

Geo-soundings

NEWSLETTER – SEPTEMBER 2015



Welcome

This edition of Geo-soundings reports on recent publications and conference presentations, the majority of which were showcased at the 77th EAGE Conference & Exhibition, held in Spain this year. EAGE 2015 also brought about other exciting events, such as the CRGC research business networking and social function, and the EAGE Student Lecture Tour. The third year field trip was also held recently and proved to be a productive and enjoyable experience for all involved.

We hope you enjoy the contents of this newsletter and look forward to future editions.

BOOK/CHAPTERS

Druhan, J. L., **S. Vialle**, K. Maher, and S. Benson. "Numerical Simulation of Reactive Barrier Emplacement to Control CO₂ Migration." In *Carbon Dioxide Capture for Storage in Deep Geologic Formations – Results from the CO₂ Capture Project, Vol. 4*, edited by Karl F. Gerdes, CPL Press, 2015.

JOURNAL PUBLICATIONS

Torkzaban, S., S. A. Bradford, J. L. Vanderzalm, B. M. Patterson, **B. Harris**, and H. Prommer, 2015, *Colloid Release and Clogging in Porous Media: Effects of Solution Ionic Strength and Flow Velocity*. Journal of Contaminant Hydrology (in press). Doi: <http://dx.doi.org/10.1016/j.jconhyd.2015.06.005>.

Takam Takougang, E. M., B. Harris, A. Kepic, and C. V. A. Le, 2015, *Cooperative Joint Inversion of 3D Seismic and Magnetotelluric Data: With Application in a Mineral Province*. Geophysics 80(4), R175-R187. Doi: 10.1190/geo2014-0252.1.

Stothard, P., **A. Squelch**, R. Stone, E. Wyk, M. Kizil, D. Schofield, and K. Fowle, 2015, *Taxonomy of Interactive Computer-Based Visualisation Systems and Content for the Mining Industry - Part 2*. Mining Technology 124(2), 83–96. Doi: 10.1179/1743286315Y.0000000006.

Yavuz, S., J. Kinkela, A. Dzunic, M. Penney, R. Neto, V. Araújo, S. Ziramov, R. Pevzner and M. Urosevic, 2015, *Physical Property Analysis and Preserved Relative Amplitude Processed Seismic Imaging of Volcanogenic Massive Sulfides—A Case Study from Neves-Corvo, Portugal*. Geophysical Prospecting 63(4), 798-812. Doi: 10.1111/1365-2478.12269.

CONFERENCE PRESENTATIONS

77th EAGE Conference & Exhibition, Madrid, Spain, June 2015

Tertyshnikov, K. V., S. Ziramov, A. Bóna, and R. Pevzner, 2015, *Application of Diffraction Imaging and Steered*.

M. Alajmi., A. Bóna, and R. Pevzner, 2015, *Quantifying Time-Lapse Seismic Signal Detection for the Otway Project Using Prestack Migration*.

Pevzner. R., M. Urosevic, and B. Gurevich, 2015, *Borehole Seismic Monitoring of a Small-scale CO₂ Injection - The CO₂CRC Otway Project Feasibility Study*.

Khoshnavaz, M. J., A. Bóna, and M. Urosevic, 2015, *Pre-Stack Time Migration in Common Source Domain without Velocity Model*.

Qi, Q., T. M. Mueller, and Gurevich, B, 2015, *The Role of Interfacial Impedance on Poroelastic Reflection Coefficient*.

Khoshnavaz, M. J., A. Bóna, M. Urosevic, S. Ziramov, and P. Ahmadi, 2015, *Pre-Stack Diffraction Imaging and its Application in Hard Rock Environment*.

Bóna, A., and R. Pevzner, 2015, *Using Fresnel Zone to Characterise and Image Different Types of Diffractors in Low S/N Situations*.

Mikhailsevitch, V., M. Lebedev, and B. Gurevich, 2015, *A Laboratory Study of the Elastic and Anelastic Properties of the Eagle Ford Shale*.

Gurevich, B., and N. Saxena, 2015, *A Simple Recipe For Solid Substitution at Low Frequencies and Application to Heavy Oil Rocks*.

Asgharzadeh, M., D. Nadri, and A. Bóna, 2015, *Inversion of Nonhyperbolic P-wave Traveltimes for Interval Transverse Isotropy Parameters*.

Beloborodov, R., M. Pervukhina, L. Esteban, and M. Lebedev, 2015, *Compaction of Quartz-Kaolinite Powders with Aggregated Initial Microstructure: Elastic Properties and Anisotropy*.

Shulakova, V., R. Pevzner, B. Gurevich, M. Madadi, A. Bóna, and M. Urosevic, 2015, *Feasibility of Cross-well Seismic as CO₂ Monitoring Tool*.

Workshop: Active and Passive Seismics in Laterally Inhomogeneous Media, Czech Republic, June 2015

Bona, A., 2015, *Imaging of Diffractors Using Passive Seismic Data*.

AAPG International Conference & Exhibition, Melbourne, Australia, September 2015

Lebedev, M., V. Mikhailsevitch, and B. Gurevich, 2015, *Laboratory Experiments for Calibration of Petrophysical Properties for CO₂ Sequestration Monitoring: CO₂CRC Otway Project Case Study*.

Meira, M. G., B. Gurevich, J. Gunning, and R. Pevzner, 2015, *Stochastic Time Lapse Seismic Inversion for Monitoring CO₂ Sequestration: CO₂CRC Otway Project Modeling Study*.

Pevzner, R., V. Shulakova, J. Dupuis, K. Tertyshnikov, D. E. Lumley, M. Urosevic, and B. Gurevich, 2015, *Improving Land Seismic Repeatability Using Buried Geophones: CO₂ CRC Field Study*.

Clennell, M. B., **T. Mueller, V. Shulakova, J. Liu, V. Mikhaltsevitch, L. Esteban, J. Sarout, B. Gurevich, C. Delle Piane, M. Josh, M. Lebedev, S. Correia-Lopes, I. Burgar, M. Pervukhina, J. Dautriat, and F. Falcao**, 2015, *Multiphysics Characterization of an Albian Post-Salt Carbonate Reservoir, Brazil*.

HONOURS / GRANTS / AWARDS

Dr Milovan Urosevic has been awarded a *Geoscientists Without Borders*® grant for his research "Assessment of Flood Damaged infrastructures in Bosnia, Herzegovina and Serbia" by the Society of Exploration Geophysicists (SEG). This humanitarian project, run by the Association of Geoscientists and Environmentalists of Serbia (AGES), will aid flood damaged areas in Bosnia & Herzegovina and Serbia. The research team has been granted \$116,000 over two years and will work to understand the present situation and prevent the risk of future landslides.

Milovan and his team have already commenced research in Bosnia & Herzegovina and Serbia.



RESEARCH ACTIVITIES

Curtin CRGC Exploration Geophysics Research Attracts International Attention

Earlier this year, Curtin's Department of Exploration Geophysics was approached by the Canadian Society of Exploration Geophysicists (CSEG) to provide an article on **Curtin Reservoir Geophysics Consortium** (CRGC)'s great research work on rock physics, attenuation and anisotropy for the **September 2015** edition of their monthly magazine CSEG Recorder.

The article provides an overview of Curtin's Exploration Geophysics research programs and notes the comprehensive range of internationally recognised specialist geophysics degree level courses provided. The article gives a brief introduction to the geophysics faculty and information on CRGC's four major research

project areas: theoretical and experimental rock physics; seismic processing and imaging; reservoir characterisation and monitoring; sea-bed electromagnetics.

Curtin's CRGC geophysics research is being used in oil exploration in Canada through characterisation of natural fracture networks from measurements of seismic anisotropy. Curtin regularly attends Australian and International industry conferences to raise awareness of their exploration geophysics research programs and courses.

The September 2015 edition of the CSEG Recorder article is currently available online only to CSEG members. As soon as it is available to Curtin University members, it will be found on the [CSEG website](#).

FOCUS ARTICLE
Coordinated by Rob Cook / Terrestrial Vibration

Geophysics Programmes at the Department of Exploration Geophysics at Curtin University, Perth, Australia

Burt Gurevich, Andrii Bania, Roman Pevzner, Mikolaj Gurevich, and Rob Cook



Curtin University is centrally located in Perth at the heart of Australia's premier energy and mining state of Western Australia. The Department of Exploration Geophysics, part of the Western Australian School of Mines at Curtin University, provides a comprehensive range of internationally recognised specialist geophysics degree level courses ranging from a BSc and MSc to PhD and MPhil. The department offers training in the latest techniques in exploration geophysics. The academic staff and postgraduate students are continuously involved in frontier research in the field in addition to Australian students, the post-graduate geophysics research degrees attract highly capable students from a multitude of cultural backgrounds from around the world.

The department places a strong focus on associations with energy industry organisations and places a vibrant link to the key academic partner with a research consortium of Australian and global industry majors and leading geophysical contractors. An annual conference of CRGC (Curtin Reservoir Geophysics Consortium) is held in Rottnest Island to provide members to receive advanced field geophysics research by the group. The broad aim of the consortium is to conduct geophysical research and develop new technologies for the benefit of the petroleum industry, and to train students in geophysical methods and research relevant to the needs of members. Current CRGC research covers the major project areas:

1. Theoretical and experimental rock physics;
2. Seismic processing and imaging;
3. Reservoir characterisation and monitoring;
4. Sea-bed electromagnetics.

For the last ten years, the department has been a participant in the Cooperative Research Centre for Greenhouse Gas Technologies (CO2CRC). As part of this participation, the department was heavily involved in the Onshore Basin CO₂ Geomechanics Project. This project established as the first land-based basin system to be sealed in Australia and continues to push scientific boundaries with the recently deployed buried permanent monitoring array.



Theoretical and Experimental Rock Physics: Seismic signatures of patchy saturation

A major effort of the department is focused on the study of the effects of patchy saturation on seismic signatures. The main objective is to quantify the effect of random spatial distribution of fluid patches. The approach is based on the general theory of effective medium parameters developed by CRGC over the last decade. The aim of the current effort is to build a general model for elastic properties of partially saturated rock with a given statistical distribution of fractures and to identify contrast between the properties of the host rock (oil, gas and liquid). The department is also performing a series of fluid injection experiments with X-ray Computer Tomography and ultrasonic control to validate the theoretical findings. The effect of capillary forces on the elastic properties of partially saturated rocks is also being explored. On-facility, the results of theoretical research have been qualified in time-lapse logs acquired in the Nagaiya CO₂ storage site.

Modeling of stress dependent attenuation and dispersion due to squirt flow in clastic and carbonate rocks

The department has developed a new squirt flow model in which all parameters can be independently measured or estimated from measurements. The pore space of the rock is assumed to consist of soft porosity and compliant porosity present at grain contacts. The effect of anisotropically distributed soft zones is modelled by considering pressure relaxation in a rigid shelled gas between adjacent grains. The derivation gives the complex and frequency dependent effective bulk and shear moduli of a rock, in which the soft zones are fluid saturated and soft zones are dry. The resulting squirt model is consistent with Gurevich's and Mukerji's idea of a quarter of low and high frequencies, respectively. In addition, dispersion and attenuation are the strongest at low effective stress and reach a plateau at higher effective stress. The department will be testing and refining this model using ultrasonic and low frequency measurements on clastic and carbonate rocks saturated with different fluids. The model is also being extended to partial saturation, anisotropy and anisotropic fluids.

Modeling of properties of rocks saturated with heavy oil

Rock physics for heavy oil is different from rock physics for conventional fluids because to obtain elastic moduli makes Gurevich theory and of its extension inapplicable to practice. The department has developed an approximate methodology for fluid substitution in heavy oil reservoirs. The methodology is based on one particular advanced medium approach known as coherent potential approximation (CPA). The methodology has been successfully tested on low frequency laboratory measurements. Currently, the department is developing an alternative model for heavy oil rocks based on the concept of open-closed squirt flow.

Low frequency anisotropic measurements

Theoretical rock physics models need to be tested and validated using laboratory measurement. To this end, the department is performing comprehensive experimental testing of these theories using broadband measurements of dynamic elastic properties of rock samples. Experiments are conducted using a combination of forced oscillation ultrasonic strain gauge measurements (0.1 Hz - 20 kHz), laser interferometry (0.1 Hz - 200 kHz) and ultrasonic sensing (100-1000 kHz). The results are being compared with theoretical predictions computed using numerical simulations.

Modeling elastic properties of fractured reservoirs

A major effort of the department's rock physics group is directed towards modelling attenuation, dispersion and frequency dependent anisotropy of porous reservoirs permeated by aligned fractures. Over the last decade, this group has developed a methodology of fluid substitution in fractured reservoirs, which is based on the combination of permeability tensor equations and Gurevich's lower order parameterisation of the effect of fractures on rock properties. Between 2002 and 2004, the group developed a model for attenuation and dispersion of P waves propagating perpendicular to a partially open system of parallel planar fractures and validated this model with numerical simulations using a systematic extension of effective medium theory. These simulations helped to assess the attenuation dispersion model to randomly oriented fractures and to obtain insights.

More recently, the group developed a model for seismic attenuation and dispersion caused by the presence of generally distributed fibre fractures in the porous reservoirs. The model is based on the combination of Biot's theory of poroelasticity with the ideas of a multiple scattering theory. The current effort in this area is focused on the deeper understanding of the implications of the theory and its extension to:

- Oblique incidence;
- Shear waves;
- Higher fracture densities;
- Anisotropic reservoirs.

While all of the above models are designed for a single set of aligned fractures, real reservoirs often contain multiple fracture sets. Moreover, similar phenomena (fluid flow between joints and fractures) lead to frequency dependent attenuation and dispersion in isotropic solids with microcracks, compliant grain contacts, etc. These effects are being studied by extending the aligned fracture models to arbitrary angular distributions of fractures.

Modeling stress-induced anisotropy

Stress is one of the major causes of anisotropy in the earth. Understanding it is important for imaging, reservoir characterisation and monitoring. There is a need to be able to distinguish stress-induced from fracture-induced anisotropy. In recent years,

Media Summary

An interview with **Dr Anton Kepic** was featured in Curtin's media summary on Tuesday 4th August in which he discussed a new mining tool he has developed that is designed to give mining exploration a new level of efficiency.

EVENTS

EAGE 2015

On Tuesday 2nd June, around 50 leading geophysicists, researchers and oil industry executives attended a research business networking and social function hosted by **Curtin University's Department of Exploration Geophysics and Curtin Reservoir Geophysics Consortium (CRGC)**.

The event was held during EAGE (European Association of Geoscientists and Engineers) 2015, Europe's foremost geoscience conference. Attendees included geophysics project managers from CRGC Consortium sponsor partners (e.g., ExxonMobil), leading academics involved in geophysics research from around the world and Curtin University Exploration Geophysics Department graduates who were attending the oil and gas conference in Spain. Attendees at the function have business interests and geophysics research ventures across the globe, including Australia, Europe, North America, Asia and the Middle East.

The networking function provided a forum for alumni, researchers, academics, sponsors and partners with diverse related interests, yet with a connection to Curtin University, to meet one another face to face and to discuss further collaboration opportunities. Attendees at the function enjoyed traditional Spanish tapas and refreshments provided by caterers Mónico Gourmet.

Professor Boris Gurevich together with associate professors and lecturers from Curtin University's Exploration Geophysics Department were heavily involved in preparing and presenting geophysics research papers during the EAGE 2015 conference and in pre-conference workshops.

Curtin University's Exploration Geophysics Department has produced many highly successful geophysics graduates who have taken leading roles in high-profile organisations operating world-wide; several of Curtin's graduates were in attendance at the event. Some of these Curtin geophysics graduates have become highly regarded and recognised for their contribution to the geophysics profession with their services and products being sought after by leading oil and gas industry organisations worldwide.

[EAGE Student Lecture Tour 2015 \(Asia Pacific\)](#)

Presenter: **Dr Gaynor S. Paton**

Lecture Title: ***“Colour perception and its role in seismic interpretation: A geological expression story”***

The EAGE extended an invitation to Curtin's geoscience departments (Exploration Geophysics and Applied Geology) an opportunity to officially host the first ever official EAGE Student Lecture Tour (SLT) in Australia starting in July 2015.

The EAGE plans to continue this student outreach program each year in the future. The SLT is an excellent opportunity for geoscience students to get acquainted with the latest developments in geosciences. SLT is subsidised by the EAGE and registrations are free of charge for all students and staff who want to attend.

The SLT event on the **21st July** at Curtin was presented by Dr Gaynor Paton of the ffa Geoteric, based in Aberdeen, United Kingdom. The lecture was held in the Applied Geology Seminar Room with assistance provided by two PhD Geophysics students—**Mr Mohammed Al Hosni** and **Mr Dmitry Popik**. Twenty-six attended from Curtin, UWA and industry.

The Department thanks both Mohammed and Dmitry for their enthusiastic involvement in this event.



Open Day

A team led by **Mr Dominic Howman** showcased our department at Curtin Open Day on **Sunday 2nd August**. We would like to thank Dominic, **Dr Andrej Bona**, **Dr Andrew Squelch**, **Dr Maxim Lebedev**, **Mr Murray Hehir**, and students **Bryce Teo** (BScHon) and **Petr Lebedev** (BSc) for their contribution to this very important event.



Third Year Field Trip

This year our third year/masters geophysics field trip was hosted by the Tropicana joint venture, between AngloGoldAshanti and Independence Group, who covered the accommodation, meals and flights into site for everyone. Tropicana is a remote gold mine producing 500 kOz of gold per annum, 350 km NE of Kalgoorlie.

Finding gold is only part of the problem at Tropicana; finding good quantities of ground water to supply the mine and mill is a significant issue. Curtin geophysicists applied their skills to this problem by deploying seismic reflection, electrical resistance tomography and ground TEM methods with supporting DGPS surveys. The students were supervised by **Dr Anton Kepic**, **Mr Dominic Howman**, **Mr Murray Heir** (Curtin staff) and by Mike Whitford (from Independence Group and a former Curtin student). Greg Cant, another ex-Curtin Student, was our AngloGold Ashanti geophysics and site guide.

As the mine camp had accommodation capacity limitations the students were split into two groups performing surveys for one week at a time. As it is a very remote site, the students flew in on a mine charter flight, but as it is a new mine everyone had decent accommodation and the camp had a pretty good mess. A special thanks to the crew leaders that drove into and out of the site and worked for two solid weeks with our students.





Thank you to 3rd Year student Kristopher Wright for the photos

STAFF NEWS

Miss Sinem Yavuz returned to the department in July and commenced employment on a casual contract as a Research Geophysicist through to the end of the year.

We farewelled visitor **Dr Clarisse Bordes**, who returned to France to resume her position as Associate Professor in the Complex Fluids and Reservoirs Laboratory, Geoscience Department, University of Pau.

We also said goodbye to **Miss Olivia Collett**, who has moved to Calgary, Canada to commence employment with Hampson-Russell.

UPCOMING EVENTS

2015 China National Symposium on Reservoir Acoustics and Borehole Logging Technologies
9th–11th October, Beijing, China

[SEG Annual Meeting 2015](#)

18th–23th October, Louisiana, USA

[EAGE 3rd Rock Physics Workshop](#)

15th–18th November, Istanbul, Turkey

[AGU Fall Meeting](#)

14th–18th December, San Francisco, USA

EDUCATIONAL SOFTWARE GRANTS AND PROGRAMS

A big thank you to all our software vendors who provide us with the continuing support and software resources we need for our teaching and research programs.

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