalous heat flow. Thermal conductivities of 145 drill core samples were measured using an optical thermal conductivity scanner. These were utilised with thermal conductivity and temperature profiles provided by Petratherm and the Department of State Development to make five new heat flow estimates in the Curnamona and Mount Painter provinces using the product and thermal resistance methods. Measured surface heat flows fall between 84.352 and 128.051 mW $m^{-2}$. Significant lateral variations in surface heat flow support previous work suggesting shallow crustal radiogenic heat generation, primarily in Mesoproterozoic high heat producing granites. Analysis of existing deep seismic data has revealed a significantly cooler and thicker lithosphere in Proterozoic South Australia compared with regions dominated by mantle heat flow such as southeastern Australia. Geotherms have been computed for steady-state regimes to demonstrate that the surface heat flow evident in the South Australian Heat Flow Anomaly is consistent with elevated upper crustal source. Thick, thermally insulating sedimentary cover in the Curnamona and Mount Painter provinces and high temperatures at shallow depths are encouraging for geothermal energy exploration, and geothermal prospectivity for these provinces was examined. Lateral thermal conductivity variations of stratigraphies in the Curnamona Province have been assessed, revealing that more data must be collected to use thermal conductivity from neighbouring boreholes as a proxy for heat flow estimates.

*Michael is passionate about using his geoscience knowledge and collaborating with others to solve global energy and climate issues. He is particularly interested in geothermal energy, solar and natural gas. He completed his Bachelor of Science (Honours) in geophysics in November 2014, and will commence work with Santos Ltd in 2015 as a graduate geophysicist.*

**Henry Johnson:** *Geographically constraining the South Australian Heat Flow Anomaly.* University of Adelaide.

The South Australian Heat Flow Anomaly is a large contiguous region of anomalously high heat flow (>90 mW $m^{-2}$) in otherwise tectonically quiescent Proterozoic lithosphere. The broad anomaly (>400 km) is nearly 40 mW $m^{-2}$ greater than the global average for terranes of similar tectonic age, but is poorly constrained geographically due to relatively few and poorly distributed heat flow data. This study reports four new heat flow determinations, located to improve the spatial sampling. The product method and thermal resistance were used to calculate heat flow. Data were obtained from drillhole core samples that traverse the anomaly. The samples were then scanned for thermal conductivity using a Thermal Conductivity Scanner. Temperature logs of the drillhole were used to determine the thermal gradient with depth. The product of thermal conductivity and thermal gradient determines surface heat flow. The spatial extent will become better defined with each new heat flow datum. Reliability of the pre-existing data source of the anomalously high heat flow was ascertained by evaluating bias in previous data measurements, recent tectonic and magmatic activity. Using existing data and measurements made in this study, evidence for and against a primarily deep mantle and shallow crustal radiogenic source was examined.

*Henry's career aspiration is to enter the geophysical exploration industry as, from his Honours project, he has found that finding something new that no one has seen before is both challenging and exciting. Coming from a rural background he finds himself wanting to be in the great outdoors, which compliments his aspiration agreeably. After furthering his professional experience he would like to gain further knowledge overseas.*

**Angus Keane:** *Carbonated mantle: modelling the effect of carbonated melts on mantle melting and conductivity.* University of Adelaide.

The effect of carbonated melts is observed to have significant deepening of the solidus and high conductivity as a function of $CO_2$ concentration in the melt. In this study these two effects are parameterised and a model is presented that determines mantle melt fraction and bulk hydration from conductivity observations, using the melting models of McKenzie and Bickle (1988), Katz *et al.* (2003) and Hirschmann (2010). This model is applied to conductivity data of Key *et al.* (2013) and (Wannamaker *et al.* 2008) for the East Pacific Rise and the Basin and Range, Colorado, respectively. Our interpretations of melting and hydration, are in agreement with those posed by Key *et al.* (2013) and Wannamaker *et al.* (2008).

**Oliver Putland:** *Magnetotelluric well stimulation monitoring.* University of Adelaide.

Hydraulic stimulation tactics allow for the economical extraction of tight-

gas plays by increasing the hydraulic conductivity of impermeable formations. The rise of shale-gas exploration and production has seen the implementation of horizontal drilling to pump pressurised fluids into a formation, reactivating palaeo-fracture networks from induced pressure instability. The fracture networks stimulate: reduction in pore pressure, increasing pore connectivity and provides new paths for hydrocarbon migration. Deep geophysical monitoring is required to analyse the geological impacts from hydraulic fracturing (fracking), they also aid to increase well success rates. Microseismic surveying is currently the primary technique employed to monitor these induced effects, however passive seismic monitoring is not directly sensitive to the physical properties of formation fluids.

This report describes early-stage evaluation of magnetotelluric monitoring of hydrogeological changes induced from a hydraulic fracturing at 3000 m depths. This study presents the findings from phase tensor dimensionality studies and inverse modelling in two dimensions of a twelve-hour recording time interval prior and post injection. The regional low resistivity of the sedimentary basin stratigraphy constrains the changes in the magnetotelluric responses associated with fluid injection to lie within the dead-band (1–10 s); thus signal-to-noise ratios are low and changes are difficult to uniquely detect.

*An incongruent path through university – software engineering, marine biology, botany to geophysics – allowed Oliver to find his true interests, for that he is forever grateful. Take some time to get to know him and you will find that he has quite simple tastes – a book, coffee and some sun make for a perfect day.*

**Michael Stepan:** *Magnetotelluric imaging of a Palaeozoic Andean margin subduction zone in western Victoria.* University of Adelaide.

The geological setting for the accretion of the Lachlan and Delamerian Orogens in southeastern Australia is controversial, with two different models proposed. The Lachlan Orogen resulted from either subducting oceanic crust and wedge accretion, or shortening and compression between two continental blocks. Broadband magnetotelluric (MT) data recorded over the transition between the Delamerian and Lachlan Orogens impose new constraints on the formation of south eastern Australia. The east–west MT survey extended for approximately 120 km, recording at 44 stations. A 2D inversion of the data in the bandwidth of 0.05–2000 s yielded a resistivity model to a depth of 150 km, with resistivity ranging from 1 to 10 000 Ωm. The upper crust was most resistive (>10 000 Ωm), and transitioned to a relatively flat conductor of 50–100 Ωm at <20 km. The upper mantle is resistive (>1000 Ωm) and uniform below this layer. The Escondida, Moyston and Avoca Faults are imaged as low resistivity pathways (100–200 Ωm) extending to the surface. Faults may be anomalously conductive from alteration to serpentinite, and other trace mineralisation such as graphite. The Lachlan Orogen likely formed from west dipping subduction of mafic to ultramafic oceanic crust. This crust was altered to serpentinite, with magnetite coating grain boundaries. Imaged conductive bodies show where shearing caused interconnectivity of the magnetite.

*In 2014 Michael was a BSc Honours student in geophysics at the University of Adelaide. Next year he will be working for Santos in a graduate role in their Adelaide office. His interest lies primarily in exploration, particularly seismic and offshore. He would one day like to live and work overseas, ideally in Europe or north Africa.*

**Sanjay Govindan:** *The nature of pore space at a weathered/fresh rock interface and its effect on the resistivity signature (special topic).* Australian National University.

We have conducted a DC resistivity survey over a 500 m section of a gold mine in Majors Creek. Inversion and forward modelling of the data produced a true resistivity model of the near sub-surface. With additional information supplied by Unity Mining, we are able to correlate alteration styles and the weathering profile over a depth of 60 m to the true resistivity model calculated from field measurements. The next stage, which is currently under way, is to collect porosity and connectivity data, both in thin section and CT form. Imaging samples from the drill core supplied by Unity Mining we are able to gain a snapshot of host rock characteristics over the entire 60 m depth. Five samples from the host rock were collected and are currently undergoing preparation for scanning and imaging. This will allow a potential relationship to be established between pore space and connectivity to the resistivity values experienced in the field. The future outlook for this topic is to conduct a similar study over transported regolith and compare and contrast the difference. It is hoped that resistivity and regolith characteristics can be better understood to assist in defining the boundary between transported and *in-situ* regolith.

*Originally from Sydney Sanjay came to Canberra to pursue an earth science and mechanical engineering degree and has enjoyed his four years there immensely. The Research School of Earth Science is highly engaging and involved with its students, pushing students to interact with researchers and learn through applying research processes. Sanjay's 4 years at the school has led him to visit some spectacular country throughout Australia, make a range of new friends and to get involved in the researched based learning that he is highly passionate about. Currently transitioning into honours he is keen to pursue research into CT scanning techniques and hopefully to apply them to the challenges at the Earth Science School. In his spare time he is always very keen take the mountain bike out to Stromlo, go climbing at Kambah pools, or go for a hike or run through the bush. In 2014 he was awarded the ACT ASEG Branch Student Conference Travel Award*

**Jack Muir:** *Bayesian inference of deep earth structure via a joint inversion of normal mode and body wave data.* Australian National University.

In this thesis, we present a hierarchical Bayesian joint inversion of the P-wave velocity perturbations in the lowermost 300 km of the mantle and the topographic perturbations of the core mantle boundary. We use a novel dataset, free of the effects of the inner core, consisting of PcP – P, PKPab – PKPbc and P4KP – PcP differential travel times. We employed a hybrid hierarchical Hamiltonian Monte Carlo/Gibbs sampler, to our knowledge thus far unused in global seismology, to generate the posterior parameter distributions arising from Bayesian analysis, using Monte Carlo simulation. After confirming the efficacy of our sampler on a synthetic dataset, we invert for the lowermost mantle and core mantle boundary. After including corrections to the differential travel time data to account for upper mantle structure, we find a root mean square P-wave velocity perturbation in the lowermost mantle of 1.26% and a root mean square topographic perturbation of the core mantle boundary of 6.04 km, with a predominantly north/south hemispherical character to the resultant maps of the perturbations.

*ASEG ACT branch member Jack Muir was awarded the ASEG ACT Branch Student Scholarship in 2014. Jack has recently completed a Bachelor of Philosophy (Science) at the Australian National University, with a thesis in seismic tomography. He has been elected as a General Sir John Monash scholar for 2015, and intends to study for a PhD in geophysics in the United States next year.*

**Alexander Costall:** *Feasibility of ground penetrating radar for delineation of the saline water interface along Perth's coastal margin.* Curtin University.

The feasibility of applying Ground Penetrating Radar (GPR) to the investigation and delineation of saline water on Perth's coastal margins has been evaluated by this paper. The research concluded that the technique can be applied to the detection and quantitative analysis of the water table at coastal boundaries; estimations to the variation in moisture content, including variability of infiltration rates along profile lines, and dilution of the saline water interface have been observed. As such, GPR is a fast, readily accessible alternative to the drilling of new monitoring wells, particularly in urban environments. Radar antennae with central frequencies of 50 and 250 MHz were used with a MALA ProEx radar system and in conjunction with a Real-Time Kinematic Global Positioning System (RTK GPS) to accurately and precisely investigate a region of Perth's coast. The area included four lines of approximately 300 m length, running pseudo-parallel in an easterly direction from the beach to the nearby road which allowed for the generation of a 3D fence diagram, as well as a general characterisation of the area from GPR data. To investigate the effect of rainfall on the research area, a second 250 MHz survey was conducted after a period during which Perth's high rainfall season had saturated the area. Analysis of the water table reflections, comparison of event times and instantaneous frequency changes show that a qualitative analysis of the water infiltration can be concluded by GPR surveying; however the saline water wedge is not easily identified. The changes identified are due to the effect of water on electromagnetic wave propagation. The degree to which the media has been saturated is able to be estimated by the travel time delays to known reflection interfaces, and the Topp relationship. From average EM propagation velocity changes of 0.2 m/ns, an estimated 3.6% increase in water saturation has been observed in the study area, equating to 36 mm/m approximate additional water content. The presence of the Tamala Limestone inhibits investigation with the 250 MHz antenna as the signal appears to be scattered, while the unshielded nature of the 50 MHz antenna became an issue with overwhelming airwave noise from wire fences along the tracks, additionally, it's inherently lower resolution resulted in hindrances to the technique over this area.

**Mathew Fleay:** *True amplitude processing and imaging of IGO 3D high-resolution seismic survey for Nickel, Kambalda, WA.* Curtin University.

**Sandy Jones:** *Analysis of a small electromagnetically driven seismic sources.* Curtin University.

This project aims to determine the effectiveness of a portable vibrating seismic source. Starting with the raw hardware, we built software code in order to create a designable sweep signal for vibroseis. The next step was to design and build the amplification system that will drive the source. Following the building of the amplification system, we aimed to design and build a testing rig that will allow measurement of the direct force output of our system. The final step in the program was to conduct some field testing, firstly to iron out issues with interfacing to a new system, and secondly, to test against a known source (sledgehammer). Unfortunately, despite the best efforts of the author and supervision team, the load cell sensors for the force testing system were behaving in an unexpected manner, and as a result, data from an absolute force test are not available at this time.

The tested hardware shows definite promise, the output frequency response and energy output seems positive compared to the hammer source. There are definite areas for improvement to the source before it could be considered as a commercial entity. The most important of these is a well-engineered weight loading system, which will enable solid ground coupling, and eliminate any 'impact' type events. Secondly, an effective transport system is need to efficiently transport the source between shot points.

It is recommended to apply some further research into this source, or similar sources. The idea of a one to two man operation of a small scale high definition seismic system is still a very attractive one. The next stage of research could involve a full reflection survey over a known area, using 10 Hz geophones, and some well-engineered solutions to the problems listed above.

*Sandy Jones is an honours graduate geophysicist from Curtin University in*

*2014. Sandy is looking forward to a rewarding career as a geophysicist, has a keen eye for innovation, and a passion for the technological advancement that is a key aspect of the geophysics industry. Sandy runs a small business providing professional musical services in Perth, based on his extensive experience in the music and hospitality industries. You can reach him at sandyjonesgeophysics@gmail.com. Or check LinkedIn here: https://www.linkedin.com/pub/sandy-jones/35/7b2/892.*

**Matt Kovacevic:** *Seismic characterisation and tectonic significance of listric fault systems in the Ceduna sub basin.* Curtin University.

The Ceduna sub-basin is considered by many to be a major potential petroleum province. Deposition is dominated by Late Albian to Maastrichtian deltaic sequences, which have been deformed through gravitationally induced listric extensional faulting. Previous studies of listric fault systems within the Ceduna sub-basin have focused on regional 2D seismic, with a line spacing of 4 km. The high resolution Trim 3D survey, covering an area of 1200 km$^2$ on the south western edge of the system, allows the evolution of fault systems to be studied in much greater detail. Faulting initiated in the Cenomanian White Pointer sequence and demonstrates a regional northwest southeast trend; however the interpretation of the Trim 3D survey has also resulted in the identification of previously unrecognised north south trending faults. After a period of quiescence in the Coniacian, renewed faulting occurred throughout the Santonian until the Maastrichtian. Faults developing during this time nucleated above previous northwest southeast trending faults, and displacement profiles indicate an upward propagation of growth through to the Maastrichtian. North south trending faults were not reactivated. The structural evolution of the Ceduna delta system has important implications for potential petroleum systems; fault reactivation may have compromised seal integrity within the White Pointer sequence.

*Matt Kovacevic is an Honours Student in the School of Exploration Geophysics at Curtin University. He is graduating at the end of 2014 at which point he will join the Chevron Australia Graduate Program as an Earth Scientist.*

**Mahesh Raghvani:** *Using seismic tomography to map shallow structures ion land seismic.* Curtin University.

One of the frequent drawbacks of seismic reflection, in its current implementation in a hard rock environment, is its inability to adequately image the top 200 m of the subsurface with conventional acquisition geometry. This depth range generally contains structures of interest such as shears, faults and fractures that typically control mineralisation. Although, the tomographic approach for delineating the near surface velocity field is commonly used in hydrocarbon exploration, it has scarcely been used in a hard rock context. For this reason, this project aimed to test the effectiveness of using travel time tomography for enhancing shallow structures in hard rock seismic.

The investigation was carried out on a high resolution 2D dataset, which was acquired in Western Australia and exhibits this shallow imaging problem. First arrivals were used to conduct travel time tomography on two different software packages using separate algorithms. The subsequent velocity models produced were used for time migration and depth conversion. These results were then critically analysed in order to make comparisons on the effectiveness of tomographic inversions.

The two models obtained from the different inversions showed strong similarities and similar distributions of velocity. The velocity models indicated an undulating low velocity upper layer, which highly varied in both thickness (10–70 m) and velocity (700–7200 m/s). Having used these velocities for time migration, localised areas in the time sections experienced significant improvements in both the continuity and resolution of the reflectors.

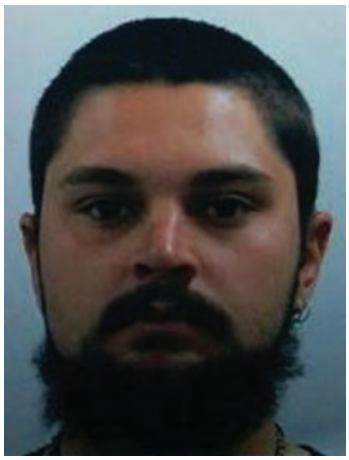
Comparative analysis between the tomographic velocities and the sonic log showed a strong correlation, indicating that tomography produced accurate and realistic velocities. The conventionally used single velocity function, in time to depth conversion, was found to have excessively high velocities in the upper 150 m when compared to the sonic log. Most importantly, a comparison between the two velocities (single velocity function and tomographic velocities) for depth conversion confirmed that to a large extent, limited shallow imaging is caused by inaccurate time to depth conversion. Utilising tomographic velocities for depth conversion showed that reflectors and structures were better imaged up to the top of the fresh rock. Small improvements observed in the time sections translated to large increases in interpretability after using tomographic velocities for depth conversion. Results from this investigation indicate significant potential for improving shallow imaging when travel time tomography is implemented in hard rock processing.

**Benjamin Williams:** *Qualitative and quantitative ranking of different seismic acquisition geometries over the Northwest Shelf using synthetic data.* Curtin University

Abstract withheld for reasons of confidentiality.

*Ben Williams received his BSc in geophysics in 2013 and is currently finishing his Honours degree from Curtin University. He has worked with Barrick Gold Corporation, and more recently with Woodside Energy as both an Intern and Geophysics Analyst. He is set to start as a graduate geophysicist with Woodside in 2015. He is a member of ASEG and PESA.*

**Ry Zawadzki:** *Test and development of a hybrid fluxgate-induction coil sensor for TEM measurement.* Curtin University.



A large part of Australia's mining industry includes the extraction of metalliferous sulphides. Time domain electromagnetic methods have proven to be the most effective geophysical method for base metal exploration, due to the conductive to semi-conductive nature of the ore deposits. As ore bodies come increasingly deeper and smaller to find, there is a need for higher power EM field transmitters, better signal processing, better receiver noise levels and bandwidth increase. Induction sensors and fluxgate magnetometers are currently industry standard TEM sensors for base metal exploration. They have complementary characteristics where one works well at low frequencies and the other at high frequencies. With this in mind, the idea of a new type of TEM sensor combining both the induction coil and fluxgate magnetometer into a single sensor sparked interest in TEM exploration industry.

A new type of TEM sensor was developed. The sensor was a hybrid of both a parallel time's deference fluxgate and induction coil sensor. Both exploited using a feedback circuit through an innovative integrated circuit created by Texas Instruments. The final result exhibited a working, highly linear, low drift sensor at DC-6 kHz fields. The idea of induction bypass at high frequencies has worked. A flat bandwidth of approximately 6 kHz was achieved. However, quantification of higher frequency sensitivity requires further testing and modifications. The hybrid is small and can be made fairly rugged for field use. This would allow for moving loop crews to access to one small (>5 kg) sensor operating off a 5 V power supply. Extensive noise level and frequency response testing has yet to be carried out at the conclusion of this thesis due to time limitation. However the prospect of this sensor providing a high bandwidth response with good high and low frequency noise levels warrants further investigation.

*Ry was born in Hobart Tasmania and moved to Western Australia at the age of 14. An interest in electronics and physics led him to pursue a high school education in physics. He completed his Bachelor's degree in geophysics in 2012. In 2013 he worked as a geophysicist with Independence Group (IGO). Primarily his role was to ensure the highest quality data was collected in both surface and downhole electromagnetic surveys and that all remote camp requirements were achieved, maintaining all field equipment and completing field repairs where necessary. This maintenance covered a wide range of equipment from basic car and generator servicing through to more technical aspects of receiver and transmitter maintenance as well as completing data QA/QC procedures to ensure all collected data was of the highest quality and contained all relevant information. Ry's honours year in 2014 allowed him to pursue the development of a new type of magnetic field sensor. In his spare time he likes submission grappling/wrestling. The sport allows him to dissociate from his work/study after a long day while still keeping physical and mentally active. He is currently looking for employment to pursue his interest in geophysical innovation and practice.*

**Justine Carstairs:** *Geophysical constraints on structural modelling in the onshore Gippsland Basin.* University of Melbourne.

The offshore Gippsland basin has been well studied since the discovery of giant oil and gas reserves, yet the onshore area remains, by comparison, poorly understood. This study aimed to produce a 3D model of the onshore stratigraphy, to accurately describe the subsurface structures, and to distribute the model with physical properties such as porosity. By integrating all available datasets, and inverting the model using new gravity data acquired by both the Geological Survey of Victoria and students at The University of Melbourne, I attempted to resolve in particular the Basement-Strzelecki interface, a difficult task given their physical similarities. Petrophysical data has been newly acquired for Yallourn North-1 using a Geotek Multi-Scanner Core Logger, and this data is added to existing well log information to geostatistically distribute porosity and density through the model. It is hoped that increasing our understanding of the regional geology – particularly the geometry of deep structures – will allow further development in fields as diverse as tight gas production, geothermal energy, and geological carbon storage and aquifer studies.

**Nicole Filling:** *Tectonic evolution of the Archaean metasediments of western St Ives Goldfield; implications from structural and stratigraphic observations (Kalgoorlie Terrane, Western Australia).* Monash University.

Gold exploration in the Kalgoorlie Terrane, Yilgarn Craton, Western Australia, has historically been biased towards the prominent greenstone belts. This has resulted in limited exploration of the overlying sedimentary sequences, comparative to the earlier greenstone sequence. The recent discovery of gold within these sediments at St Ives Goldfield has prompted a shift in exploration towards these younger units, specifically the Speedway Corridor on the western flanks of the exposed greenstone sequences. This region is poly-deformed and consists of complex structures. There is a need to better understand both the structures and the stratigraphy of importance of further exploration.

This study addresses discrepancies in the current structural and stratigraphic models of the southern Speedway Corridor using observations from drill core and field mapping, reconciled with high resolution geophysical surveys. Lithological observations were combined with petrographic analysis to characterize the predominant sedimentary sequences. The first of these two sequences is the Black Flag Group, a sub-aqueous feldspar-rich sequence, consisting of a

syn-sedimentary andesitic unit, reworked volcaniclastic debris flows and turbidite units. In comparison the Merougil beds consist of subaerial, quartz-rich sediments interpreted as a braided river deposit. Petrophysics analysis was conducted to determine the magnetic susceptibility of the identified lithofacies. Structural analysis illustrated the complicated relationship between faulting and folding throughout the area. Geophysical surveys were processed and analysed to produce and interpretive geological map of the area, with structural and lithological data providing constraints. From this geophysical investigation the southern Speedway Corridor was interpreted to consist of two synclines that have been juxtaposed together by a gently east dipping thrust fault. Some structures interpreted correlate with deformation events associated with gold deposition in the St Ives Goldfield, providing possible targets for future exploration within the regions, especially within the underexplored sedimentary sequences.

*Nicole completed a Bachelor of Science Advanced at Monash University, majoring in Geology. Nicole has just completed honours (October 2014) focussing on structural geology, geophysics and sedimentology in the Kambalda Domain of Western Australia.*

**Janenie Moghan:** *Ground penetrating radar (GPR) used as a geophysical method for subsurface utility mapping and lateritic bauxite exploration.* Monash University.

The operation of ground penetrating radar (GPR) is based on the propagation of electromagnetic waves to probe subsurface materials. Once raw GPR datasets are acquired, it is key that suitable data processing functions and parameters are used to ensure the data is processed and interpreted as accurately as possible. GPR was used to detect buried utilities at a street intersection in Port Melbourne (Australia) and for bauxite exploration at a lateritic bauxite exploration site in Sanxai (Laos). The datasets from these two localities were collected at 400 MHz, and 30 and 80 MHz respectively. Data processing methods for these two applications were studied and compared to identify similarities and differences in the processing functions used. Several key comparisons were able to be made but overall, the utility mapping dataset was found to be simpler and required less processing efforts than the bauxite exploration dataset.

It is important to note that the performance of GPR varies and is highly influenced by subsurface properties. This can sometimes be a disadvantage, especially if ground conditions are unfavourable. Factors such as high soil conductivities, shallow water tables, inadequate signal penetration and inefficient coupling of electromagnetic radiation into the ground may limit the success of GPR surveys. The processing GPR datasets are often subject to individual bias, which can lead to inaccurate or inconsistent interpretations.

*Janenie is currently completing her Bachelor of Science (Honours) in Geophysics at Monash University, Australia. In 2013, Janenie graduated from The University of Melbourne with a Bachelor of Science in Geology. She is actively involved in The Australasian Institute of Mining and Metallurgy (The AusIMM) and has undertaken a number of leadership roles such as Treasurer (2012/2013) and President (2013/2014) of The AusIMM Melbourne Student Chapter. Janenie completed work experience with Rio Tinto Exploration between August 2013 and June 2014. She has a passion for travelling and aspires to work as a geophysicist with an Australian or international mining organisation.*

**Wang Liang:** *Characterizing unwanted laboratory signals and noise in B field EM sensors.* RMIT.


The amplitudes of desired signals, unwanted signals and internal noise are the main factors that determine how useful an individual electromagnetic a sensor is in geophysics. Because many unwanted electromagnetic signal sources are widespread in the urban environment, sensitive sensors may be difficult to test in the laboratory, or to use in urban or mine environments. The aim of this project was to characterise the general electromagnetic noise variability at RMIT.

To explore temporal variations, experiments were conducted on weekdays, weekends and public holidays. Each major experiment lasted at least five consecutive days to investigate multiple component amplitude distributions with time. Electromagnetic spectra of weekdays and weekends were compared and it was shown that:

• Tram and other types of public transport created low-frequency signals sub 5 Hz. The magnetic sensor response is dominated by responses from electrical equipment, this equipment including computers, air conditioners and lights. The higher the floor in the building, the lower was the noise that detected by a sensor. In other words, the basement of RMIT University is the 'noisiest' location and level 12 is the 'quietest' location for electromagnetic interference. The Geophysics lab is on level 6, and during working hours unwanted signals are 4 to 5 orders of magnitude greater than sensor noise levels. At every location noise detected after midnight, on a weekend or a public holiday is lower than that detected on the weekdays.

*Wang Liang is a Chinese national who completed Honours in Physics at RMIT in 2014. As well his geophysics degree, Wang previously completed a Master's degree in Medical Physics.*

**Andrew Pacey (Grad Diploma Mineral Resources):** *Predictive deconvolution for coal seismology.* University of Queensland.

One of the oldest algorithms in seismic reflection, predictive deconvolution, is based on the assumption that reflecting interfaces are randomly distributed. This assumption is often violated, with coal systems providing an important example of the problem.

The formation of non-white reflectivity is demonstrated with reference to quantitative geological observations of periodicity in sedimentary facies. Novel deconvolution techniques, which

allow for non-random reflectivity, are evaluated, with particular reference to coal seismology.

**Daniel Reyes:** *Geophysical indicators of CSG sweet spots.* University of Queensland.

Recent research suggests that the gas-storage potential in coal seams may be causally related to P and S-wave velocities, and density. The possibility of surface detection of variable CSG potential has been evaluated, via numerical modelling of multi-component AVO effects in reflection packages from coal seams of realistic dimensions.

**Nick Josephs:** *Ground penetrating radar and an Honours case study on the eastern coast of Queensland.* Queensland University of Technology.

The purpose of this project was to find evidence of the most recent high-stand sea-level in the Holocene through mapping of the sub-surface using ground penetrating radar (GPR). It is the hypothesis of this project that Holocene sea-level change has influenced the landscape evolution on the Capricorn Coast of Central Queensland and that previous mid-Holocene high stand sea levels have created accommodation space inland from the modern day shore-line. This accommodation space and the deposited sedimentary successions provide evidence for the palaeo-depositional environment, which includes estuarine, barrier systems and palaeo-beach deposits. A difference in dielectric constant between sedimentary features associated with the mid-Holocene high stand and more recent sediments will result in a radar reflector that can be imaged with GPR. Identification of such a reflector as the formation top of mid-Holocene high stand can be achieved through correlation with other physical observations such as boreholes and outcrops.

Using GPR imaging one prominent reflector was found across all sites using the 200 MHz antennae and a second continuous reflector was found using the deeper penetrating 50 MHz antenna. The first reflector was identified as the local water-table and the second showed point reflectors over a strong planar reflector interpreted as being a palaeo-beach environment. The radargram facies and features are exhibited as specific geomorphology in the modern day coastline to the east of the sites. Data also indicate that the velocity of the sediment between sites is constant and fairly homogenous confirming similar sedimentary composition over the area and contributing to the steady Quaternary tectonics hypothesis for this region on the eastern coast of Australia. This study conclusively shows that an ancient beach was found approximately 2.5 m above present local sea-level at 180 m back from the seashore. Due to the tectonic stability of the area, this study provides evidence that sea-level has previously reached up to 3 metres higher compared to present day.

*Nick completed a BBiomedSc at QUT in 2007, then worked in an electro-chemical sensing lab until a field and lab technician opportunity presented itself in 2011 at Sigra Pty Ltd; a Civil and Mining Engineering company. Nick's love of geology pushed him to come back to study in 2012 where he finished his BSc (Geology and Geoscience) and has recently completed his BSc (Honours) in the area of Geophysics at QUT.*

**Ashby Cooper:** *The crustal structure of the Bass Strait region from combined passive seismic methods.* University of Tasmania.

The receiver function method is sensitive to deep crustal and upper mantle (5–50 km) seismic velocity variations, and provides an insight into the structure and evolution of the crust beneath the seismometer. Application of the method is particularly appropriate in less explained regions, or as a reconnaissance in regions of contrasting adjacent terranes. Receiver function analysis of teleseismic earthquake events was conducted using twenty-four broadband seismometers distributed around Bass Strait. This was motivated by the need to understand the enigmatic relationship between terranes in Tasmania and Victoria, as well as the poorly understood and undercover association between the tectonic elements across Bass Strait. Using the Neighbourhood inversion Algorithm, a seismic velocity model of the crust was inferred for each location. Well-fitting models are characterised by a synthetic receiver function that matches the variations in the observed receiver function. In the case where more than one structure is a good fit to the waveform, this is shown in the output of the inversion procedure. New determinations of crustal structure were made that significantly improve the constraints on the Moho depth for Bass Strait and surrounding areas. The results from this study suggest a shallow (20–27 km) Moho with a gradational transition beneath west Bass Strait and a deeper (30–40 km) Moho with a sharp transition beneath east Bass Strait. A low velocity zone in the upper mantle beneath King Island is consistent with mafic underplating and subsequent detachment of cooled and fractionated material. The sharp Moho beneath east Bass Strait is not typical of the orogenic terranes in the southeast of mainland Australia. Further implications of the new structural findings are discussed in the light of theories concerning the tectonic evolution of southeast Australia.

*Ashby is a geophysics student at the University of Tasmania and part-time adventurer. He has wanted to be a geologist since primary school and over his time at university has developed a passion for global tectonics. He looks forward to learning more about all areas of geology and to getting outside and discovering more about our planet.*

**Alistair Harvey:** *Depth to basement below the Bowen and Surat Basins, Chinchilla, Queensland.* University of Tasmania

The Jurassic-Cretaceous Surat Basin in the Darling Downs region of southern-central Queensland is currently the focus of major coal seam gas (CSG) exploration. The economics of CSG extraction are in part determined by the structure of the basin, which controls the depth to coal resources and permeable pathways for gas extraction. In the Darling Downs region, around the town of Chinchilla, the Surat Basin overlies Palaeozoic basement rocks of the New England Orogen in the east, and the Permian Bowen Basin in the west. Depth to basement varies significantly, from outcrop to the northeast of the region to greater than 10 km in the Taroom Trough to the west. This study provides a detailed depth to basement surface centred on tenements held by QGC near the town of Chinchilla, using public access potential field, well and seismic data.

The basement surface was created predominantly by synthesis of potential field forward modelling guided by wells and 2D seismic. Time horizons picked on 2D seismic data for several prominent reflector packages were interpolated and converted to depth horizons to help constrain the basement interpretation. Interpretations of seismic data and automated potential field source depth estimation guided forward modelling and potential field inversions. The final basement surface was created by ranking the confidence in individual techniques and datasets to compile a surface that reflected the best constrained model.

Well and seismic data are the best methods for determining basement depth, particularly in the east of the study area where there is good seismic coverage and the basement lies relatively close to the surface. However, the limited distribution of wells and seismic further west, together with the difficulty of identifying basement beneath the Bowen Basin in seismic data, meant that potential field techniques were utilised to infill gaps. Potential field automated depth estimation techniques locate lateral contrasts and produce a range of plausible depths, although considerable filtering of source solutions was required to identify the most probable solutions. Inversions of magnetic and gravity data provided few additional constraints on the basement depth surface. Difficulties with synthesizing the individual datasets meant that forward modelling, guided by the seismic and automated depth estimate techniques, was heavily relied upon to produce the final model

*Alistair has a double degree in Economics and Science, majoring in Economic Analysis, Economic Geology and Geophysics, and has just completed his Honours year in Geophysics at the University of Tasmania. He has been actively involved in the Tasmanian Student Chapter of the AusIMM as Treasurer in 2012 and has undertaken internships in both the Mining and Energy sectors. He will commence work with Evolution Mining as a Graduate Geoscientist in 2015.*

**Jie Yu:** *A geophysical investigation of the Mt Lindsay-Lynch Hill area, western Tasmania.* University of Tasmania

The Mt Lindsay-Lynch Hill area is characterized by a complex succession of late Proterozoic to Ordovician rocks that has been intruded by Devonian granitic rocks. The study utilizes potential field geophysical methods to reinterpret the three-dimensional geology of this region with particular emphasis on the distribution of Devonian granitic rocks.

New petrophysical data from drill core indicates that the Meredith Granite, Owen Group and Eldon Group may produce negative residual Bouguer anomalies, while positive anomalies are likely associated with denser units like the Success Creek Group, the Crimson Creek Group and Cleveland-Waratah association. Cambrian ultramafic units display significant variation in density, due to the high degree of sepentinistation of the samples. Cambrian ultramafic complexes and mineralized rocks are the strongly magnetic rocks within the study area and account for almost all of the anomalies observed in the TMI data.

Addition of new gravity data on systematic application of automatic terrain correction in the study area has better defined the form of the major anomalies and suggests a steeper southern margin for the Meredith granite than previously interpreted. Constrained inversion of the residual Bouguer gravity data suggests the presence of a previously undocumented subsurface granite body in the east of the study area. Unconstrained magnetic inversions suggest that Cambrian ultramafic units do not continue under the Huskisson syncline in all areas. The zones where Cambrian ultramafic units appear to be discontinuous are spatially associated with the referred subsurface granite body. The discontinuous distribution of Cambrian ultramafic units provides a supporting evidence for a subsurface granite body in this area.

*Jie Yu is Chinese and came to Australia to study in 2011. She holds a Bachelor of Science with Honours in Geophysics from University of Tasmania. She is interested in geophysical mapping and mineral exploration.*

## Masters projects

**Sabbath Akhabue:** *Analysis of time lapse signal over a depleted gas field.* Curtin University.

**Vanessa Gutierrez:** *Cooperative evaluation of post-stack inversion techniques over the Maitland Reservoir and adjacent prospects.* Curtin University.

The Maitland Gas field located in the Barrow Sub-basin of the offshore Carnarvon basin shows a distinctive seismic amplitude anomaly at the base Tertiary level, where three wells have intersected gas charged sandstones. The Moon-1 well located approximately 15 km towards the north of the Maitland gas field shows poor reservoir development at the Maitland sand horizon at the base Tertiary level with weak seismic amplitude response. Even though the presence of gas in Maitland Sand shows a general elevated amplitude response, a judgment based only on amplitude will not be enough to characterize the Maitland reservoir. Therefore, impedance estimation over the area is required by performing a poststack inversion. This analysis will allow mapping of the spatial variability of the acoustic impedances related to the Maitland gas charged sand by performing poststack inversion. From that process will be possible to see better sand quality in those areas where the acoustic impedances is lowest. The poststack inversion results will be evaluated by comparing different conventional poststack algorithms, then a comparison with previous study will be performed This will help in the identification of the largest continuous areas of lowest impedance and in the evaluation of their spatial distribution and potential geological boundaries. All of this interpretative work was done on Apache Energy's offices using the Hampson-Russell Inversion software package (Strata) and Insight3.1.0.

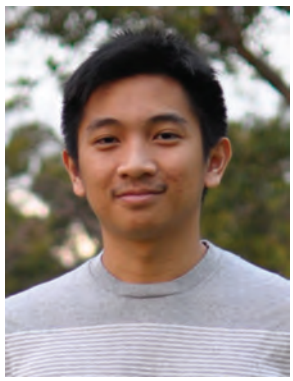
The different inversion results show clearly the reservoir, a low impedance sand. The post-stack inversion gives the best results was the Coloured based algorithm, at the well location this model shows to be the closest to the values of the impedances from well logs. The distribution of the Maitland sand was best represented by the Band Limited inversion, as it matches with geological features observed on seismic data.

*Vanessa Gutierrez is from Venezuela, South America. She studied for her Bachelor's degree at the Simon Bolivar University in Caracas, Venezuela. After that, she spent 1 year and 5 months working for a service company. This working experience made her think about going to university to complete a Master's degree in Geophysics. In 2012, she decided to come to Australia to study for a Master's degree in Science (Geophysics) at Curtin University of Technology. After a year, she joined Apache Energy as a vacation student, which allowed her to complete her thesis project during 2014. Vanessa is very interested in continuing to learn whilst working as a geophysicist in Australia.*

**Zacharia Shitakwa Hoidi:** *An investigative study on static correction methods to optimise on processing time and cost.* Curtin University.

**Raqatim Seru:** *A field test of electrical resistivity changes occurring during flow through a whole core sample.* Curtin University.

**Ridha Ramadhan Soedarsono:** *Pseudo 3D processing of crooked 2D Seismic profiles.* Curtin University.



Land 2D seismic survey is often restricted due to various terrain issues and ends up as a crooked 2D seismic profile. In complicated 3D geological structures, out of plane events are frequently introduced. These are cross-dip events produced away from the midpoint track which do not correspond to the CMP line. These events may both create false structure as well as distorting true structure.

In case of a severely crooked seismic profile, the midpoint distribution would scatter forming a wide area instead of a single line. Therefore, there is a possibility to treat a crooked profile data as a portion of 3D survey. This project attempts to identify out of plane events by performing a pseudo-3D processing algorithm on the crooked profile data. Subsequently comparison with both conventional 2D processing data and true 3D data is done to see the robustness of the method.

There are issues found with this method. It has a lower stack quality due to lower fold density and, as it also lacks of actual crossline information, it does not represent the accurate crossline interface compared to true 3D data. Nevertheless, result shows the pseudo-3D processing method is capable of identifying out of plane events by presenting less of these events in the final image compared to the conventional 2D processing method. This result is also confirmed by comparison with the true 3D data.

*Ridha Ramadhan Soedarsono is a Masters in Geophysics student at Curtin University. He has a Bachelor's degree in Physics from Institut Teknologi Bandung, Indonesia. He is currently interested in seismic data processing.*

**Alexandre Lemenager:** *Assessment of the geothermal attributes of the Northern Permian Sydney Coal Measures.* Macquarie University.

Coal samples from the Northern Sydney Basin coal measures were collected and analysed through a thermal conductivity tester in order to determine individual thermal conductivities of each coal specimen. Thermal conductivities were acquired at temperatures between 20 and 300°C. Petrographic and XRF/ICPMS analysis are underway which will aim to constrain certain parameters such as pore space, grain size, cement mode and signs of alteration in coal samples, as well as determining the bulk composition to be correlated with known thermal conductivities. The majority of samples were acquired through exploration mining companies. Samples of the St Heliers coal seam, part of the Greta coal measures, were obtained through MusCoal based at Muswellbrook; samples of the Lemington and Bayswater seams, part of the Whittingham coal measures, were obtained through the Ravensworth Surface operation exploration mining group; samples of the Big Ben and B3, part of the Tomago coal measures, were obtained through Bloomfield Collieries based at East Maitland;

and lastly the Catherine Hill Bay coal seam samples from the Newcastle coal measures were obtained through a coastal outcrop, southeast of Lake Macquarie. Current results show that the majority of coal samples out of a total of 18 have predictable thermal conductivity gradients between 20 and 300°. There are exceptions, which are due to the presence of quartz veins and apparent silicification, resulting in higher thermal conductivities. Thermal conductivity measurements can be used to predict the potential heat flow of specific coal seams at various temperatures. Low and high temperature calibrations were done to accommodate potential instrumental drift and reduce uncertainties in thermal conductivity measurements, where slight variations in thermal conductivities were observed between stock factory and recent calibrations. Thermal conductivity measurements can be used to predict the potential heat flow of specific coal seams at various temperatures and provide a basis for the understanding of the thermal properties of coal measures in the Hunter Valley region and the role of coal as a thermally insulating structure in potential geothermal systems.

*Geology and geophysics have been the main focus of Alexandre's studies at Macquarie University, his Bachelor's Degree and his current Masters project. More specifically, the field of geothermal energy has been a personal field of interest. This interest stemmed from pure curiosity but eventually led to a research project regarding coal measures in the Sydney Basin.*

**Ben Patterson:** *A geophysical investigation of the Woodend base metal occurrences.* Macquarie University.

This report contains the findings of a two week geophysical survey and subsequent data processing, modelling and evaluation of the Woodend base metal occurrences east of Cooma, New South Wales. Three targets were identified within the prospect after the analysis of samples acquired during surface prospecting. Two of the samples returned economic grades of zinc and the third target was the site of an abandoned copper shaft surrounded by malachite stained dump rocks. Analysis of these rocks suggested a promising opportunity for exploration and warranted a geophysical investigation to determine the validity of any possible ore grade deposits. To determine the size and extent of possible subsurface mineralisation a variety of geophysical methods were employed. Industry proven gravity, magnetic, and electromagnetic techniques were deemed the most appropriate in the investigation of the suspected metallic deposits. These methods were also evaluated in terms of their respective ability to resolve the underlying geology of the Woodend prospect. In-depth data processing was undertaken to improve the quality of the various data sets. Each of the data sets was evaluated in terms of their ability to delineate sulphidic mineralisation and the local geology of the Woodend survey area. Although the TEM survey displayed a small anomaly over the abandoned copper shaft, it was ultimately concluded that the methods used in the survey did not identify a massive sulphide deposit but rather detected varying geophysical responses within the local geology.

*Ben is currently completing a Master's of Science (Geophysics) at Macquarie University where he also attained his Bachelor of Science majoring in Geophysics and Geology. His focus is on mineral exploration, in particular data modelling and the application and associated challenges of various geophysical techniques. Ben is a student member of the AIG, ASEG and AusIMM.*

**Tunde Adekoya, Jeffrey Shragge, Mattias Leopold and Gavan McGrath:** *Time-lapse geophysical monitoring of the subsurface hydrology at Kings Park.* The University of Western Australia.

*Tunde Adekoya*

The increasing occurrence of drought stress throughout southwestern Western Australia is postulated to have contributed to the decline of Banksia populations both in Kings Park, Perth, and in the Banksia woodlands in the greater Swan Coastal Plain region. To help quantify these assertions, there is an urgent need to better understand the base levels of soil moisture content – as well as seasonal variations thereof – in these geographical regions. As a baseline study, we applied repeat (i.e. time-lapse) geophysical methods to image the geology and the hydrology at two Kings Park locations with contrasting elevations and depths to groundwater in order to develop a conceptual model of the subsurface hydrology and plant-water use in the Park. We conducted time-lapse (TL) electrical resistivity tomography (ERT) and ground penetrating radar (GPR) methods on a monthly basis and combined with soil analyses and direct soil moisture measurement to refine and constrain the conceptual model.

The two geophysical survey transects were situated within Kings Park roughly 1.3 km apart with the western line situated 40 m higher in elevation than the lower eastern site. Time-lapse ERT and GPR data were acquired at both sites between May and August 2014. Electrodes were left in the ground for the 4-month period to ensure repeatability of measurements and to serve as guides for the repeat GPR acquisition. In addition, at each site we hand-augured test holes to a depth of 3–4 m and collected samples at 20 cm intervals to enable grain-size analysis, soil moisture content and water retention tests. PR2 capacitance probe measurements were also acquired when auguring to enable a moisture content comparison study.

The temporal variations in resistivity profiles from the inverted TL ERT datasets were interpreted in terms of changes in moisture content. These profiles reveal significant calendar variations in the spatial distribution of moisture content. The TL ERT inversions also detected isolated less resistive lithologies and the depths to groundwater. Processed TL GPR data were interpreted to show vertical variations in the vadose zone moisture content. Temporal water content variations were consistent with the rainfall data. However, the TL GPR data could not be used to characterise the spatial variations in the subsurface volumetric water content because the GPR waveforms exhibited

no significant velocity variations and thus low sensitivity to water content changes. We established a highly correlated relationship between dielectric permittivity and water content, which suggests that one may characterise volumetric water content from the dielectric permittivity of the vadose zone. Statistical analysis of the sample grain-size distributions indicate that the particle-size distributions between the two sites do not vary significantly. We examined soil water retention by plotting volumetric water content as a function of pressure, which shows a sharp drop in water content from low-to-high pressures as is typical of sands. The inverted resistivity profiles and observed volumetric water content are strongly correlated ($R^2 = 0.84$) as may be expected from Archie's law. Soil moisture content analysis results including the PR2 probe measurements were plotted as a function of depth, the result shows vertical variations in moisture content with depth. The hydrological tests indicated the properties of the subsurface lithologies confirm the responses of the resistivity measurements.

This research work monitors water variations within the Kings Park and how they are related to the hydrological properties of the subsurface soils. The geophysical investigations indicated that water varies periodically and its availability and variations depends on the frequency of the rainfall. The hydrological tests reveal that the soils are mainly sands with low water retention capacity; however, water retention capacity increases with depth from about 3.5 m (due to an increase in silt/clay content). These observations suggest that during the long dry summer period, water may not be available to plants with shallow roots (plants with roots < 3.5 m deep). Water may therefore be a limiting factor responsible for the decline in Banksia plants.

*Tunde Adekoya received a BSc degree in Geology from the University of Ilorin, Nigeria (2000) and MSc degree in Geology with an Applied Geophysics option from the University of Ibadan, Nigeria (2004). Tunde worked for Nigerian Geological Survey Agency between 2007-08 and then as a Field Engineer for Pilbara Wireline Services between 2009-12 conducting downhole geophysical surveys throughout the Midwest and Pilbara regions of Western Australia. In 2012, he commenced a part-time MSc Geosciences degree at the University of Western Australia (UWA) whilst continuing his Field Engineering work. Tunde recently was awarded the 2014 UWA Postgraduate Mentor of the Year Award (Muhammad Rizwan Hussain Award), and is expecting to finish his UWA MSc Geosciences degree in 2014.*

## PhD projects

**Dr Kent Inverarity:** *Electrical geophysics of carbonate mound spring complexes of the South-Western Great Artesian Basin.* University of Adelaide.

Artesian mound springs occur along the southwestern edge of the Great Artesian Basin, in northern South Australia, but their underground structure and relationship to faulting is not well understood. This work aims to address that with geophysical surveys over three mound spring systems (Beresford and Warburton Springs, the Bubbler Spring complex, and Freeling Springs), using a range of techniques: self-potential, magnetotellurics, and time-domain electromagnetics.

The self-potential data contain elevated local responses to spring vents and seeps. Spatial correlation suggests that these responses are caused by flow related to springs. Similar responses also occur underneath 'extinct' springs, suggesting shallow subsurface discharge of aquifer waters is still occurring. Little evidence was found for significant downward infiltration from spring tails.

Modelling of time-domain electromagnetic and magnetotelluric data show that the confining Bulldog Shale, which is generally very conductive, contains slightly more resistive areas underneath springs and spring complexes, which may be related to a combination of carbonate buildup in the subsurface and more resistive aquifer water. Magnetotelluric data and modelling suggests that fault zones exist under many of the mound springs, particularly at Beresford and Warburton Springs and the Bubbler Spring complex, with data consistent with models containing parallel vertical fault planes striking NW/SE. The models contain fault zones in the aquifer and immediately underlying basement, suggesting that fluids may be sourced from the aquifer and deeper layers. The fault zone is not sensed in the aquitard, due to the very slight resistivity contrast.

Conduits to specific springs have not been successfully imaged using the techniques employed here, suggesting that the conduits are narrow and present only a slightly fluid resistivity contrast.

*Kent Inverarity is working as a Geophysicist / Project Officer in the SA Department of Environment, Water and Natural Resources.*

**Dr Aixa Rivera-Rios:** *Multi-order vector finite element modelling of 3D magnetotelluric data including complex geometry and anisotropy.* University of Adelaide.

This thesis presents the development of a computational algorithm in Fortran, to model 3D magnetotelluric (MT) data using a Multi-order Vector Finite Element Method (MoVFEM) to include complex geometry (such as topography, and subsurface interfaces). All the modules in MoVFEM have been programmed from the beginning, unless specified by referencing the libraries used. The governing equations to be solved are the decoupled electromagnetic (EM) partial differential equations for the secondary electric field, or the secondary magnetic field, with a symmetric conductivity tensor to include anisotropy. The primary fields are the solution of a plane-wave within the air domain. Two boundary conditions are implemented, namely the Generalized Perfect Matched Layers method (GPML) and Dirichlet boundary conditions. Three Dirichlet

boundary schemes are applied, first considering zero EM fields at the boundaries of the computational domain; secondly, considering the boundaries as homogeneous Earth; and finally, considering the boundaries as a layered Earth. Two formulations of GPML are implemented in this algorithm, firstly the original GPML formulation and secondly, the GPML parameters are modified for the MT and Controlled Source Electromagnetic (CSEM) problem. High-order edge-elements are defined based on covariant projections, and mixed-order edge-elements for hexahedra. The vector basis functions are defined for linear elements (12 edge-elements), quadratic elements (36 edge-elements), and Lagrangian elements (54 edge-elements). By this definition, the vector basis will have zero divergence in the case of rectangular elements and relatively small divergence in the case of distorted elements.

The validation of this computational algorithm is performed with a homogeneous Earth, where the analytic solution of the MT problem is known. In the validation, the convergence of the solution is analysed for different grid spacing and for different element-orders with Dirichlet boundary conditions. High-order elements produce accurate solutions with larger spacing than the fine grid needed for linear-order elements. After the convergence analysis, the solution obtained with all the proposed boundary conditions, and edge-element orders are compared for one frequency, and for a frequency range. In the homogeneous Earth, Dirichlet boundary condition presents backward reflections from the boundaries of the computational domain to the centre of the model. Both GPML formulations produce more stable solutions, where no boundary reflections are present. However the MT responses fluctuate within a small range close to the values for the homogeneous Earth. The GPML formulation for MT and CSEM produce more accurate results and stabilize the MT responses over a frequency range. This algorithm is applied to synthetic examples with complex conductivity structures. Some of these synthetic examples have been published previously, thus the results of this algorithm are compared qualitatively. In the case of anisotropy and complex geometry, the proposed synthetic examples have not been published, and a discussion of how the MT responses behave for these Earth examples is presented. This computational algorithm could be extended with the use of an adaptive method, and it could be implemented in an algorithm for 3D inversion of MT data.

*Aixa Rivera-Rios is now working for Schlumberger in Houston.*

**Dr John Wilford:** *New regolith mapping approaches for old Australian landscapes.* University of Adelaide.

The regolith, or 'critical zone', forms a discontinuous layer that covers large areas of Earth's terrestrial surface. It is a dynamic zone that forms and changes through time in response to interactions between air, rocks (minerals), water and biota. Knowledge of regolith is critical because of its key role in supporting terrestrial life, through physical, chemical and biological processes that operate at mineral-water interaction scales up to the regional scale through geological and tectonic activity. There are many disciplines or areas of applied integrated research that rely on an improved understanding of regolith formation and information on surface and sub-surface regolith properties at appropriate spatial scales. These areas of study include; agriculture, land use sustainability, hydrology, salinity management, ecology, mineral exploration, natural hazard risk assessment and civil engineering. Furthermore, mapping regolith is critical in understanding the origin and evolution of regolith through space and time. Mapping the regolith and formulation of associated robust process models are in their infancy compared with geological and soil mapping, which have had a long history of development and refinement. Regolith mapping can be seen as a hybrid approach combining elements from the existing mapping disciplines of geology, soil and geomorphology. The regolith-landform approach, used extensively in Australia, is broadly similar to soil-landscape mapping where landforms are used as the principal surrogate to map regolith. Regolith-landform and soil-landscape mapping are inherently empirical and qualitative. However, in the last ten years there has been a move from the qualitative land resource survey (i.e. soil-landscape mapping) approaches to quantitative, digital survey underpinned by statistical methods. These new quantitative approaches are enabling the prediction of specific soil properties with associated estimates of model confidence or uncertainty not possible using traditional approaches.

The aim of the thesis is to demonstrate and assess the application of quantitative soil mapping approaches in predicting regolith properties. Four case studies are presented that illustrate the application of quantitative mapping approaches in predicting regolith across a range of spatial scales and within different landscape settings. These four investigations include: 1. A continent-wide prediction of weathering intensity using a step-wise multiple regression-based model using airborne gamma-ray imagery and terrain relief; 2. A continent-wide prediction of near-surface secondary carbonate using environmental correlation and regolith geochemistry; 3. A regional-scale prediction of soil-regolith thickness over the Mt Lofty Ranges in southern South Australia using environmental correlation, drilling and legacy data, and 4. A regional-scale 3D regolith-landscape evolution model of valley-fill deposits from the Jamestown area in South Australia based on dataset integration, regression analysis and optically stimulated luminescence dating. The investigations are interpreted within a landscape evolutionary framework and future research directions are discussed.

Digital regolith mapping shows considerable potential in predicting regolith properties over different landscape scales. This mapping is also important for understanding the complex interaction of environmental factors that control regolith formation, removal and preservation. Addressing gaps in predictive datasets that describe or reflect properties within the sub-surface (i.e. 5–100 m depth interval) and systematic collection of quantitative regolith attributes such as weathering depth and geochemistry will greatly enhance the future applications of digital regolith mapping in Australia.

*John Wilford is currently with Geoscience Australia.*

**Dr Faisal Abdulkader Alonaizi:** *Application of diffracted wave analysis to time-lapse seismic monitoring of $CO_2$ geosequestration.* Curtin University.

**Dr Majed Ahmed Almalki:** *Borehole Seismic methods in high permeability sandstones.* Curtin University.

**Dr Mehdi Asgharzadeh:** *Analysis of seismic anisotropy at the CO2CRC Otway project site.* Curtin University.

**Dr Eva Caspari:** *Effect of scale and saturation on effective properties of porous rocks for seismic monitoring of CO2 sequestration.* Curtin University.

**Dr Sofia Correia Lopes:** *Fluid injection in reservoir rocks with x-ray CT scanning*

*and active ultrasonic monitoring.* Curtin University.

**Dr Konstantin Tertyshnikov:** *Seismic imaging in hard rock environments.* Curtin University.

**Robin Armit:** *High-heat geodynamic setting during the Palaeozoic evolution of the Mount Painter Province, SA, Australia: evidence from integrated field structural geology and joint potential-field inversions.* Monash University.

A method for subsurface recognition of blind geological bodies is presented using combined surface constraints and 3-D structural modelling that incorporates constraints from detailed mapping, and potential-field inversion modelling. This method is applied to the Mount Painter Province and demonstrates that addition of low density material is required to reconcile the gravity signature of the region. This method may be an effective way to construct 3-D models in regions of excellent structural control, and can be used to assess the validity of surface structures with 3-D architecture. Combined geological and potential-field constrained inversion modelling of the Mount Painter Province was conducted to assess the validity of the geological models of the region. Magnetic susceptibility constrained stochastic property inversions indicates that the northeast to southwest structural trend of the relatively magnetic meta-sedimentary rocks of the Radium Creek Group in the Mount Painter Inlier is reconcilable with the similar, northeast to southwest trending positive magnetic anomalies in the region.

Radium Creek Group packages are the major contributor of the total magnetic response of the region. However field mapping and the results of initial density constrained stochastic property inversion modelling do not correlate with a large residual negative gravity anomaly central to the region. Further density constrained inversion modelling indicates that an additional large body of relatively low density material is needed within the model space to account for this negative density anomaly. Through sensitivity analysis of multiple geometrical and varied potential-field property inversions, the best-fitting model records a reduction in gravity rms misfit from 21.9 to 1.69 mGal, representing a reduction from 56 to 4.5 per cent in respect to the total dynamic range of 37.5 mGal of the residual anomaly. This best-fitting model incorporates a volumetrically significant source body of interpreted felsic, low density material (1012 $m^3$) impinging on the central-west of the Mount Painter Inlier and overlying Neoproterozoic sequences, and the emplacement of more mafic affinities in the northeast and east. The spatial association and circular geometry of these granitoid bodies suggests an affinity with the Palaeozoic ~460–440 Ma British Empire Granite that outcrops in the Mount Painter Inlier. The intrusion of this additional material in the Palaeozoic could either be the product of; or contributed to, an increased local geotherm and heat flow in the region during the Palaeozoic.

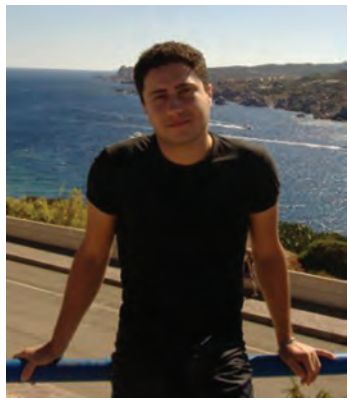
*Robin completed his PhD at Monash University studying the geodynamic evolution of the northern and eastern marginal terranes of the Gawler Craton. The research includes the integration of structural geology, geochronology, Hf isotopes and structural geophysics. Robin is also an assistant lecturer in Geophysics at Monash University and a Principal Geologist at PGN Geoscience specialising in geological interpretation mapping from potential-field data.*

**Teagan Blaikie:** *Interpreting the subsurface architecture of maar volcanoes using geologically constrained 3D gravity inversions.* Monash University.

Geophysical modelling techniques are applied to examine and compare the subsurface morphology of maar volcanoes within the Newer Volcanics Province to better understand their eruptive histories and the hazards associated with future eruptions within the province. High-resolution ground gravity and magnetic data were acquired across several maar volcanoes, including the Ecklin maar, Red Rock Volcanic Complex, and Mount Leura Volcanic Complex and the Anakie maar. The depth and geometry of subsurface volcanic structures were determined by interpretation of gridded geophysical data, and constrained 2.5 Dforward and 3 Dinverse modelling techniques. Bouguer gravity lows identified across the volcanic craters reflect lower density lake sediments and pyroclastic debris infilling the underlying maar-diatremes. These anomalies were reproduced during modelling by shallow coalesced diatremes. Short-wavelength positive gravity and magnetic anomalies identified within the centre of the craters suggest complex internal structures. Modelling identified feeder vents, consisting of higher proportions of volcanic debris, intrusive dykes, and ponded magma. Because potential field models are non-unique, sensitivity analyses were undertaken to understand where uncertainty lies in the interpretations, and how the models may vary between the bounds of the constraints. Rather than producing a single 'ideal' model, multiple models consistent with available geologic information are created using different inversion techniques. The modelling technique we present focuses on maar volcanoes, but there are wider implications for imaging the subsurface of other volcanic systems such as kimberlite pipes, scoria cones, tuff rings and calderas.

*Teagan Blaikie won the ASEG Victorian Branch student night award for her presentation on her PhD thesis.*

**Dr Giovanni Spampinato:** *Deep Australia.* Monash University.



Geophysical interpretation and 2.5 D potential-field forward modelling suggest that the Thomson Orogen in Queensland represents the interior extensional architecture during the Rodinia break-up that has been subsequently extensively modified by multiple extensional basin forming events and transient episodes of crustal shortening and basin inversions. In this scenario, the Cork Fault separating the Thomson Orogen and the Mount Isa Terrane does not define the zone of break-up as has been previously proposed nor is required to represent the boundary between the Proterozoic crust and the Phanerozoic crust of the Australian continent. This implies that the Thomson Orogen differs from the rest of the Tasmanides and the Thomson and the Lachlan orogens are two fundamentally different terranes.