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Education matters

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NExUS: a new national field school for geophysics

The University of Adelaide and the Minerals Council of Australia have teamed up to run a three week student field camp in geophysics, with a strong UNCOVER theme. The national UNCOVER project http://www.uncoverminerals.org.au/ is supported by Geoscience Australia, all the State geological surveys, a range of industry partners, and is a guiding light for much of the academic research conducted in Australia for the mineral industry.

The University of Adelaide, led by Professor Graham Heinson and Research Fellow Dr Richard Lilly, has taken a further initiative to run a three-week field camp for geoscience students, exposing them to the excitement and challenges of mineral exploration and the geophysical techniques which are making deep exploration possible. The inaugural camp took place in the Adelaide Hills and the Yorke Peninsula of South Australia, and attracted 30 students from 13 universities around Australia. Richard Lilly highlighted a goal of the course thus:

'The tools and processes introduced in the programme are those which will be required by the next generation of explorers in the hunt for the next Tier 1 mineral deposits.'

The NExUS national programme is uniquely targeted to Australian requirements, but it builds on a tradition started 35 years ago in North America by the University of Arizona. The Summer of Applied Geophysical Experience (SAGE) programme has reached its 35th field season, and has an impressive track record of demonstration of the 'discovery-oriented approach' to teaching, having been involved in geophysical characterisation of buried waste, mapping archaeological sites, and studying tectonic

Graham Heinson

Richard Lilly

NExUS students at their final field location of the 2016 NExUS Programme with (at right) Steve Hill (Director of GSSA).

structure and water resources of the Rio Grande rift (Baldridge, 2012).

Back in South Australia, our inaugural NExUS programme began at the state of the art South Australia Drill Core Reference Library at Tonsley, SA, with presentations from senior industry representatives including Gavin Lind (MCA), Robbie Rowe (NextGen/UNCOVER), Steve Hill (GSSA), Stephan Thiel (GSSA), Carmen Krapf (GSSA), Malcolm Sheard (GSSA), Ross Cayley (GSV), Jon Huntington (CSIRO), Ravi Anand (CSIRO), Ian Lau (CSIRO) and Graham Heinson (UofA). Workshops included regolith characterisation and mapping interpretations, a HyLogger hyperspectral data workshop, core logging and 3D visualisation of the South Australian geology database and geochemical dispersion in regolith. During the evenings chances for networking were encouraged, with senior industry professionals flying in especially to meet with and share career tips with the NExUS students.

In the second week students went exploring in the Adelaide Hills. Hillgrove Resources supported the programme by providing ground access and data resources to one of their exploration tenures in the area. Participants carried out detailed mapping and practiced acquiring ground based geophysical data (including magnetics, gravity, magnetotellurics (MT), induced polarisation (IP) and Nano TEM) across the historical Wheal Ellen Cu (Zn-Pb) deposit. Soil geochemistry and an awareness of the different approaches for regolith sampling were also on the agenda for the students. During the evenings students processed the geophysical data acquired in the field with assistance from industry geophysicists including Matt Zengerer (Gondwana Geoscience). Soil samples were analysed with a pXRF, followed by creation of thematic geochemical dispersion maps of the results using GIS software. Data was then collated, which allowed students to determine potential further exploration targets. Hillgrove Resources also provided the opportunity to visit the Kanmantoo Cu Mine and kindly laid out grade control drill core for the NExUS students to log and practice their mineral identification skills.

For the final week, NExUS headed for the historic ‘Copper Coast’ of the Yorke Peninsula, SA. The focus for the start of the week was identification of ore and gangue minerals, hydrothermal alteration and breccia textures and mineral paragenesis. Building from the skills gained over the past two weeks, students were again provided with a practical learning exercise of logging and interpreting the mineral paragenesis of exploration drill core with senior geologist Craig Went at REX Minerals Hillside Cu deposit, which was discovered under alluvial cover. Steve Hill (Director of GSSA) provided a one day field-based workshop on biogeochemistry and regolith, explaining the potential for exploration companies to use vegetation to better define targets before moving in with a drill rig. He also encouraged students to accurately describe the regolith, and explained the importance of understanding regolith evolution in order to ensure exploration activities, such as soil sampling, are conducted as effectively as possible.

As the end of the three week course was fast approaching, the programme moved from exploration into resource estimation and project feasibility. Students were introduced by Gavin Springbett (G&S Resources) to 3D ore body modelling in Vulcan and the process of resource and reserve calculations in accordance with the JORC Code. This process took the NExUS course full circle from conceptual exploration models to highlighting the importance of detailed reporting and ore body modelling.

On the final night students were given the opportunity to reflect and share what they learned during the 3 week course and to thank one another for their friendship, encouragement and teamwork during the course. The professionalism and comradery between all the NExUS students was observed by all involved and commented on by industry professionals throughout the programme, with some saying that they are happy to leave the mineral exploration industry in the hands of such talented individuals.

As Craig Pereira from UQ put it, ‘The NExUS programme provided me with exposure to new technology and exploration techniques that have the potential to be game changers when exploring undercover’. Allison Cooke from Monash added, ‘The diversity of experiences and material was inspiring as were the industry professionals who came to speak with us’.

The next NExUS course is planned for end of 2017; further information and application forms are available at www.nexus.org.au.

And, in a couple of decades time, may Australia’s NExUS boast, like North America’s SAGE, of a cadre of top professionals and ore-body finders who point to the student field camp as one of their key learning experiences.

Acknowledgements

Thanks to Genna McDonagh and Richard Lilly for their description of the programme; read it in full at https://www.linkedin.com/pulse/report-inaugural-nexus-national-exploration-undercover-richard-lilly.

Reference

Baldridge, W. J., 2012, SAGE at 30: *The Leading Edge*, June 2012, 702–708.

ASEG student member Kathryn Hayward wins an IGC Early Career Travel Grant

Congratulations to Kathryn Hayward, PhD student at the Australian National University, on winning one of five Early Career Travel Grants offered by the Australian Geoscience Council. The grants are offered annually and are made possible by the financial success of the 34th International Geological Congress held in Brisbane in 2014. The award will allow Kathryn to attend and present research at the Deformation, Rheology and Tectonics Conference in Inverness, Scotland and undertake state-of-the-art laboratory earthquake slip experiments at ENS Paris.

Kathryn Hayward in her laboratory, with a high-temperature deformation apparatus.

Kathryn uses experiments undertaken at pressure and temperature conditions comparable to those found deep in the crust to learn about the strength and behaviour of faults. Specifically she is interested in understanding the processes that occur during the first seconds of fault slip as this is central to understanding whether a fault rupture grows to become a large, damaging earthquake, or strain is accommodated as a small, possibly non-seismic event. During the first seconds of slip, the extreme forces acting on fault contacts, or asperities, result in heat generation, formation of damage and changes in the physical properties of a surface. As slip proceeds, these processes can result in an evolution of fault strength through a process referred to as 'dynamic weakening'.

A key aspect of the current research is the role that fluids play in affecting the behaviour of faults during the initial stages of slip. Fault zones are recognised as fluid conduits within the crust and large-scale injection experiments (such as in Basel, Switzerland) have shown a direct correlation between fluid pressure and rates of seismicity. This has important implications for the development of hydraulic fracture technologies such as enhanced gas recovery, geothermal energy extraction and geo-sequestration. However, presently little is known about how pore fluids modify fault strength and asperity behaviour during rupture and how this could facilitate or impede rupture propagation.

During the visit to the ENS laboratories Kathryn will be using experimental techniques pioneered by that lab to explore differences in fault processes between earthquakes resulting from increases in shear stress (such as classic mainshock-aftershock events) and those driven by changes in pore fluid pressure (e.g. during an injection driven swarm sequence). Experiments will focus on deformation occurring prior to and during the onset of slip using highly sensitive acoustic emission sensors. These measurements will provide information on rupture velocities at various conditions and waveforms will be inverted to characterise the 3-D geometry of earthquake nucleation and propagation. In-situ strain gauges will allow measurement of co-seismic stress drop in real time with a temporal resolution of approximately 1 million samples per second.

The next step in this research will be back in Australia making use of the latest high-resolution electron microscopy imaging techniques to provide information on the microstructural changes that are occurring on the fault surface during the early stages of slip. The combined mechanical and microstructural data will give us new insights about how fluids alter fault strength and behaviour during rupture. This knowledge will help us improve understanding of earthquake nucleation and potentially assist with mitigation of seismic risk associated with new injection technologies.

SEG 2017 Distinguished Instructor Short Course: Doug Oldenburg

Geophysical electromagnetics: fundamentals and applications

Doug Oldenburg

Summary

Electromagnetics has applications in oil and gas exploration and production, mineral exploration, groundwater exploration and monitoring, geotechnical and environmental industries. Although it has widespread applications as a geophysical technique, it is not generally understood by the geoscience community. As a result it is underutilised, and in some cases misused, as a technology.

The aim of this course is to provide a fundamental understanding about EM geophysics so that practitioners can decide if an EM technique can help solve their problem, select which type of survey to employ, and set realistic expectations for what information can be gleaned. Case histories, spanning applications from many areas in the geosciences, are used as an underlying framework to bind the material together. For more information, see the online resources at http://disc2017.geosci.xyz.

Fundamentals and applications

Case histories pertain to problems in resource exploration, including oil and gas, minerals, water, environmental, and geotechnical areas and are contributed by experts worldwide. (http://disc2017.geosci.xyz/).

These include:

1. resource detection (e.g. methane hydrates) or de-risking (e.g. offshore-hydrocarbons),
2. imaging SAGD steam chambers or monitoring hydraulic fracturing,
3. mineral exploration (on land, on the ocean floor sea floor massive sulfides),
4. water issues (e.g. monitoring salt water intrusion, imaging aquifers),
5. imaging geothermal systems,
6. detecting and discriminating unexploded ordnance,
7. geotechnical characterisation, including slope stability, and more (see http://em.geosci.xyz/content/case_histories/index.html for a growing list).

These applications are motivation for investigating fundamentals of electromagnetics. Applications successively investigated include those that make use of:

1. steady state fields (e.g. DC resistivity, induced polarisation),
2. frequency domain EM (e.g. marine CSEM, airborne surveys),
3. time domain EM (e.g. airborne, ground, borehole surveys),
4. natural source EM (e.g. magnetotellurics, Z-Axis Tipper/ZTEM).

The energy sources for these surveys can be man-made or natural. Man-made sources include inductive transmitters (loops of wire carrying a current) or galvanic sources where current is injected into the ground. The natural energy sources promote MT (magnetotellurics), which is important for characterising deep conductivity structures for geothermal energy, and ZTEM, which has proven to be valuable in geologic mapping and mineral exploration. The various surveys can be carried out in the air using helicopters or airplanes, on the earth's surface, or underground; the geoscientific question to be addressed determines which survey is selected. Case histories and survey types presented will be tailored to each location at which the DISC is presented, and chosen based on the local problems of general interest.

Each case history is presented in a seven-step process that begins with the description of the geologic or geophysical problem to be solved and ends with the impact of the EM geophysical survey to help solve the problem. At points in the middle, the details of the particular EM survey are investigated, together with some fundamentals of electromagnetic induction, and techniques for processing/inverting the data. The ability to move seamlessly between these different levels of information, so that relevant questions or concepts can be addressed, is facilitated by new open-source numerical software, interactive simulations, and the 'textbook' resource http://em.geosci.xyz. Although we work continually with Maxwell's electromagnetic equations, the presentations are mathematically 'light' and the learning aspect is facilitated by the use of open-source, interactive numerical software and visual aides.

The site http://disc2017.geosci.xyz contains further details on the course, its goals, links to the open-source resources that will be used, and ways to get connected!

Who should attend?

Geophysicists and any geoscientists who have the potential to use, or be associated with, electromagnetic data. The 2017 DISC is designed to be of interest to a broad audience, including researchers, practitioners, and industry geoscientists, and accessible to those with little background in EM.

Biography

Doug Oldenburg's 40-year research career has focused upon the development of inversion methodologies and their application to solving applied problems. He, with students and colleagues at the University of British Columbia Geophysical Inversion Facility (UBC-GIF), have developed forward modelling and inversion algorithms for seismic, gravity, magnetic and electromagnetic data. The inversion techniques and software are widely used in resource exploration problems. In recognition for his work building collaborative interactions between industry and academia, he was awarded the NSERC Leo Derikx and the AMEBC Special

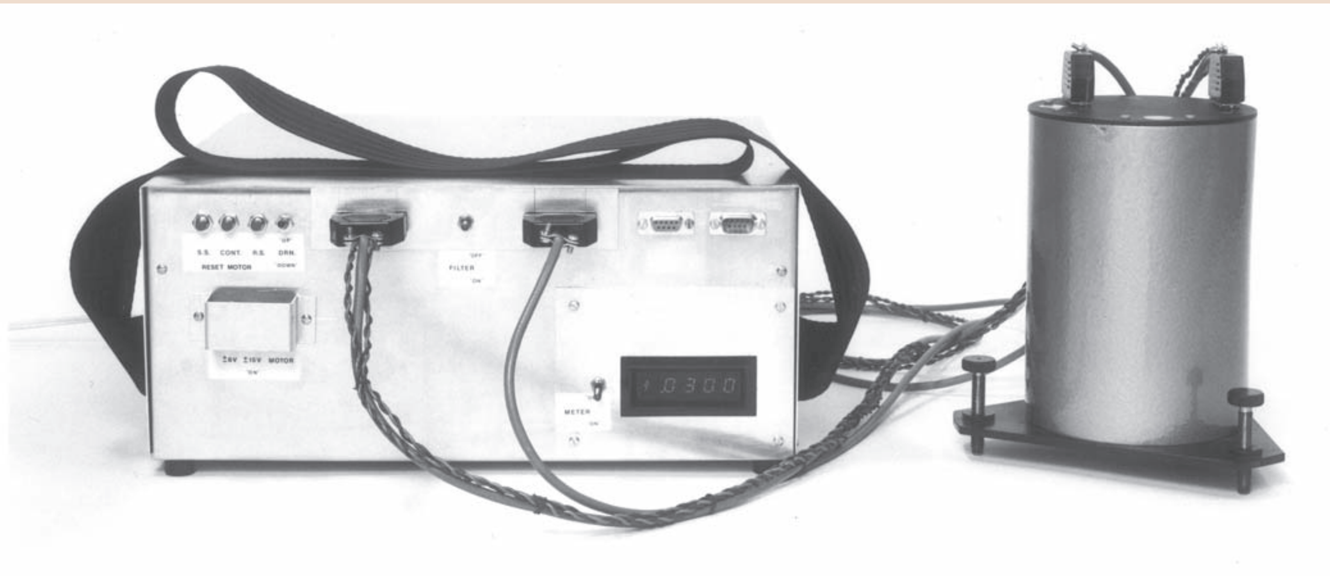
Tribute awards as well as the J.Tuzo Wilson medal. In 2011, Doug was the SEG Distinguished Lecturer; his presentation was entitled 'Imaging the Earth's near surface: The why and how of applied geophysics for the 21st century'.

Doug's current research activities include: inversion of EM data and their application to a wide range of problems, development of practical methodologies for combined inversion of geophysical and geological data, development of software for unexploded ordnance discrimination, and the use of self-potentials for dam safety investigations. He is passionate about the development of open-source educational resources for applied geophysics and increasing the visibility and benefits of using quantitative geophysics to help solve geoscience problems (http://geosci.xyz). These efforts will form the cornerstone of the SEG 2017 DISC.

Doug received his BSc Honors degree in Physics in 1967, and his MSc in geophysics in 1969, from University of Alberta in Edmonton. He completed his PhD in 1974 at UCSD in earth sciences. After a three-year postdoc in Alberta, he joined the Geophysics and Astronomy department at University of British Columbia. He remains at UBC where he is currently a Professor, Director of UBC-GIF and holder of the TeckCominco Senior Keevil Chair in Mineral Exploration. He is an honorary member of the CSEG, SEG and a Fellow of Royal Society of Canada

The schedule for Doug Oldenburg's DISC course is being finalised with the SEG over the coming weeks. If you are interested in the course you should contact your Branch Secretary or Emma Brand, Chair of the Continuing Education Committee continuingeducation@aseg.org.au so as to ensure that your Branch/State doesn't miss out!

Upcoming OzStep course: 'Reservoir Geophysics – Applications', a one-day course by Bill Abriel will be held at various locations in May. Please contact Emma Brand, Chair of the Continuing Education Committee continuingeducation@aseg.org.au for more information.



The gravimeter shown in this photo is the ***Flinders gravimeter****, a prototype gravity meter manufactured in South Australia. It was developed over the period 1980 to 1984 by Andrew Hugill, a PhD student at Flinders University of South Australia. Although other gravimeters at the time used electronics, the distinguishing feature of the Flinders gravimeter was that electronics was integral to the design, rather than being used to enhance an existing design.*

Improvements of this sensor over earlier instruments were:

- *Highly sensitive electronic displacement sensing and force feedback utilized in the meter design enabling the development of a gravity sensor that was much less complicated and easier to build than existing instruments that were based on microscopes, finely tuned mechanisms and complicated systems of screws and levers.*
- *Automatic electronic feedback making the meter easier to align and read and less prone to operator errors.*
- *Eliminating the requirement for mechanical feedthroughs, thereby ensuring the chamber containing the sensor in the Flinders gravimeter had better sealing and temperature control, further simplifying the mechanical design.*

In 1984, Dr Hugill took up a position as project leader for the development of a new gravimeter at Scintrex Ltd in Canada. Scintrex's quartz technology and data acquisition expertise was used to build on the Flinders gravimeter design to produce the CG-3 Autograv, the first of a new generation of gravimeters, the latest of which being the CG-6.

Since being released in 1987, the CG-3 and its successor, the CG-5, have sold over 2000 units. Flinders University received one of the first CG-3 gravimeters in exchange for providing Scintrex with the Flinders gravimeter for use in the development project.