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SECTION 4
POSTER ABSTRACTS

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Energy

P001. CARBON ISOTOPE FRACTIONATION IN COAL AND MARINE SOURCE ROCKS AND IMPLICATIONS FOR EXPLORATION

Mohinudeen Faiz, Alison Zoitsas, Carl Altmann, Elizabeth Baruch-Jurado and David Close*
Origin Energy Ltd
*Mohinudeen.faiz@originenergy.com.au

Stable isotope composition of gas is widely used in hydrocarbon exploration to determine the composition and thermal maturity of source rocks. Analyses of Australian coal and marine shale samples indicate that during gas desorption both molecular and isotopic compositions change with time. Therefore, a detailed understanding of the mechanism of isotope fractionation is required to improve our ability to better characterise source rocks and fluids.

δ13C of Permian coals range between –22 and –26‰ (VPDB) and that of thermogenic methane generated from these range from –25 to –40‰. δ13C of gas desorbed from coal varies with time according to molecular weight and sorption properties. For example, in a set of deep Bowen Basin coals the difference in δ13C-CH4 between early and late desorbed gas varies from 2‰ to 29‰. For higher hydrocarbons this fractionation is lower, where for ethane it is <8‰ and for propane <3‰.

Similar isotope fractionation happens during desorption from marine source rocks in the Beetaloo Basin. δ13C for an immature kerogen from the Velkerri shale is –33‰. Where the Velkerri shale is gas mature, during desorption, δ13C-CH4 shows fractionation of up to 28‰. δ13C-C2H6 and δ13C-C3H6 show lower isotope fractionation of 1.6‰ and 0.9‰, respectively.

Many published classification systems relating isotope composition of gas to source rock and thermal maturity do not consider the effects of such isotope fractionation. The fractionation mechanism may also have an impact on the so-called 'isotope reversal' behaviour in some shale reservoirs which, at present, is poorly understood.

P002. BIOMARKER SIGNATURES OF UPPER CRETACEOUS TO PALEOGENE HYDROCARBON SOURCE ROCKS FROM THE LATROBE GROUP, GIPPSLAND BASIN

Lian Jiang and Simon C. George*
Department of Earth and Planetary Sciences, Macquarie University, Sydney, NSW, Australia
*lian.jiang@hdr.mq.edu.au

Gas chromatography-mass spectrometry analyses have been carried out to investigate the geochemical characteristics of shales and coaly shales from the Latrobe Group in the Gippsland Basin, Australia. The depositional environment, organic matter sources and thermal maturity of hydrocarbon source rocks in the study area were evaluated using biomarker analyses. The distribution of isoprenoid alkanes and pentacyclic triterpanes reveals an oxic environment with fresh water (Pr/Ph >3.0, gammacerane index <0.3). The carbon preference indices (CPI) ratios of the n-alkanes are higher than 1.0, suggesting terrigenous higher plant-derived organic matter in the sediments. The high predominance of C_{29} sterane over C_{27} sterane as well as the occurrence of conifer and angiosperm biomarkers (i.e. labdane, isopimarane, phyllocladane, rimuane, oleanane, retene, chrysene, and piece, etc.) corroborates input from higher vascular land plants. Biomarker thermal maturity indices, such as C_{31} 22S/(22S+22R) hopanes, C_{30} βα/(βα+αβ) hopanes and C_{29} ααα 20S/(20S+20R) steranes, indicate rather thermally immature hydrocarbon source rocks, in agreement with the above CPI data. This maturity trend is also supported by the triaromatic sterane index [TA(I)/TA(I+II)], which is generally lower than 0.2.

P003. IDENTIFICATION OF CLAY MINERALS WITHIN THE SPRINGBOK FORMATION, SURAT BASIN

Mitchell Levy and Oliver Gaede*
Queensland University of Technology
*mitchell.levy@hdr.qut.edu.au

The Walloon Coal Measures in the Surat Basin in Queensland are an important coal seam gas resource. Development of this resource requires a thorough understanding of the surrounding lithologies. The Springbok Sandstone unconformably overlies the Walloon Coal Measures in a significant portion of the basin. Despite this, there have been limited studies undertaken to understand the well log response of its clay phases.

The Springbok Sandstone has previously been classified as a generally permeable sandstone aquifer, however reported lithologies presented in the literature range across sandstones, mudstones, tuff, and coal layers. Conventional well log analysis (for instance using gamma logs) has proved insufficient in differentiating relatively low clay sandstones from more clay rich sandstone and mudstone layers.

Here we investigate the hypothesis that potassium free or low-potassium clay minerals are the dominant clay minerals in the Springbok Sandstone, and that the low overall potassium content throughout may explain the inability of traditional well log analysis to successfully highlight high clay content rock units within the formation. A laboratory analysis program comprising mineralogy and major and trace element analysis using drill core from 5 wells within the basin provides new and detailed insight into the composition of this important formation. Results from XRD, XRF, and ICP-MS analysis will be presented.

P004. VTI ANISOTROPY IN THE BROWSE BASIN: CASE STUDY OF TOROSA-6 WELL

*Aymen Beji, Yevhen Kovalyshen, Valeriya Shulakova, Jean-Baptiste Peyaud, Boris Gurevich, M. Ben Clennell and Marina Pervukhina**
CSIRO, Energy, Perth, Australia
*Marina.Pervukhina@csiro.au

Overburden shales that overlay and seal hydrocarbon reservoirs usually exhibit polar anisotropy, also called Vertical Transverse Isotropy (VTI). This anisotropy is important to correct seismic data processing, seismic to well tie as well as geomechanical applications. P-wave anisotropy cannot be determined from a vertical well unless a walkaway vertical seismic profile (VSP) has been obtained, however, such measurements are still rare.

S-wave anisotropy though can be estimated when the speed of sound in mud and Stoneley wave velocity in the shale are known. The Stoneley wave velocity is nowadays routinely measured by acoustic tools and the absence of reliable sound velocity in mud can be overcome by calibrating the signal in an isotropic interval. Then, P-wave anisotropy can be restored using theoretical models or empirical trends. Using this method, we analyse VTI anisotropy in Torosa-6 well in the Caswell Sub-basin of the Browse Basin, the North West Shelf of Australia. Torosa-6 intersected the Jamieson, Echuca Shoals and Plover shaly formations and a walkaway VSP was acquired. The S-wave anisotropy ranges from 0.2 to 0.6 and shows good correlation with the volume of clay within each of the shaly formations. However, in different formations, the anisotropy displays differences within intervals with similar clay content. A mineralogy model is built to explain these differences. It is worth noting that the observed VTI anisotropy shows no positive trend with the burial depth.

P005. THE STRUCTURAL EVOLUTION OF THE NORTH WEST SHELF: A THERMOMECHANICAL MODELLING APPROACH USING STRATIFIED LITHOSPHERIC RHEOLOGIES AND SURFACE PROCESSES

Romain Beucher[1]*, *Sara Moron-Pollanco*[1], *Louis Moresi*[1], *Tristan Salles*[2], *Patrice Rey*[2], *Gilles Brocard*[2] *and Rebecca Farrington*[1]
[1]University of Melbourne
[2]University of Sydney
*romain.beucher@unimelb.edu.au

The processes involved in the structural and stratigraphic evolution of the North West Shelf (NWS), one of the most productive and prospective hydrocarbon provinces in Australia, remain controversial. The complex structural characteristics of the NWS include large-scale extensional detachments, difference between amounts of crustal and lithospheric extension and prolonged episodes of thermal sagging after rifting episodes. It has been proposed that the succession of different extensional styles mechanisms (Cambrian detachment faulting, broadly distributed Permo-Carboniferous extension and Late Triassic to Early Cretaceous localised rift development) is best described in terms of variation in deformation response of a lithosphere that has strengthened from one extensional episode to the next. However, previous models invoking large-scale detachments fail to explain changes in extensional styles and over-estimate the structural importance of relatively local detachments (e.g. Scholl Island Fault). Here, we hypothesise that an initially weak lithosphere would distribute deformation by ductile flow within the lower crust and that the interaction between crustal flow, thermal-evolution and sediment loading/unloading could explain some of the structural complexities recorded by the NWS. To test this hypothesis we run a series of fully coupled 3D thermo-mechanical numerical experiments that include realistic thermal and mechanical properties, as well as surface processes (erosion, sediments transport and sedimentation). This modelling approach aims to provide insights into the thermal and structural history of the NWS, and a better understanding of the complex interactions between tectonics and surface processes at the scale of the margin.

P006. MULTIPHASE DFEORMATION OF THE NORTHERN CARNARVON BASIN

*Chris Elders**
Department of Applied Geology, Curtin University
*c.elders@curtin.edu.au

The Northern Carnarvon Basin has experienced a complex history of deformation, which has been well documented in the past. However public domain 2D and 3D seismic data allows regional scale mapping over large parts of the Basin in unprecedented detail, and allows re-evaluation many aspects of that history. Observations from different parts of the Basin show that N–S to NE–SW oriented rifts were active from the Devonian into the early part of the Carboniferous, but a significant change in fault orientation occurred in the Upper Carboniferous-Permian, forming the NW–SE structural grain that dominates the North West Shelf. After a significant phase of post rift subsidence in the Triassic, extension resumed during the uppermost Triassic and continued until to the Middle Jurassic. The E-W oriented extension was more or less perpendicular to the Devonian to Lower Carboniferous structures, but oblique to the Upper Carboniferous to Permian structures, resulting in highly segmented margins of Jurassic depocentres, including the structures that contain the fields defining the Rankin Trend. Triassic shales provide a detachment which influences the geometry of some Jurassic faults, accounting for the development of large synclinal structures associated with some Jurassic rifts, as well as some antiformal traps. Sediment supply from the east resulted in a sediment starvation in the western parts of the Exmouth Plateau and erosion of uplifted fault block crests.

A significant plate tectonic re-organisation occurred in the Upper Jurassic and Lower Cretaceous. There is some rotation of the stress field, resulting in a change in orientation of active faults in parts of the basin. There was also a significant change in sediment supply, with uplift to the south, possibly associated with hot spot activity resulting in a large influx of sediment that drowned previously exposed fault block on the Exmouth plateau, but with reduced sediment supply in the east. The more uplifted parts of the plateau may have nucleated a later (Neogene) large scale compressional fold which contain one of the larger gas fields in the basin.

P007. TRIASSIC PROVENANCE ANALYSIS OF THE ROEBUCK BASIN, NORTH WEST SHELF OF AUSTRALIA

Megan Lech[1]*, *Chris Lewis*[1], *Lloyd T. White*[2] *and Steve Abbott*[1]
[1]Geoscience Australia
[2]School of Earth and Environmental Sciences, University of Wollongong
*megan.lech@ga.gov.au

The Roebuck Basin is on Australia's North West Shelf, between the Browse and northern Carnarvon basins. The Basin consists of Paleozoic to recent fluvial to deep marine mudstones and sandstones, carbonate platforms and reefs, and volcaniclastics. Recent hydrocarbon discoveries in the Bedout Sub-basin have renewed exploration interest and changed existing perceptions about the regions prospectivity.

The interpretation of U-Pb detrital zircon dating from offshore petroleum well cuttings provides new information regarding the origin of sediments and changes in sediment provenance. This analytical work has the potential to better understand reservoir

quality within the Triassic Upper and Lower Keraudren deltas (and equivalent sequences). A range of detrital zircon age spectra were obtained. Analyses of zircon grain shapes (i.e. roundness) somewhat supports transportation of some distance, but could also signify multi-phase recycling. However, the combined detrital age spectra and grain shape reveals that the Roebuck Basin deltas had multiple sediment sources. The Roebuck Basin's Triassic sediments appear to be derived from Australia's interior, potentially transported either directly via large rivers or from subsequent sediment reworking and transport via long-shore drift.

Seismostratigraphic interpretations have identified potential sediment transport mechanisms including clinoforms and submarine canyons. Significant landward uplift and erosion associated with the latest Permian-aged Bedout Movement supports the reworking of Permian sediments. Integration of additional samples, and linking these to palaeogeographic settings, will provide additional clarity of the potential Australian and non-Australian Triassic sediment sources. This study aims to provide further insight into the origin of the reservoir units in the Roebuck Basin.

P008. THE NORTH WEST SHELF (NWS), A DIGITAL PETROLEUM ECOSYSTEM (PDE) IN A BIG DATA SCALE

Shastri L. Nimmagadda, Torsten Reiners and Amit Rudra*
Curtin University, Perth, WA, Australia
*shastri.nimmagadda@curtin.edu.au

The North West Shelf (NWS) and its associated petroleum systems have varied geographies, geomorphologies and complex geological environments. In spite of the ongoing exploration activities in many sedimentary basins, the appraisal and field development campaigns are challenging. Besides, interpreting the connectivity between petroleum systems is challenging. The heterogeneity and multidimensionality of multi-stacked reservoirs associated with multiple oil and gas fields complicate the data integration process. Volumes and varieties of data existing in these basins are in different scales, sizes and formats, demanding new storage and retrieval methods, emphasising both data integration and data structuring. Since the data are in terabyte size; the multiple dimensions and domains need to be brought in a single repository, we take advantage of Big Data tools and technologies. In this context, we aim at articulating the digital petroleum ecosystems and petroleum database management systems with new data modelling, data warehousing and mining, visualisation and interpretation artefacts. This approach facilitates data management not only for individual basins but groups of basins in the NWS. Warehoused cuboid metadata can explore the connections providing new insights in the data interpretation and knowledge of new prospective areas. The multidimensional warehousing repository that is supported by cloud computing, data analytics and virtualisation features, provides new opportunities for delivering quality and just-in-time online ecosystem services. Other goals are deducing an integrated unified metadata model and characterising the connectivity among the basins of the NWS and associated oil and gas fields. The study supports the features of PDE and its knowledge management.

P009. FULL-VOLUME INTERPRETATION METHODS: APPLICATIONS FOR QUANTITATIVE SEISMIC STRATIGRAPHY AND GEOMORPHOLOGY OF THE LOWER BARROW GROUP, NORTHWEST AUSTRALIA

Victorien Paumard[1], Julien Bourget[1], Benjamin Durot[2], Sébastien Lacaze[2] and Tom Wilson[2]*
[1]Centre for Energy Geoscience, School of Earth Sciences, The University of Western Australia
[2]Eliis SAS, benjamin.durot@eliis.fr[3]
*victorien.paumard@research.uwa.edu.au

Following decades of technological innovation, geologists have now access to extensive 3D seismic datasets. How these data will help understanding the complexity of the subsurface relies on developing stratigraphic workflows that allow very high-resolution interpretation in a cost-effective timeframe.

Here, the use of full-volume, semi-automatic horizon tracking tools allowed interpreting ultra-high resolution seismic sequences (~40 000 years duration) within a Cretaceous prograding shelf-margin (Lower Barrow Group (LBG), Northwest Australia).

Initially, semi-automated horizon tracking allowed mapping key regional unconformities defining 3rd-order seismic sequences. In a second step, a very high resolution grid (nodes corresponding to seismic traces) was generated in each 3rd-order sequence. An automatic propagation algorithm then linked the nodes based on their similarities, resulting in a very dense network of 'proto'-seismic horizons. Volume interpolation resulted in the creation of a Relative Geological Time model from which a very high number of chronostratigraphic surfaces were extracted. This allowed a full volume 3D mapping of every clinoform in each 3rd-order sequence, from which quantitative data (clinoform height, slope, topset vs bottomset thickness) and seismic attributes (seismic geomorphology) were extracted.

This analysis unveiled the high resolution changes in sediment supply and accommodation in time and space in the LBG, and provided new insights on the distribution of shallow and deep marine plays in the basin. This innovative workflow constitutes a new step in sequence stratigraphy as it allows interpreters to map sequences in a true 3D environment hence taking into account the full variability of depositional systems in time and space.

P010. RECALIBRATING AUSTRALIAN TRIASSIC PALYNOSTRATIGRAPHY TO THE INTERNATIONAL GEOLOGIC TIMESCALE USING HIGH RESOLUTION CA-IDTIMS DATING

Tegan Smith[1], Robert Nicoll[1], John Laurie[1], Jim Crowley[2], John McKellar[3], Hamish Campbell[4], Ian Raine[4], Daniel Mantle[5] and Arthur Mory[6]*
[1]Geoscience Australia
[2]Boise State University
[3]Geological Survey of Queensland
[4]GNS Science
[5]MGPalaeo
[6]Geological Survey of Western Australia
*tegan.smith@ga.gov.au

The Triassic is an important interval for Australian petroleum exploration, with Middle to Upper Triassic Mungaroo Formation reservoirs in the Northern Carnarvon Basin, and recent Lower Triassic discoveries in the Roebuck Basin. The chronostratigraphic understanding of Triassic petroleum systems

is underpinned by biostratigraphic dating using palynological zonations. The numerical ages of these zones are usually assigned through inference and interpolation, often via tenuous correlations to the international geologic timescale using scattered marine biota, (primarily foraminifera, and rare ammonites, conodonts and/or dinoflagellates). In contrast, we tie Australian biozones to the timescale through Chemical Abrasion-Isotope Dilution Thermal Ionisation Mass Spectrometry (CA-IDTIMS) dating of interbedded volcanic tuffs. Such ashfalls are reasonably common in Australian basins, and can provide high-precision CA-IDTIMS ages if they contain magmatic zircons. We recently recalibrated Australian middle and late Permian palynozones using this approach and preliminary results suggest that Triassic biozone ages are likewise in need of considerable revision.

We have targeted Triassic tuffs across Queensland, (Tarong beds, Brisbane Tuff, Moolayember Formation, Rewan Group), New South Wales (Garie Formation, Coal Cliff Sandstone, Milligan Road Formation), and Tasmania (upper Triassic coal measures) to provide numerical ages for palynozones. Additional dates in New Zealand (Murihiku Supergroup) and Timor-Leste (Wailuli Formation) will allow international correlation of dinocyst and spore-pollen zones. Numerical constraints for Triassic biozone boundaries facilitate correlation of Australian biozones with the international geologic timescale. This can impact burial history models used in petroleum exploration anywhere these biozones are used, often far beyond the basins from which the samples were collected.

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P011. SURFACE PROCESS MODELS OF THE LAKE EYRE BASIN USING BADLANDS SOFTWARE

Ruken Alac, Sabin Zahirovic, Tristan Salles, Dietmar Muller, Sally Cripps, Fabio Ramos and Rohitash Chandra*
EarthByte Group and Basin GENESIS Hub, University of Sydney, Australia
*ruken.alac@sydney.edu.au

Surface process dynamics play an important role in sedimentary basin evolution. They affect hydrologic and carbon cycling, which are particularly difficult to simulate because of their complex interactions and the large range of spatial and temporal scales on which they operate. By considering uplift/subsidence, sea level change and climate change, surface process models are able to assimilate and represent several dynamic processes, including crustal deformation, mantle-convection-driven dynamic topography, erosion, sediment deposition, burial, and compaction. In order for these models to be useful for the industry they need to be able to reproduce depositional histories in sedimentary basins. Here we propose to use Badlands (BAsin anD LANdscape DynamicS), a landscape evolution modelling software, to evaluate the topographic and sedimentary evolution of the Lake Eyre Basin, a large, dominant feature in the Australian landscape with economic resources and good data coverage. Analyses of the long-term Lake Eyre sedimentation can provide valuable information about the connection between processes operating at the Earth's surface and the deeper mantle. From our calibrated models, we will be able to characterise reconstructions of the burial of stratigraphic layers in a sedimentary basin through space and time. Our approach will provide an integrated set of forward models and data assimilation framework which may help us better constrain source-to-sink basin models, and shed light on the contribution of mantle convection processes on the stratigraphic evolution of basins. Furthermore, data science and machine learning methods can be used in conjunction to develop surrogate-assisted models in order to assist existing model for large-scale implementation.

P012. U-PB GEOCHRONOLOGY OF APATITE AND CALCITE AT THE ERNEST HENRY DEPOSIT, NW QUEENSLAND; IMPLICATIONS FOR HYDROTHERMAL EVOLUTION AND ORE GENESIS

B. W. Cave, R. Lilly and S. Glorie*
University of Adelaide, Department of Earth Sciences, Mawson Building, North Terrace, SA
*bradcave@mail.com

The Ernest Henry deposit represents the largest known Iron Oxide Copper Gold (IOCG) deposit in the Eastern Succession of the Mount Isa Inlier. The orebody consists of a structurally controlled pipe-like breccia hosted in complexly altered Proterozoic volcanics with mineralisation occurring post-peak metamorphism during a regional transpressional deformational event (D_3). Ore formation was controlled by the mixing of magmatic, metamorphic and basal fluids, resulting in the precipitation of chalcopyrite, pyrite, calcite, quartz, magnetite and accessory gold. Coarse-grained apatite is present as an accessory mineral in areas of high sulphide mineralisation and in shear zones adjacent to the orebody.

The paragenesis and relative timing of the alteration and mineralisation stages have been well constrained by previous workers. However, advances in U-Pb geochronology via the *in situ* laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS) method means that for the first time apatite and calcite from the ore body and adjacent structures may be suitable for age dating.

This project will use an established apatite dating technique and aims to develop a calcite dating technique to provide dates for individual paragenetic stages. These time constraints will improve the current understanding hydrothermal evolution and ore genesis at Ernest Henry. As calcite is a common accessory mineral in ore deposits, this technique could be widely implemented to date mineralisation events and may allow hydrothermal events at different deposits to be linked.

P013. 3D MAPPING OF NSW PROJECT: SYDNEY–GUNNEDAH BASIN

John Davidson and Felipe Oliveira*
Geological Survey of NSW, Division of Resources and Geoscience, NSW Department of Planning and Environment
*john.davidson@industry.nsw.gov.au

The Geological Survey of NSW (GSNSW) is using its geological databases to create a digital seamless geology map of NSW. This is being integrated with subsurface information such as drillhole logs and seismic data to generate 3D models in areas

of geological interest. A statewide depth to basement model, with consolidated and unconsolidated cover, has been completed and provides a framework for more detailed models of specific basins and orogens. The Sydney–Gunnedah Basin model includes best available geological mapping from the NSW Seamless Geology Project and new 3D modelling.

The onshore Sydney Basin comprises the southern section of the Permo-Triassic Sydney–Gunnedah–Bowen system. This basin system initiated in a back-arc extensional setting during the Permian, and was followed by thermal subsidence and subsequent foreland basin down-warping. The Sydney Basin contains up to 4500 m of Permo-Triassic clastic sedimentary rocks and overlies the Lachlan Orogen and Late Carboniferous volcaniclastic rocks. To the north of the Liverpool Ranges, the Gunnedah Basin extends the basin system, containing alluvial and deltaic sequences. The Hunter–Bowen Orogeny formed the adjacent New England Orogen and resulted in uplift and erosion that deposited Jurassic sedimentary sequences of the Surat Basin over large parts of the Gunnedah Basin.

In addition to the Sydney–Gunnedah Basin, the Tamworth Belt, the Clarence–Moreton Basin, the Hunter Coalfields and the Southern Coalfields have also been modelled. Integration of surface and subsurface geology provides strategic information to companies and government, to inform resource assessment and land-use decision-making in NSW.

P014. MODELLING RIFTING SEQUENCE STRATIGRAPHY COUPLED WITH SURFACE PROCESS AND THERMO-MECHANICAL MODELLING

Xuesong Ding[1], Tristan Salles[1], Nicolas Flament[2] and Patrice Rey[1]*
[1]EarthByte Group and Basin GENESIS Hub, School of Geoscience, University of Sydney
[2]School of Earth and Environmental Science, University of Wollongong
*xuesong.ding@sydney.edu.au

Rift settings preserve high-fidelity records of their depositional history in response to multiple processes, such as climate change, which significantly influences the sediment input, and tectonic deformation, which contributes to accommodation generation or consuming. Integrated studies of geomorphology, thermochronology, analog experiments and numerical modelling improved our understanding of the rifting processes and associated structural evolution. However, the interplay between climate change, sediment transport from eroding highland to rift basins and rift-related deformation is poorly understood.

We present a forward numerical scheme that couples surface process with thermo-mechanical modelling on a rift setting. In the coupling numerical framework, a 2D (potentially 3D) lithospheric scale model is set up. The erosion, sediment transport and deposition are controlled by surface processes with the boundary conditions of climate force (precipitation) and erosion coefficient. The resulting sediment volumes are transferred to the thermo-mechanical system, which has a significant effect on crustal deformation. The produced tectonic uplift or subsidence then contributes to the change of surface topography and thus the sediment routing. We focus on investigating the climatic controls on source dynamics, sediment transport, and the deposition in both marine and nonmarine environments. We then quantify the influence of sediment accumulation on crustal deformation and rift evolution. The resulting stratigraphic architecture will be analysed through evolving stratal stacking patterns and shoreline trajectories to explore the feedbacks between erosion/deposition patterns and the rift structural. We will then apply our modelling to typical rifting examples such as East Africa rift system.

P015. CONSTRAINING UPLAND ERODIBILITY IN CATCHMENTS DELIVERING SEDIMENT TO THE GULF OF PAPUA

Rhiannon Garrett, Gilles Brocard, Tristan Salles and Patrice Rey*
Basin Genesis Hub, School of Geosciences, University of Sydney
*rhiannon.garrett@sydney.edu.au

The landscape of Papua New Guinea is very young, shaped by Plio-Quaternary tectonic events. Tectonic uplift rates exceed 400 m/Myr and rainfall exceeds 10 m/year. Uplift and rainfall combine to generate very high erosion rates. The Gulf of Papua is the ultimate sink for a very large terrigenous flux of ~$365 \cdot 10^6$ t/year stemming from the southern New Guinean mainland and from the Papuan Peninsula. Sediment cores indicate sediment accumulation rates of 0.12–0.8 mm/year in the deep-sea basin since the Late Pleistocene.

Rock types and erosion rates determine the nature and burial rate of the sediments delivered to the basin. Understanding their evolution through space and time helps predict the petrological stratigraphy of the basin. We use Badlands, a surface process numerical model developed by the Basin Genesis Hub, which simulates sediment erosion, routing and deposition, in order to simulate present-day fluxes and assess their evolution in the past. To reproduce landscape evolution in deep time we need to constrain the erodibility of the source areas. To achieve this we calibrate the model over the present-day landscape, using the present-day topography, rainfall patterns, distribution of source rocks, recent surface uplift field, and estimates of Late Quaternary sediment fluxes. Relative uplift along the southern flank of the Papuan Peninsula is constrained by the elevation of remnants of extensive late Miocene volcanics and by the modern elevation of contemporary low-lying surfaces. They reveal an uplift rate that increases from 0 m/Myr at the coastline to 440 m/Myr in the headwaters.

P016. DATA VISUALISATION AND INTEGRATION: AN UNDERGRADUATE PERSPECTIVE ON THE FRANK ARNOTT AWARD

Mike Reiger, Larissa Collins, Ben Kay, Angus Nixon, Sarah McDonald, Teagan Romyn, Kiryeong Lee, Melissa Stinear, Racheal Mahlknecht, Jianan Chen, Jamieson Woolcock and Graham Heinson*
University of Adelaide
*larissa.collins@adelaide.edu.au

Over the summer of 2016/17, a team of students from the University of Adelaide were brought together to develop a unique proposal for the Frank Arnott Geophysical Challenge (http://www.frankarnottaward.com), with a focus on data integration and visualisation.

Geoscientific data is critical to exploration success, yet as projects move deeper under cover it is more critical than ever to maximise the value of existing data. Our challenge was to develop a means of integrating and manipulating the data to provide a clearer picture to better tell the story of the geological structures of the Gawler Craton. For this we used Wavelet

Transformations to alter 2D geophysical datasets into 3D datasets using the Poisson Wavelet and to work out the Fractal Dimensions. Subsequently we were tasked with developing an innovative method of visualising that data to give a unique experience and improve interaction and comprehension of the data. This was achieved by interactively projecting data onto a 3D surface to be able to locate areas of interest and see through the subsurface to better understand the geology.

Ultimately the aim of this project is to lend itself to the exploration industry and examine new ways to approach the challenges faced by geoscientists today and tomorrow. We developed a simple method of data integration and visualisation that uses all open source programs and accessible materials.

P017. IMPROVED IMAGING OF THE SUBSURFACE GEOLOGY IN THE MOWLA TERRACE, CANNING BASIN USING GRAVITY GRADIOMETRY DATA

Irena Kivior[1], Stephen Markham[1], Fasil Hagos[1], Mark Baigent[2] and Tony Rudge[3]*
[1]Archimedes Consulting
[2]Baigent Geophysics
[3]Buru Energy
*ikivior@archimedes-consulting.com.au

A study was undertaken to test whether it is possible to map the basement configuration and sedimentary horizons from the gravity gradiometry (AGG) data within the EP431 Buru Energy permit on the Mowla Terrace in the onshore Canning Basin.

By applying the Horizon Mapping (ESA-MWT) method to AGG data, we conducted a test study in a narrow 8 km long swath along 2D seismic traverse, HCG-300, and at three wells: Pictor-1, Pictor-2 and Pictor East-1, and three additional wells located nearby.

ESA-MWT, which is based on energy spectral analysis, was applied to gridded Bouguer and tensor gravity data. The ESA-MWT procedure was conducted at stations 1 km apart. At each station, multiple spectra were computed over incrementally increasing windows. For each spectrum, the depth was interpreted and plotted versus window size, and from these graphs, multiple *Depth-Plateaus* were detected at each station. These *Depth-Plateaus* which correspond to density contrasts within the sediments and the underlying basement, were laterally merged with those from adjacent stations forming density interfaces. These results were then validated with seismic and the litho-stratigraphy from well data showing a good correlation with the tops of several sedimentary formations and intra-formational lithological boundaries. Ten density interfaces were mapped: Top Precambrian Basement, Top Nambeet Formation, Intra-Willara Interface, Top Acacia Sandstone, Top Willara Formation, Intra-Goldwyer Interface, Top Goldwyer Formation, Top Nita Formation, Intra-Tandalgoo Group Interface and Intra-Tandalgoo Group Interface.

The geological model built along the test profile from interpretation of the AGG data shows good correlation with the wells and seismic data.

P018. GROUNDFLOOR EM: A NEW ADAPTATION

*Paolo Berardelli[1], Brian Bengert[2] and Jean M. Legault[1]**
[1]Geotech Ltd
[2]Consultant
*jean@geotech.ca

Geotech has been working on new methods for exploring for higher conductive targets such as nickel and VMS. One method which is early in its development is an adaptation of the Ground Floor EM concept proposed by Vale in 2015.

Since 2004 Vale had been experimenting with the idea of using surface based EM receiver equipment in conjunction with an airborne transmitter, known as Groundfloor EM and described by Bengert (2015) using a case-history from Melville Peninsula, Nunavut, Canada.

Groundfloor EM was the term given to an electromagnetic surveying method that uses receiving equipment on the surface with an airborne transmitter. This technique has several significant advantages that cannot be achieved with an airborne receiver. Given the large transmitter-receiver separation, it is possible with Groundfloor EM to compute the received primary field from the airborne loop with sufficient accuracy to allow non-decaying anomalies to be observed in the system on-time. This allows the detection and discrimination of the kinds of extremely high conductivity targets that are commonly encountered in nickel sulfide exploration.

Groundfloor EM can be used in conjunction with a traditional airborne EM survey with only a minor increase in effort. This increases the confidence in the airborne data, and reduces the need for surface follow-up. This can be of great benefit to projects where surface geophysics is hampered by topographic, logistic, or land access issues.

The new adaptation proposed for Groundfloor utilises a lower frequency signal generated from the airborne transmitter and will be showcased using field results.

P019. ENHANCING THE RL SMITH TEST RANGE – A DEMONSTRATION OF IMPROVED PROCESSING AND NOISE RESULTS USING FULL SPECTRUM FALCON DATA

Chris van Galder, Mark Dransfield and Tianyou Chen*
CGG Multi-Physics
*christopher.vangalder@cgg.com

During May of 2017, CGG re-acquired data over the RL Smith Test Range using the Full Spectrum Gravity system. The Full Spectrum Gravity system combines the high resolution Falcon Airborne Gravity Gradiometer (AGG) data and the sGrav strap-down gravimeter log wavelength gravity data. This system is the product of years of development work in both technology and processing improvements.

In previous years, we have demonstrated that Falcon has the lowest noise data using the RL Smith Test Range. Using this enhanced processing technique we are able to better differentiate acquisition noise from geologic signal. This allows us to better remove the acquisition related noise, while retaining higher resolution data and getting improved noise results.

With the introduction of Full Spectrum Gravity, we have had to create new quality control mechanisms to evaluate data accuracy. We will demonstrate these quality control tools that

can be applied to verify the Falcon data, sGrav data and Full Spectrum Gravity data.

In conclusion, we show the improvement achieved after years of development with the Full Spectrum Gravity System. We demonstrate the improved noise results and new quality control measures used to evaluate the quality of the Full Spectrum Gravity data using the RL Smith Test Range.

P020. RESEARCH ON DC RESISTIVITY FOR AN ARBITRARILY ANISOTROPIC EARTH USING CIRCULAR SCANNING MEASUREMENT

*Zhilong Yang and Changchun Yin**
Jilin University
*yinchangchun@jlu.edu.cn

The electrical anisotropy of underground media increases the non-uniqueness and uncertainty of geophysical interpretation in electrical prospecting. In order to identify the electrical characteristics of the arbitrarily anisotropic subsurface objects, we extend the existing researches and present a 3D anisotropic forward modelling algorithm using adaptive finite-element method based on unstructured grids. The adaptive finite-element code was validated against 1D semi-analytical solutions for a layered arbitrarily anisotropic earth. Considering the existence of anisotropic paradox, circular direct current (DC) scanning measurement is applied. We study the characteristics of apparent resistivity by simulating an arbitrarily anisotropic half-space and an arbitrarily anisotropic ore body surrounded by an isotropic or anisotropic rock. Based on this, we demonstrate how to identify the underground anisotropy from DC resistivity data. The algorithm and results from our numerical experiments can offer technical support in processing and interpreting DC resistivity data in areas with distinct electrical anisotropy.

P021. ACCELERATION OF 3D POTENTIAL FIELD DATA INVERSION USING A BB ITERATIVE ALGORITHM

Zhaohai Meng, Fengting Li, Hao Yu, Lin Ma and Zhongli Li*
Tianjin Navigation Instrument Research Institute, Tianjin, China
*526468457@qq.com

The efficiency of 3D inversion of potential field data can be paid enough attention by scholars owing to the arrival of the big-data age. A new solution method was considered for 3D inversion of potential field data in the geophysical data process. This program takes as an input gravity or magnetic vector and tensor measurements and produces 3D volumes of density and susceptibility with a fast convergence method. Here, in this paper, the gravity data is used to represent the potential filed data to test our method. To achieve this aim, the survey area is divided into a large number of rectangular prisms with unknown densities. In the potential filed data inversion, the inversion process is usually to solve an underdetermined linear system of equations problem. The problem was formulated by incorporating regularising constraints to obtain the stable inversion results. According to these acceleration requirements of inversion method, a new Barzilai–Borwein iterative algorithm was applied to accelerate the convergence of inversion method. Iterative gradient descent algorithms and iterative conjugate gradient algorithms were studied as the comparisons. To test the potential of the application of the new fast developed method, synthetic gravity data and real gravity data were performed. Numerical test and practical test indicate that this method is promising for practical potential field data inversion.

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Near Surface and Groundwater

P022. TRACE ELEMENTS AND NATURALLY OCCURRING RADIOACTIVE MATERIAL ASSOCIATED WITH PRODUCED WATERS IN COAL SEAM GAS AND SHALE GAS RESOURCES AND MECHANISMS THAT INFLUENCE FLUID MIGRATION

*Nikolce Aleksieski**
University of Southern Queensland
Petroleum Exploration Society Australia
*Nikolcee.Aleksieski@gmail.com

The aim of this project is to determine the chemical properties of formation, produced and flowback fluids and to analyse the mechanisms that could contribute to fluid migration associated with coal seam gas and shale gas resources by reviewing global case studies. This can be achieved by: (a) determining the concentration of naturally occurring radioactive material (NORM) and trace elements associated with mining fluids; (b) determining the quality and quantity of produced water extracted at the surface; and (c) analysing the mechanisms that contribute to fluid migration through subsurface geology, which involves evaluating stress fields surrounding hydrocarbon resources.

The geochemical trace element and NORM composition associated with produced water depend on the type and grade of the fossil fuel, the original depositional environment, composition of the source rock, post depositional genesis processes and the mobility of trace elements by their capacity to dissolve into an aqueous solution. Therefore, an analysis of the geochemical characteristics of various formations around the world on a case study basis should be able to illustrate the variation of toxic concentration in numerous hydrocarbon bearing rock formations. Furthermore, having a clear understanding of regional hydrogeology and the mechanisms that relate to stress magnitude and orientation should illustrate the impact of stress characteristics to well integrity and fluid migration through sub-surface geology.

Lastly, the information compiled should provide a framework for decision makers to make recommendations on ways to monitor, control and minimise impact to important ground and surface water resources.

P023. THE USE OF GEOPHYSICS AS AN AID FOR CRICKET UMPIRES

Tim Dean[1] and Paul Hawkins[2]*
[1]Curtin University
[2]Hawk-eye Innovations
*tim.dean@curtin.edu.au

A particularly difficult part of cricket umpiring is judging whether the batsman has ‘nicked’ the ball on its way from the bowler to wicket keeper. If they have then the batsman is

dismissed, if not, or if the batsman has hit his pad rather than the ball, then the batsmen remains in. Even with modern high-speed cameras discerning a nick by eye is virtually impossible so during international cricket matches the umpire is aided in their decision making by an audio recording. This can be inconclusive, however, if there is considerable other noise being made (usually by the crowd), and especially if there is the possibility that the batsman may have hit the ground or another part of his body or equipment. To a geophysicist the solution to this problem is obvious, attach three component vibration sensors to the bat, record the data, and then look for any impacts, and this is in-effect what we have done. The results are convincing, not only can we detect impacts but also the type of impact and even the position of the bat upon which the impact occurred. Not only is the data superior to audio recordings but can be obtained more easily and cheaply making its application to the lower levels of cricket possible.

P024. USE OF ELECTRICAL GEOPHYSICS TO DELINEATE SHALLOW GROUNDWATER PATHWAYS

Anthony Finn and Mark Lackie*
Macquarie University
*anthony.finn@hdr.mq.edu.au

Soil erosion poses significant consequences from an agricultural, economic and infrastructural perspective on a global scale. In particular, gullying processes have been a scientific focus for an extended period of time now in an attempt to understand and quantify the initiation and development of these erosion features (Beavis, 2000). Gullying is a natural process that is accelerated by unsuitable farming practices, clearing of vegetation and alterations to the local hydrological conditions; all of which are associated with European settlement of Australia over two centuries ago (Sidochuk, 1999). In order to develop appropriate management options a greater understanding of gullying is required, part of this is the prediction of head-cut movement (knickpoint) retreat uphill. Prediction of gully retreat would allow for preventative measures to be implemented to specific areas minimising affected areas and costs of management. Shallow geophysical investigations have the potential to track the preferential pathways of water through the soil/rock profile uphill from existing gully formations, effectively tracing the future movement of the knickpoint. Specifically the most appropriate geophysical techniques involve electrical resistivity and frequency domain electromagnetics, implemented to locate shallow conductors associated with existing gullies.

P025. STRUCTURAL EVOLUTION OF THE THIRLMERE AND MOUNT TOMA MONOCLINES SOUTHERN SYDNEY BASIN NSW - A GROUNDWATER PERSPECTIVE

Tim McMillian[1], Titus Murray[2] and Wendy Timms[1]*
[1]UNSW
[2]FaultSeal Pty Ltd
*t.mcmillan@unsw.edu.au

The Southern Sydney Basin is a geological region of almost flat lying conforming strata, with significant coal measures that have been mined for over 100 years. This apparently simple ‘layer-cake’ geology has resulted in the overlooking of many complexities associated with intrusions and a variety of geological structures. This over-simplification has contributed to the non-negligible, unpredicted impacts from mining on the surface hydrology and groundwater systems. The aim of this study was to identify and characterise geological complexities within the Southern Sydney Basin with a particular focus on near surface groundwater and wetlands that could be sensitive to these mining impacts.

An initial desk top review of existing drill-hole data and outcrop maps was undertaken to highlight areas of possible structural inconsistency and areas with a high probability of faults or other structures such as monoclines. This data was then used in combination with field based geological mapping and high quality digital terrain modeling to develop a series of kinematic cross-sections.

This enabled the modeling of fault propagation folds associated with the inversion of growth faults, which was important in the development of a framework to better identify and define the geometry of aquitards, associated with the Thirlmere Lakes and groundwater surface expression dependent ecosystems (swamps) over the Southern Sydney Basin. This greater understanding of the features around the Thirlmere Lakes area has led to the development of a structural evolution model that explains the incision of Blue Gum Creek and the development of Thirlmere Lakes within an entrenched meander.

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Energy

P026. DETERMINING UPFLOW/OUTFLOW ZONE AND FLUIDS FLOWS IN GEOTHERMAL PROSPECT AREA BASED ON GEOINDICATOR COMPARISON VALUE: A CASE STUDY OF MT TELOMOYO, CENTRAL JAVA, INDONESIA

Hasbi Fikru Syabi, Rifqi Alfadhilah Sentosa, Agil Gemilang Ramadhan and Boy Yoseph CSSSA*
Department of Geology Engineering, University of Padjadjaran, Indonesia
*hasbi14002@mail.unpad.ac.id

Mt Telomoyo is situated in Magelang Regency, about 400 km from Jakarta. In the studied area, eight geothermal surface manifestations were found, consisting of four hot springs and four cold springs. This research aims to identify upflow and outflow zones in the geothermal area using compared values of geoindicators and tracers obtained from sampled geothermal surface manifestations, and also to identify fluids flow of the Mt Telomoyo geothermal system. The method used in this research is to compile geoindicator comparison results, which are B/Li, Cl/B, Na/Ca, Cl/SO4, SO4/HCO3, and Na/K. Comparison results are then converted into geoindicator comparison maps. Faults and fractures are used to identify density of lineaments, also direction of lineaments where manifestations are found. Afterward overlain geoindicator maps and FFD maps are correlated to identify upflow/outflow zones and flow trends of geothermal fluids. The results of this research show that the upflow zone in the study area is located beneath Mt Telomoyo, the upflow zone has a high density of lineaments. Furthermore, the outflow zones are found with two tendencies. The major trend of outflow is directed toward the western part of upflow

zone, where geothermal manifestation APPD and APCU were found in ENE-WSW direction. The other outflow trend is directed toward the northeastern part of interpreted upflow zone, where geothermal manifestation APCD-1 and APCD-2 were found in NNW–SSE direction.

P027. SOIL AND FLUIDS GEOCHEMISTRY ANALYSIS TO DETERMINE NON-VOLCANIC GEOTHERMAL POTENTIAL, CASE STUDY OF BAYAH, BANTEN, INDONESIA

Hasbi Fikru Syabi, Rifqi Alfadhillah Sentosa and Agus Didit Haryanto*
Department of Geology Engineering, University of Padjadjaran, Indonesia
*hasbi14002@mail.unpad.ac.id

Bayah is an area with complex geological conditions located administratively in Lebak District, Banten Province, approximately 80 kilometres southwest of Jakarta. In this area, six geothermal manifestations were found in the form of four hot springs and two cold springs, also 139 soil samples were taken. This study aims to determine the non-volcanic geothermal potential of the Bayah area. The method used in this research is the calculation of the geothermometer and geoindicators of geothermal manifestations to know the estimated reservoir temperature and the origin of the fluid manifestation. After that, a map was created based on soil chemistry data, which are Hg and CO_2 distribution anomalies in the soil. Analysis of Fault and Fracture Density (FFD) were also carried out to determine the fracture density developed in the study area. The results were used to calculate the real prospect area. The results of this study show that the geothermal prospect zone in the Bayah region is located in the southeast of the research area, precisely around APPC-1, APPC-2, and APPC-3 manifestations, having an area of about 10.36 km^2. Based on the geothermometer calculation, geothermal potential of Bayah area has medium enthalpy with reservoir temperature around 141–161ºC. The resources calculated in this study were 103 MWe.

P029. STRUCTURAL GEOLOGY ANALYSIS USING REMOTE SENSING METHOD AND ITS CORRELATION TO GEOTHERMAL OCCURENCE IN BAYAH DISTRICT, BANTEN

Rifqi Alfadhillah Sentosa, Hasbi Fikru Syabi, Agil Gemilang Ramadhan and Iyan Haryanto*
Department of Geology Engineering, University of Padjadjaran, Indonesia
*rifqi14008@mail.unpad.ac.id

The research area is located in Bayah District, Lebak Regency, Banten Province. The research location is approximately 80 km southwest of Jakarta. This area has a complex geological structure, as well as many intrusive and metamorphic rocks. In this research area, geothermal manifestations were found in the form of four hot springs (APPC-1, APPC-2, APPC-3, and APC) and two cold springs (ADC-1 and ADC-2). This study aims to identify the relationship of geological structure control with the occurence of geothermal manifestations in the research area, as well as to determine the Bayah non-volcanic geothermal prospects. The method used is Fault and Fracture Density (FFD) analysis for structural analysis of research area, and magnetic map analysis for interpretation of geothermal prospects. Structural analysis methods performed in the form of lineament delineation, determination of lineament density and major trends, and application of structural sequence model. The results of the structural analysis will be correlated with the occurences of geothermal manifestations with the aim of identifying the most influential structural patterns as the pathway for geothermal fluid to reach surface in the study area. Magnetic data is also used to determine the possibility of Bayah non-volcanic geothermal prospects. The developing structure in the research area has NE–SW and NW–SE directions. The FFD analysis shows that high-density lineament is located in the southeast of research area where three hot spring manifestations APPC-1, APPC-2, APPC-3 are present. These manifestations appear in the lineament with NE–SW direction. Magnetic data also obtained negative magnetic anomalies in the southeast of the study area. It can be concluded that the lineaments with NE–SW direction influence the fluid outflow the most, and Bayah non-volcanic geothermal prospect areas are located around APPC manifestations.

P030. GEODYNAMIC AND SURFACE PROCESS EVOLUTION OF NEW GUINEA SINCE THE JURASSIC

Carmen Braz, Sabin Zahirovic and Dietmar Müller*
EarthByte Group and Basin GENESIS Hub, School of Geosciences, University of Sydney, NSW
*carmen.braz@sydney.edu.au

Regional scale flooding of New Guinea has occurred episodically since the Jurassic. The most recent flooding event during the Miocene occurred despite falling long-term eustatic sea levels. Recent work has suggested dynamic topography, the long-wavelength low-amplitude topographic response to mantle flow, as a factor in the emergence and flooding of this region, and therefore influencing the depositional history of New Guinea basins. The link between deep Earth and surface processes has not yet been explored for this region. We use forward numerical models coupling plate kinematics, mantle convection, paleogeography and eustasty to investigate the time-dependent topographic response of the New Guinea margin. Dynamic topography estimates derived from mantle convection models are then coupled with surface process modelling code *Badlands* to study the landscape evolution of New Guinea and the adjacent Australian continent. Reproducing the inundation history of New Guinea, our models show that continental scale dynamic topography plays a significant role in the development of drainage systems, and erosion-deposition regimes. Our work demonstrates the necessity in linking geological processes that operate across wide spatial and temporal scales to better understand how the interplay between deep Earth and surface processes control the source to sink evolution of basins.

P031. NEW PERSPECTIVE OF MESOZOIC HYDROCARBON PROSPECTIVITY WITHIN WEST TIMOR

Aurio Erdi[1], Novian Martha Kusuma[1], Benyamin Sapiie[2], Alfend Rudyawan[2] and Indra Gunawan[2]*
[1]Geodynamic Research Group-ITB
[2]Institut Teknologi Bandung
*aurioerdi@geodin.net

Compared to the success of a Mesozoic play in the Westralian Superbasin (WASB), the lack of hydrocarbon discovery in West Timor within Timor Trough and North West Shelf Australia is still an enigma. The West Timor is still a frontier petroleum province with problems in uncertainties of working petroleum system plays as well as the hydrocarbon prospectivity.

This study tries to approach this issue by integrating of fieldwork data with published well data and offshore seismic data from recent publications to re-evaluate potential hydrocarbon prospectivity in this area. Using these datasets, this study identifies structural framework across West Timor Island and offshore area, as well as potential petroleum system plays including source rock, reservoir presence and trap configuration.

The results of this study identify two potential petroleum province regions including Timor deformation front and Australian passive continental margin. Within these areas, three main plays based on structural configuration were identified, which are fold related fault, sub-thrust and tilted fault block. Reservoir targets for these main plays are Jurassic sequences including sandstone of the Early-Middle Jurassic of Plover equivalent and Late Triassic Malita equivalent with seal rock including Early-Middle Jurassic shale of Wai Lui Formation and Early Cretaceous shale interval. These plays are expected to be charged from source rock intervals of Triassic formations.

The novelty of hydrocarbon prospectivity in this study will guide exploration screening of petroleum system analysis in the West Timor area where current play analysis has not yet been tested.

P032. UNRAVELLING DEEP STRUCTURES ALONG A PASSIVE-TRANSFORM MARGIN: INSIGHTS FROM AN INTEGRATED GEOPHYSICAL STUDY OF THE NORTHERN PERTH BASIN

Guillaume Sanchez[1], Lisa Hall[2], Lynn Pryer[1], Zhiqun Shi[1], Irina Borissova[2] and Chris Southby[2]*
[1]FROGTECH Geoscience
[2]Geoscience Australia
*gsanchez@frogtech.com.au

The Houtman Sub-basin lies adjacent to the Wallaby-Zenith Transform Margin, an under-explored region of Australia's continental margin located at the transition between the non-volcanic margin of the northern Perth Basin and volcanic province of the Wallaby Plateau. New data in the Houtman Sub-basin enables better understanding of the structural architecture and rifting development along a passive-transform margin and provides the framework for a detailed integrated margin-scale basin evaluation.

Profile modelling of potential field data, combined with 2D seismic, reveals complex along strike and dip variability in the crustal thinning of the Houtman Sub-basin, with extreme thinning (<5 km thick) beneath the main Permian depocentre. Outboard of this hyperextended zone, along the basin margin, is a zone of volcanic SDRs. Five different structural domains have been mapped across the margin, reflecting abrupt change in crustal thinning and volcanic emplacement. These domains trend roughly NW-SE to NNW-SSW, parallel to major basement terrane boundaries. Magnetic modelling suggests that the nature of the basement underlying the proximal domain and the hyperextended domain in the central Houtman Sub-basin are different and that a major Proterozoic basement terrane boundary lies beneath the necking domain.

The margin was structured during polyphase Permian and Late Jurassic rifting events which led to hyperextension prior to continental magmatic break-up and formation of oceanic crust during the Early Cretaceous. Our results suggest that the distribution of Early Permian rifts localised strain during Jurassic–Early Cretaceous rifting and strongly controlled the location and style of rifted margin during Valanginian continental break-up.

P033. STRUCTURAL CHARACTERISTICS OF THE NORTHERN HOUTMAN SUB-BASIN, PERTH BASIN

Chris Southby, Irina Borissova, Lisa Hall, Emmanuelle Grosjean, Ryan Owens, George Bernardel and Cameron Mitchell*
Geoscience Australia
*chris.southby@ga.gov.au

The northern Houtman Sub-basin is an under-explored region of Australia's continental margin. It is located at the transition between the non-volcanic margin of the northern Perth Basin and the volcanic province of the Wallaby Plateau and lies adjacent to the Wallaby-Zenith Transform Margin. In 2014, Geoscience Australia acquired new 2D seismic data (GA-349, 3455 km) across the northern Houtman Sub-basin to assess its hydrocarbon prospectivity. Previous studies of the Houtman Sub-basin indicated that en-echelon basin bounding north-northwest trending faults are associated with the Permian half graben complex, however, it was not known if this structural style continued into the northern area of the Houtman Sub-basin.

This study integrated interpretation of the recently acquired survey with regional interpretation of the Houtman Sub-basin, underpinned by ties to well data and geophysical modelling, to develop a regional 2D structural and stratigraphic interpretation. Structural mapping was done for several surfaces: the basement, Early Triassic (Woodada Formation) and Early Jurassic (Eneabba Formation).

The basement structure of the northern Houtman Sub-basin is controlled by a series of large en-echelon northwest-southeast trending southwest dipping faults, some of which have a throw of more than 10 km. They control a series of Permian half graben separated by transfer zones and fault ramps. This basement architecture is similar to the inboard part of the southern Houtman Sub-basin, but the structures are larger. The Early Triassic and Early Jurassic faults trend northwest-southeast similar to the basement-involved faults, however the focus of faulting shifts westwards in the younger successions.

P034. TECTONO-STRATIGRAPHIC DEVELOPMENT OF THE NORTHERN HOUTMAN SUB-BASIN, PERTH BASIN

Ryan Owens, Irina Borissova, Chris Southby, Lisa Hall, Emmanuelle Grosjean, George Bernardel and Cameron Mitchell*
Geoscience Australia
*ryan.owens@ga.gov.au

New 2D seismic data (GA-349) acquired by Geoscience Australia in the northern Houtman Sub-basin, Perth Basin, provides important new insights into the tectono-stratigraphy of this frontier area. Interpretation of the GA-349 data tied to a regional interpretation of the Houtman and Abrolhos sub-basins reveals that the northern depocentre contains up to 19 km of Permian to Cenozoic sediments. As there are no wells in the northern Houtman Sub-basin, the age and lithologies of the mapped sequences were derived from regional mapping, stratal relationships and seismic facies. A series of large half-graben (7–10 km thick) extend the length of the inboard part of northern Sub-basin. These are interpreted to have formed as a result of rifting during the Permian. Overlying these half-graben,

and separated by an unconformity, is a thick succession (up to 6 km) interpreted to represent a subsequent late Permian to Early Jurassic phase of the thermal subsidence. A second phase of rifting started in the Early Jurassic and culminated in breakup in the Early Cretaceous. The sedimentary succession deposited during this phase of rifting is highly faulted and heavily intruded in the outboard part of the basin adjacent to the Wallaby Saddle, where intrusive and extrusive complexes are clearly imaged on the seismic. In contrast to the southern part of the Houtman Sub-basin that experienced rapid passive margin subsidence and regional tilting after the Valanginian breakup, the northern Sub-basin remained mostly exposed subaerially until the Aptian, as the Wallaby Zenith Transform Margin continued to develop.

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Mineral Geoscience

P035. TOWARDS A U–PB AGE MAP FOR NORTHERN AUSTRALIA

Jade Anderson and Geoff Fraser*
Geoscience Australia
*jade.anderson@ga.gov.au

Understanding the geological evolution and resource prospectivity of a region relies heavily on the integration of different geological and geophysical datasets. Age datasets are key to understanding the geological evolution and resource prospectivity of a region.

Northern Australia is a vast and relatively underexplored area that offers enormous potential for mineral and energy resource development. The area has a long and variably complex tectonic history, which is yet to be fully understood. Numerous geochronology studies have been completed at various scales throughout northern Australia over several decades; however, these data are scattered amongst numerous sources limiting the ease with which they can be used collectively.

To address this, over 2000 U–Pb ages from the Northern Territory, Queensland and eastern Western Australia have been compiled into a single, consistent dataset. Data were sourced from Geoscience Australia, State and Territory geological surveys and from academic literature. The compilation presented here includes age data from igneous, metamorphic and sedimentary rocks. Thematic maps of magmatic crystallisation ages, high-grade metamorphic ages and sedimentary maximum depositional ages have been generated using the dataset. The maps allow for spatial and temporal trends in the rock record to be visualised up to semi-continental scale. Further, the integration of U–Pb age maps with other isotopic, structural, geochemical and geophysical thematic maps enables a visual multi-component approach to better understand the geological evolution and resource potential of northern Australia.

P036. INTERPRETING GEOLOGY FROM GEOPHYSICS IN POLYDEFORMED TERRANES: THE OTAGO SCHIST, NEW ZEALAND

Casey Blundell[1]*, *Laurent Ailleres*[1], *Robin Armit*[1] *and Adam Martin*[2]
[1]Monash University
[2]GNS Science
*casey.blundell@monash.edu

Acquisition of airborne geophysical data across Otago, New Zealand, presents a unique opportunity to explore in detail the subsurface geometries of the Otago Schist, a polydeformed Mesozoic belt. A relationship is known for hard-rock Au (±W) occurrences with increasing metamorphic grade across the exhumed metasedimentary belt, though structural controls are less clear at a regional scale. Using new geophysical data, this study aims to identify the structural controls leading to mineralisation in the schist within the broader framework of the tectonic evolution of the South Island since ca. 150 Ma. Interpreting geology from geospatial data requires critical assessment and integration of this data with detailed structural field mapping and other geochemical and petrophysical analyses. This workflow aims to identify lithology distributions, patterns and anisotropies resulting from tectonic juxtaposition and the development of structural fabrics at regional scales. The Otago Schist preserves a complex history of deformation and metamorphism beginning with terrane accretion to southeastern Gondwana in the Paleozoic, to the present dextral translation of terranes along the Australian-Pacific plate boundary. This study presents for the first time a detailed geological interpretation of 3-dimensional geometries of the Otago Schist using regional geophysical data and places it in a regional tectonic context for the crustal assimilation and deformation of the South Island.

P037. HOW TO ACCESS NEW SOUTH WALES GEOPHYSICAL DATA

*Astrid Carlton**
Geological Survey of New South Wales
*astrid.carlton@industry.nsw.gov.au

The Geological Survey of New South Wales (GSNSW) is custodian of geophysical data sets acquired by private companies and the NSW government. Many are open file, free and can be accessed via the GSNSW website.

NSW government acquired surveys (magnetic, radioelement, digital elevation model and ground gravity surveys) can be accessed using the Geoscience Australia GADDS portal or purchased on portable hard drive. The hard drive also includes government hyperspectral, airborne electromagnetic and airborne gravity gradiometry data.

Statewide merges of NSW government surveys and open-file company data are available through the Geoscientific Data Warehouse (GDW) (and portable hard drive). Seven different geophysical images, displaying magnetic, gravity, radiometric and geothermal data, can be downloaded for use in Google Earth, as mobile phone maps, or for use in common GIS platforms. The GDW can also clip statewide images to your project area.

The 250K geophysical imagery suite was generated to enhance subtle features not readily visible in statewide imagery. More than 20 types of geophysical georeferenced imagery have been

generated for each map sheet area and are available through the DIGS online system.

Company geophysics includes geophysical data acquired by exploration companies and submitted to the NSW Government as part of exploration reporting requirements. The NSW Government recently legislated that all data must become open file five years after submission. Data submitted before June 2016 will become available in June 2021. These data commonly have higher resolution than government-acquired regional surveys and can be searched and discovered using the MinView online system.

P039. ELECTRICAL RESISTIVITY MAPS OF THE AUSTRALIAN LOWER CRUST

Graham Heinson[1]*, *Stephan Thiel*[1,2], *Kate Robertson*[1,2], *Yohannes Didana*[1] *and Paul Soeffky*[1]
[1]University of Adelaide
[2]Geological Survey of South Australia
*Graham.Heinson@adelaide.edu.au

Crustal silicate rocks at sub-solidus temperatures normally have high electrical resistivities. However, although upper crust is typically >1000 Ω.m, it is not unusual for lower crust to be <100 Ω.m, and in places ~1 Ω.m. That lower crust (below 15 km) can be as electrically conducting as seawater is remarkable, and indicates a substantial and highly-connected mineral, melt or aqueous phase. To date, temporal and spatial mechanisms to give rise to the low resistivity are speculative and poorly constrained by observation and laboratory measurement.

We present new maps of the Australian lower crust resistivity. The project addresses the question as to whether the low resistivity is primary in the formation of the crust, or overprint due to melt and fluid migration from a deeper thermal source. A secondary question is how regions of low resistivity from an interconnected phase can be preserved through time-scales of billions of years. Observations are drawn from: the Australian Lithospheric Array Magnetotelluric Project (AusLAMP); 2D MT transects, and legacy MT and geomagnetic depth sounding (GDS) data.

Our research demonstrates a strong spatial correlation of lower crustal resistivity with tectonic domains in Australia. Lowest resistivities are often imaged just below the rheological boundary between upper and lower crust at ~15 km. Below, low resistivity is often imaged as a broad zone, tens of kilometres wide and thick; above the boundary, regions of low-resistivity appear as narrower pathways. We show a strong spatial correlation between gradients of lowest crustal resistivity and major mineral systems.

P040. WHY DO WE NEED TO KNOW THE ELECTRICAL RESISTIVITY STRUCTURE OF OCEANIC LITHOSPHERE?

Jake Macfarlane and Graham Heinson*
University of Adelaide
*Jake.Macfarlane@adelaide.edu.au

Regional-scale continental MT programs such as AusLAMP are naturally bounded by continental shelf and oceans. Within a few hundred kilometres of the coastline, long-period MT data are strongly influenced by conductive seawater. Thus, 3D modelling of the continental lithosphere requires good constraints on the resistivity of the seawater, oceanic crust and upper mantle, and into the asthenosphere where there are no data.

Oceanic lithosphere is generated at mid-ocean ridges with the extraction of melt and volatiles from upper mantle. With distance, oceanic lithosphere thickens as the plate cools. In contrast to continental lithosphere that undergoes cycles of deformation and magmatism over billions of years, oceanic lithosphere exhibits more uniform properties across all basins, and varies in age by at most 200 million years.

However, determining the resistivity of oceanic lithosphere from seafloor long-period MT is surprisingly difficult. Primarily, this is because oceanic lithosphere is depleted of conducting phases during formation, and is very electrically resistive (>10 000 Ω.m). As a consequence, all coastlines boundaries, thousands of kilometres away from seafloor MT sites, will distort the observations.

In this paper, we show that analytical and 3D models of the entire Pacific Ocean are required to reproduce observations on 30 Ma seafloor about 1000 km from the coastline of California. By allowing for distortion at the surface, we show that the oceanic lithosphere resistivity is largely a function of conduction in olivine with temperature. We demonstrate that this new oceanic lithosphere resistivity is very important in 3D AusLAMP models in defining the continental properties.

P041. CONSTRAINING AIRBORNE ELECTROMAGNETIC REGOLITH MAPPING WITH LANDSCAPE EVOLUTION

Andrew King and Ignacio González-Álvarez*
CSIRO
*andrew.king@csiro.au

A typical product from an airborne electromagnetic (AEM) survey is a conductivity depth image (CDI) along each of the flight lines. These CDIs overcome the problem of non-uniqueness by choosing one model that fits the data, typically a smoothest model. However, in the case of using AEM for mapping regolith, an understanding of the landscape evolution processes that formed the regolith gives us knowledge about what the stratigraphic units are that make up the regolith, and also something about their likely geometry. In addition, knowledge of their mineralogy tells us something about their likely ranges of conductivity, and understanding of the processes that formed them tells us about their geostatistical properties. For example, materials which are well mixed, such as channel clays, will typically be homogeneous over large distances, whereas material that has formed by *in situ* weathering could be much more heterogeneous. It therefore makes sense to try to invert the AEM data for stratigraphic boundaries and conductivity variations within stratigraphic units rather than smooth models. This immediately gives estimates, with uncertainty bounds, for the depths to various interfaces, which are of more direct interest to a geologist than the conductivity values in the CDI.

The work presented here shows how the use of this information can produce improved inverted models of the regolith from AEM data. A better understanding of regolith structure then allows for optimisation of drilling sites for geochemical sampling, focussing on stratigraphic units where the geochemical footprint of an orebody is likely to have been concentrated.

P042. DEVELOPMENT OF THE MTPY SOFTWARE PACKAGE FOR MAGNETOTELLURIC DATA ANALYSIS

Alison Kirkby[1]*, *Jingming Duan*[1], *Fei Zhang*[1] *and Jared Peacock*[2]
[1]Geoscience Australia
[2]United States Geological Survey
*alison.kirkby@ga.gov.au

The magnetotelluric (MT) method is increasingly being recognised as a valuable geophysical technique for exploration, as data analysis and inversion tools have become more sophisticated. However, the software available for MT data processing and analysis is still very limited in comparison to other geophysical methods such as gravity, magnetic and seismic. Using such software often requires specialist knowledge, and this has impeded the widespread use of this technique.

MTpy is an open source software package, originally developed at the University of Adelaide to assist with MT data processing, analysis, modelling, visualisation and interpretation. Written in Python, it contains modules to carry out much of the processing and analysis that needs to be applied to MT data, working with the industry standard EDI file format amongst other formats. It also contains modules to create inputs, and visualise outputs, from many of the inversion codes that are currently in use in the MT community. However, despite continued development of this software, it is still largely untested, and contains bugs and gaps. These factors, together with a lack of user interface, have limited its use in the wider MT community to date.

Geoscience Australia (GA) is continuing development of MTpy to improve its functionality and provide increased user support. The aim in doing this is to provide software to the MT community that will make it easier to work with MT data and thus facilitate the use of MT as an exploration method.

P043. DETRITAL ZIRCON ANALYSIS FROM THE GALILEE BASIN, QUEENSLAND

Laura Phillips[1]*, *Charlie Verdel*[1], *Charlotte Allen*[2] *and Joan Esterle*[1]
[1]School of Earth and Environmental Sciences, University of Queensland
[2]School of Earth, Environmental and Biological Sciences, Queensland University of Technology
*l.phillips3@uq.edu.au

Little is about the effects of the Permian onset of the Hunter-Bowen Orogeny on sedimentation patterns in the Galilee Basin of Queensland. Through a comparison of age populations of detrital zircon grains in sandstone of the Galilee Basin, a potential shift in sediment provenance has been recognised. One key well (OEC Glue Pot Creek 1) was selected from the Galilee Basin for detrital zircon analysis. This well intersected both Cisuralian (early Permian) and Lopingian (late Permian) strata. Nine sandstone samples were collected (three from the Cisuralian and six from Lopingian) and zircon grains were extracted. U-Pb isotopic data was gathered using the Laser Ablation – Inductively Coupled Plasma Mass Spectrometer (LA-ICPMS) technique.

A total of 271 concordant ages were obtained from the nine samples. The Cisuralian samples a varied age population range, with multiple peaks between 300 and 1200 Ma, suggesting numerous sources and orogenic recycling. In contrast, the Lopingian samples have a dominant peak of 250 to 300 Ma zircons, with a singular minor peak of 1500 Ma zircons, suggesting a transition in provenance between the Cisuralian and Lopingian. This transition corresponds with the onset of the Hunter-Bowen Orogeny and may mark a change in the tectonic setting of the Galilee Basin from an earlier back-arc (extensional) setting to a subsequent foreland basin position.

P044. SQUARE-WAVE PROCESSING OF MEGATEM DATA

Daniel Sattel[1]* *and Eric Battig*[2]
[1]EM Solutions
[2]BHP Billiton
*dsattel@comcast.net

The recording of raw or streaming data, as done by CGG during a MEGATEM survey, allows for the reprocessing of the acquired EM data, including square-wave processing. During the latter, the recorded EM response to the actual half-sine waveform is replaced by the EM response to a square-wave, derived via deconvolution/convolution in the frequency-domain. This makes the on- and early-time information more accessible for data modelling, including 1D inversions and conductivity-depth transformations. Square-wave EM data can also be corrected for survey height, transmitter-receiver offset and transmitter attitude. That correction allows for the interpretation of early-time EM response grids, which generally offer better spatial resolution than derived conductivity-depth slices.

The advantages of square-wave processing are demonstrated on a MEGATEM data set acquired in 2013 in South America. With survey terrain clearance ranging from 100–1600 m, due to the rugged topography, early-time grids of elevation-corrected square-wave data outlined the shallow conductivity structure, whereas early-time grids of the original half-sine data mostly reflected the variable system elevation. Further, derived conductivity-depth sections of the square-wave data show more continuity than the sections derived from the original half-sine data. These results show that the early-time information of square-wave is more accessible than in the original data, facilitating interpretation of shallow conductivity structures.

P045. MERCURY AND SOIL CARBON DIOXIDE ANALYSIS TO DETERMINE GEOTHERMAL RESOURCES IN MT TELOMOYO, CENTRAL JAVA, INDONESIA

*Rifqi Alfadhillah Sentosa**, *Hasbi Fikru Syabi, Agil Gemilang Ramadhan and Boy Yoseph CSSSA*
Department of Geology Engineering, University of Padjadjaran, Indonesia
*rifqi14008@mail.unpad.ac.id

Mercury and soil carbon dioxide are elements that can be used to determine the approximate of geothermal resources. The elements are commonly present in geothermal fluids and can migrate to the surface. The study area is located in Mt Telomoyo, Central Java Province. This area is located approximately 400 km east-southeast of Jakarta. Around the mountain, four hot springs and four cold springs were found, also 144 soil samples were taken. The study aims to determine geothermal resources using soil and fluid geochemistry analysis. In this study the geothermal prospect zone is determined using mercury and soil carbon dioxide analyses of soil samples from the Mt Telomoyo area. Geoindicators and geothermometer calculations on the geothermal surface manifestations and fault-fracture density mapping are used. The result zones were

then overlain to create the prospect zone. After that, the area value of the prospect zone was applied in the formula to calculate geothermal speculative resources of the study area. The results of this research show the geothermal prospect zone is located at the northern side of the Mt Telomoyo and the area is about 5.65 square kilometres. Based on the geothermometer calculation, the geothermal area of Mt Telomoyo has high enthalpy with a reservoir temperature about 236–250ºC. From the calculation of all existing data obtained geothermal resources in the Telomoyo area are about 84.7 MWe.

P046. EXPLORING MAGNETOTELLURIC MODEL SPACE

Janelle Simpson[1,2] and Graham Heinson[2]*
[1]Department of Natural Resources and Mines, Geological Survey of Queensland, Brisbane, Australia
[2]The University of Adelaide, Adelaide, Australia
*janelle.simpson@dnrm.qld.gov.au

Magnetotelluric (MT) inversions are inherently non-unique. Due to the large computational requirement of 3D MT inversions, there is often a trade-off between exploring model space and the amount of time invested in the inversion process. A standard approach is a 2 stage inversion, where the coarse features are resolved in the first inversion. The output from the coarse inversion is then used as the starting model for a finely discretised final inversion. Inversion may be followed by a combination of sensitivity analysis and forward modelling to test the robustness of features returned during inversion. This approach leads to a low RMS model but has a limited capacity to explore the range of potential models.

In this paper, we compare inversion results from a range of inversion parameters. Three inversions were run using a starting half space with only the input data varied: one inversion using the un-rotated full tensor and tipper data; one inversion using only the tipper data; and the third inversion using the rotated tensor and tipper data.

In addition to these half-space models, two inversions were run using starting models based on geological constraints. One used three domain boundaries with roughness penalties turned off between units. The other starting model was subdivided into fault blocks and roughness penalties between blocks eliminated. Resulting inversions explore a larger section of model space than more typical workflows.

P047. USING DOWNHOLE RESISTIVITY TO BETTER UNDERSTAND MAGNETOTELLURIC INVERSION

Janelle Simpson[1,2] and Graham Heinson[2]*
[1]Department of Natural Resources and Mines, Geological Survey of Queensland, Brisbane, Australia
[2]The University of Adelaide, Adelaide, Australia
*janelle.simpson@dnrm.qld.gov.au

Previous studies have used downhole resistivity either as a direct constraint during magnetotelluric inversion or as a qualitative validation of inversion accuracy. This study instead uses synthetic magnetotelluric data based on downhole resistivity to better understand inversion results in the context of a depth to basement study.

One-dimensional models with representative geology for the area were generated directly from downhole resistivity data. These models were used to generate synthetic data, which was then inverted using a range of methods. The synthetic modelling made a significant contribution to selecting an appropriate inversion technique and the quality of the interpretation.

Joint use of 1D and 2D inversion proved the most effective combination to understand the geology of the project area. The synthetic modelling also enables production of realistic error bars on the interpretation.

P048. 3D AIRBORNE EM ANISOTROPIC EFFECT AND IDENTIFICATION MODELING BY SE METHOD

Xin Huang, Changchun Yin, Xiaoyue Cao, Yunhe Liu and Bo Zhang*
Jilin University
*yinchangchun@jlu.edu.cn

Spectral-element (SE) method is a kind of higher-order finite-element method based on weighted residual technique; however, the basis functions for SE are polynomial, like Gauss–Lobatto–Legendre (GLL) or Gauss–Lobatto–Chebyshev (GLC) polynomials. Because of its high modeling accuracy and flexibility, it has been successfully used in computational electromagnetism. In this paper we use the SE method for 3D frequency-domain airborne electromagnetic (AEM) modeling for an anisotropic earth and we take horizontal coplanar and vertical coaxial coil systems as example for the modeling. We first derive the discrete governing equation from Maxwell equations, in which the conductivity tensor is obtained by 3 Euler rotations of a principal conductivity tensor. GLL polynomial is selected as the vector SE basis functions, while GLL integration is applied for calculating matrix elements. A direct solver is used for the solution of the matrix equations system. The modelling accuracy is checked against a semi-analytical solution. Further, we calculate AEM responses for different anisotropic models and demonstrate that SE method can obtain high precision by either increasing SE order or refining meshes, so that it can save computation cost vastly. Numerical results further confirm that the anisotropy of both 3D body and host rock can be identified from the polar plots of ratio of magnetic field components.

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Near Surface and Groundwater

P049. TRANSCONTINENTAL CENOZOIC PALEOVALLEYS OF WESTERN AUSTRALIA

Gilles Y. Brocard, Tristan Salles, Sabin Zahirovic, Patrice Rey and Dietmar Müller*
Basin Genesis Hub, School of Geosciences, University of Sydney
*gbrocard@sydney.edu.au

Transcontinental palaeovalleys 800–2400 km long straddle the modern landscape of Western Australia (WA). These valleys formed following emergence of the Canning Basin at the end of the Lower Cretaceous, and reached their greatest development during Eocene time. They owe their preservation to limited erosion/burial and to an overall drying climate since the Upper Cretaceous. They represent the largest network of inactive valleys visible at the Earth's surface.

They connect at their downstream end to well-dated depocentres and palaeo shorelines, which provide their age and firm milestones on their temporal and spatial evolution. The geometries of the drainage network and of the valleys' long profiles constrain the timing of long (~1000 km) to intermediate wavelength (~200 km) variations in uplift rate over the continental interior since the Upper Cretaceous. We use them to document the respective contributions of regional tectonics and dynamic topography to the evolution of the Northwest Shelf. Uplift determined the shape of the drainage that initially grew over the emerging landmass. The changing uplift field later triggered drainage rearrangements during the Cenozoic. Rearrangement resulted in piecemeal rerouting of surface sediments and groundwater, with progressively increasing the area shedding to the Northwest Shelf.

Increasing aridity during the Neogene contributed to the tectonic defeat of the rivers. We use the *Badlands* software developed by the Basin Genesis Hub to quantify sediment and water delivery to the North West Shelf, and to constrain the development of aridity in the continental interior, which we find to be quite advanced by the Early Miocene.

P050. MAGNETIC IMAGING OF ULTRAMAFIC BODIES ON THE SITE OF THE OHI NUCLEAR POWER STATION, CENTRAL JAPAN

Shigeo Okuma[1], Masahiko Makino[1], Ayumu Miyakawa[1], Tadashi Nakatsuka[1], Yoshiharu Otsuka[2], Shunsuke Kudo[2], Makoto Yanagida[3], Toshinori Sasaki[4] and Tatsuji Sugimori[5]*
[1]Geological Survey of Japan, AIST
[2]Kansai Electric Power Co., Inc.
[3]Hanshin Consultants Co., LTD
[4]Central Research Institute of Electric Power Industry
[5]DIA CONSULTANTS CO., Ltd
*s.okuma@aist.go.jp

The Ohi nuclear power station is located at the northern Oshima Peninsula in the Wakasa Bay on the coast of Japan Sea, central Japan. The geology of the site of the power station is composed mainly of shales, diabases, gabbros and ultramafic rocks of the Paleozoic Yakuno Ophiolite. Ultramafic rock is a key geology since fracture zones in the study area can be found only in the ultramafic bodies.

To map the distribution of ultramafic bodies, we conducted magnetic surveys on ground and at sea around Daibahama beach. A ground magnetic survey was carried out on a grid and along specified lines on a small peninsula and some reeves by using a proton magnetometer. A seaborne magnetic survey was also conducted by a small rubber boat on which a Cesium magnetometer was mounted. Both measured data were merged and IGRF residual magnetic anomalies were reduced onto a smoothed surface at an altitude of 2.5 m above ground and above sea level at sea assuming equivalent anomalies below the observation surface.

3D magnetic imaging has been applied to the magnetic anomalies and the magnetic structure is generally associated with a dipping-dike by a previous 2D modeling. A reversely magnetised body was imaged with a seaward dip below the surface along the 2D profile but has a horizontal limitation. This means the magnetic imaging is helpful to reveal the three-dimensional subsurface structure of the area.

P051. USING HYDROGEOPHYSICAL TECHNIQUES TO CHARACTERISE AND MAP SEA WATER INTRUSION AND PREFERENTIAL FLOW PATHS IN HOWARDS EAST AQUIFER, DARWIN RURAL AREA, NORTHERN TERRITORY

Laura Gow[1], Melissa Woltmann[2], Niels B. Christensen[3], Ken Lawrie[1], Des YinFoo[2], Eamon Lai[1], Sam Buchanan[1], Martin Smith[1] and KokPiang Tan[1]*
[1]Geoscience Australia
[2]Northern Territory Department of Environment and Natural Resources
[3]Aarhus University
*melissa.woltmann@nt.gov.au

In the Howards East Aquifer (HEA) in Darwin's Rural District, groundwater resources in a dolomitic and karstic aquifer system provide important water security for Darwin and a large horticultural industry. Previously (2011), a widely spaced (550 m) regional airborne electromagnetics (AEM) survey in this area mapped conductivity anomalies that were interpreted as potential zones of seawater intrusion (SWI) coincident with major fault zones. Subsequent drilling confirmed elevated groundwater salinities in some bores marginal to the main aquifer. It was recommended that more detailed investigations be undertaken to better define the SWI risk.

The Howards East Project is an inter-disciplinary study which focussed on delineating and characterising the present SWI interface and potential future hazards from sea water intrusion. The Project is funded by Geoscience Australia (GA) as part of the Exploring for the Future (EFTF) Program. New data acquisition includes 2096 line-kilometres of 100 m line-spaced AEM and airborne magnetics data, ground magnetic resonance (GMR), and borehole nuclear magnetic resonance (NMR) data, drilling and pump testing; and hydrochemistry. The main aims of this study are to: (1) delineate potential SWI zones; (2) quantify the porosity, permeability and transmissivity of the Koolpinyah-Coomalie Dolomite aquifer along potential fault zones (coincident with magnetic anomalies) and (3) identify other structural and/or sedimentological preferential flow paths or barriers to ingress.

This paper reports on: (1) initial AEM inversion results and spatio-temporal changes in groundwater quality arising since acquisition of previous AEM in 2011; and (2) the interplay between the sea water intrusion interface and structural/sedimentological flow paths/barriers.

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Energy

P052. MIDDLE ORDOVICIAN CONODONTS AND FISH FROM THE STAIRWAY SANDSTONE, AMADEUS BASIN

Andrew Kelman and Kamal Khider*
Geoscience Australia
*andrew.kelman@ga.gov.au

The Middle Ordovician Stairway Sandstone consists of a succession of siliciclastic shallow marine sediments,

stratigraphically positioned between the dark organic-rich siltstones of the Horn Valley Siltstone, and the regressive siltstones and shales of the overlying Stokes Siltstone, in the Amadeus Basin. The Stairway Sandstone is notable for containing early arandaspid fish fossils, and is a prospective reservoir for Larapinta Petroleum System hydrocarbons. The unit has not been directly dated, but a field sample from the uppermost Stairway Sandstone has yielded an abundant and well-preserved fauna, including micro-vertebrate and conodont fossils that enable correlation to high resolution international conodont biozonation schemes. Vertebrate microfossils represent three agnathan genera, *Arandaspis*, *Porophoraspis* and *Sacabambaspis*. Conodont species include *Microzarkodina ozarkodella* and *Baltoniodus medius*; index fossils that allow correlation to the upper subzone of the *Eoplacognathus pseudoplanus* Zone of the Middle Darriwillian. The conodont fauna also includes stratigraphically wide-ranging larapintine species, as well as endemic forms and new species. The abundance of the fauna, and the presence of *Erraticodon,* indicates sea-level rise at the time of the latest Stairway Sandstone deposition. The global Stein Lowstand event, represented by a hiatus at the top of the Horn Valley Siltstone and the subsequent shallow or aeolian influence over the lower and middle parts of the Stairway Sandstone, occurs at 463.71 ma, and the top of the *E. pseudoplanus* zone occurs at 462.52 ma (GTS2016). The intervening time constrains the end depositional age of potential reservoir sands of the Stairway Sandstone, and age of the earliest Gondwana fish fauna.

P053. THE CONDUCTIVITY STRUCTURE OF THE GEORGINA-ARUNTA REGION FROM MAGNETOTELLURICS

Alison Kirkby and Jingming Duan*
Geoscience Australia
*alison.kirkby@ga.gov.au

The 09GA-GA1 deep magnetotelluric (MT) and seismic survey was collected in 2009 under Geoscience Australia (GA)'s Onshore Energy Security Program. The survey, also known as the Georgina-Arunta line, extends approximately north-south across the Georgina Basin, Irindina and Aileron provinces of the Arunta Region, across the Casey Inlier and onto the northeastern Amadeus Basin.

The MT data comprise 39 broadband stations with a spacing of 10 km, and 17 long period stations spaced 20 km apart. In 2009, the broadband data were processed to a period range of 0.04 to 100 s, while the long period data were processed to a period range of 10 to 10 000 s. Preliminary 2D inversions were carried out; however little was done in terms of geological interpretation of these inversions.

As part of GA's Exploring for the Future program commencing in late 2016, the broadband MT data have been reprocessed, giving an extended period range of 0.04 to 1000 s. The data have been merged with the long period data. The phase tensor ellipses correlate well with the mapped geology. Inversions have been carried out in 2D using the Occam inversion code, and in 3D using ModEM. The conductivity structure revealed by these inversions show consistency with the results of the deep seismic reflection survey carried out in this area, and reveal new insights into the conductivity structure of the key geological domains crossed by this survey.

P054. METAL MOBILISATION DURING WATER REACTION OF THE ROSENEATH AND MURTEREE SHALES OF THE COOPER BASIN

J. K. Pearce[1], L. Turner[1] and D. Pandey[2]*
[1]School of Earth and Environmental Sciences, University of Queensland, Australia
[2]Department of Earth Sciences, IIT Roorkee, India
*j.pearce2@uq.edu.au

Production or flow-back water from shale gas stimulation has been reported in the USA to have high salinity, TDS and variable concentrations of potentially toxic metals such as uranium, barium, or lead. A few studies have performed experiments to understand the controls on metal mobilisation from gas shale, mainly for the Marcellus shale. The Roseneath and Murteree shales of the Cooper Basin REM sequence have a high prospectively for unconventional gas. Water reactions of shale core samples were performed under mildly oxic conditions and at elevated temperature (75°C) and pressure (200 bar). The shales both contain (Mg)-siderite, quartz, illite/muscovite and kaolinite with traces of pyrite. The Roseneath shale core contained sphalerite, and the Murteree core a higher proportion of siderite and also ankerite. A relatively higher concentration of lead, vanadium, chromium, zinc and copper, was measured in the Roseneath shale, which on water reaction mobilised a higher concentration of uranium, cadmium, cobalt, chromium, zinc, copper and nickel. Mobilised metal concentrations were, however, mainly <10% of the amount available in the core. Higher concentrations of calcium and sodium were mobilised from the Murteree shale. SEM-EDS and geochemical modelling indicated that the carbonates were most reactive, with dissolution creating pores in the Roseneath shale. Fe-rich precipitates were also formed in both cases. We found the presence and type of carbonate and sulphide minerals have a strong control on water chemistry and generated acidity. This is in agreement with other studies on black shales from Germany, and the Marcellus shale, USA.

P055. DRAINED PORE MODULUS DETERMINATION USING DIGITAL ROCK TECHNOLOGY

Shakil Ahmed[1], Tobias Müller[1], Mahyar Madadi[2] and Victor Calo[2,3]*
[1]CSIRO Energy Business Unit, Kensington, WA, Australia
[2]Curtin University of Technology, Kensington, WA, Australia
[3]CSIRO Mineral Resources Business Unit, Kensington, WA, Australia
*shakil.ahmed@csiro.au

Geomechanics helps us understand the life-cycle of a hydrocarbon reservoir and, in turn, impacts geophysical monitoring programs. One common problem is to predict reservoir compaction. This estimation uses static poroelasticity parameters. We present a digital rock workflow to determine poroelastic parameters that are difficult to extract from well log or laboratory measurements. For the compaction problem, the drained pore modulus ($1/K_p$) is determinant. This modulus is the ratio of pore volume change to confining pressure when the fluid pressure is constant

$$\frac{1}{K_p} = -\frac{1}{V_{p0}} \frac{\partial V_p}{\partial p^c}\bigg|_{p^f = 0} \quad (1)$$

V_{p0} is the initial pore volume. In laboratory experiments, bulk volume changes are accurately measured while pore volume changes are notoriously difficult to measure. Hence, determining the drained pore modulus is challenging. We simulate static

deformation experiments at the pore-scale utilising digitised rock images.

We model an Ottawa F-42 sand pack obtained from X-ray micro-tomographic images. We stack 2D micro-CT images to generate the 3D F-42 sand pack sample. We extract a sub-volume from this sample to model numerically. The small sample consists of grains and pore spaces, which are segmented and used to generate a volumetric mesh. We compute the elastic, linear momentum balance in the structural domain (grains) and solve the system using the commercial software package ABAQUS. The grains are assumed elastic, isotropic, and homogeneous. We calculate the change in pore volume using an in-house post processing tool, which computes the change in pore spaces due to applied load. Finally, the drained pore modulus is obtained using equation (1).

P056. OPTIMUM IMAGE RESOLUTION OF A MICRO-CT IMAGE TO CHARACTERISE SHAPE DESCRIPTORS AND MICROSTRUCTURE OF AN UNCONSOLIDATED SAND

Zubair Ahmed and Maxim Lebedev*
[1]Department of Exploration Geophysics, Curtin University
[2]DET CRC, Australia
*Zubair.ahmed1@postgrad.curtin.edu.au

The quality of a micro-CT image and its resultant quantitative outputs are highly dependent on spatial resolution. High resolution images of an unconsolidated sands, which are common reservoirs for petroleum and groundwater, capture the outer voxels of the grains in so much detail that they can provide accurate shape characteristics such as sphericity and roundness. However, in the high resolution images, the trade-off is the number of imaged grains, as the numbers might be too small to be representative of the whole volume. To get an acceptable result from micro-CT images without compromising the representativeness of the sample, we need to determine an optimal resolution on the basis of grain size distribution and shape complexity prior to image acquisition.

Comparing grain shape characteristics in the same sample at a different resolution, we find that the sphericity and the roundness show lower and higher values respectively. Moreover, other microstructural properties such as coordination number and contact surface area show lower values. The number of boundary voxels that delineate the grains' perimeter is responsible for this difference in results. To mitigate this discrepancy in choosing a standard result, we are studying sand particles with different sizes and shapes captured at a range of resolutions. Our goal is to get the optimal resolution of an image with respect to any particular grain size, shape and microstructural properties. This optimum image resolution can help acquiring images with appropriate resolution to study reservoir characterisation from micro-CT image analysis.

P057. COUPLED MEASUREMENTS OF HYDRAULIC PERMEABILITY AND FULL STIFFNESS TENSOR COMPACTION TRENDS IN ARTIFICIAL SHALES

R. Beloborodov[1], M. Pervukhina[2] and M. Lebedev[1]*
[1]Curtin University, Perth, Australia
[2]CSIRO Energy, Perth, Australia
*Roman.Beloborodov@postgrad.curtin.edu.au

The knowledge of compaction trends of elastic and hydraulic properties of anisotropic shales is crucial for energy resources exploration, nuclear waste disposal and hydrogeological applications. However, complexity of the natural shale mineralogy and shortage of quality data available for analysis results in lack of understanding of these compaction trends.

This deficiency was to some extent compensated with compaction experiments on artificial shales. However, these experiments usually limited to measurements of compressional and shear velocities normal to bedding. Here for the first time we present methodology and describe a setup that allows simultaneous acquisition of all five independent elastic constants and extremely low hydraulic permeability values of transversely isotropic artificial shale samples during mechanical compaction experiments (porosity ranges from 40% to 15%).

Hydraulic permeability values of artificially compacted samples are comparable to those of natural shales. Permeability drops exponentially with compaction. Silt fraction and clay mineralogy are the two key parameters that are responsible for broad variations of permeability in shales with the same porosity. We provide analytical equations that allow calculating permeability if porosity and silt fraction are known.

Elastic constants of clay matrix exhibit positive linear trends with the porosity decrease. Small variations in clay mineralogy have a minor effect on absolute values of elastic coefficients or anisotropy but lead to noticeable increase of the compressional (V_p) to shear (V_s) velocities ratio at the same porosity. Finally, strong correlations (R^2 above 0.95) of the hydraulic permeability with acoustic impedance and V_p/V_s ratio are observed for all the prepared samples.

P058. A COMPARISON OF CONVENTIONAL BOREHOLE TOOLS AND DISTRIBUTED ACOUSTIC SENSING AT A DEDICATED FIELD LABORATORY

Julia Correa, Tim Dean, Layne Van Zaanen, Konstantin Tertyshnikov, Roman Pevzner and Andrej Bona*
Curtin University
*julia.correa@postgrad.curtin.edu.au

Distributed Acoustic Sensing (DAS) uses standard telecom fibre optic cables to detect acoustic signals. The technique utilises optical time-domain reflectometry; a 'light-box' measures the light backscattered from a series of laser pulses emitted into the fibre. As acoustic waves impinge on the cable, the fibre is strained, causing variations in the time taken for the backscattered light to travel back up the fibre. The acoustic signal can then be reconstructed by analysing phase differences in the backscattered light. DAS is especially suited for VSP applications, as it offers significant efficiency advantages when compared to conventional borehole acoustic sensors. Conventional VSP surveys usually take an extended period to acquire as the tools need to be placed in multiple positions in the well to record data. With DAS, the complete fibre is a sensor, and thus all levels are acquired simultaneously, and no tools are required, reducing the cost considerably. In this work, we compare the results of acquiring a VSP survey using three difference sensors: DAS, a conventional 3-component geophone tool, and a conventional hydrophone tool. The datasets were acquired in a 900 m deep, vertical well, located on the campus of Curtin University in Perth, Western Australia. Results show that DAS approached the quality of a conventional geophone VSP survey, and presented superior quality when compared to hydrophones.

Downhole Assay: A game changer for the mining industry

Huw Rossiter (Kinetic Logging Services), Vincent Flahaut (Sodern)

From exploration to mining, quantifying grade and tonnage of the mineral resource requires an enormous effort. Collection of geochemical data is achieved by drilling to sample the ore body. This generates a huge amount of samples, and significant costs and time in preparation and assay. A new technology to the mining industry – The FastGrade™ Pulsed Fast & Thermal Neutron Activation (PFTNA) has been proven to have several advantages over conventional sample based assays including improving safety through reduced site exposure to manual handling, the measurement size of the sample, depth accuracy, cost, and reducing the cycle time for results from up to months to almost immediately once the hole has been logged with the tool.

Figure 1. The FastGrade™ being run in hole

Introduction

Currently 100mm diameter tools are primarily run in iron ore where the tools are being used to log in excess of 150km / year. One major resource company has stated that the tool has saved them in excess of USD 10 million in a year. The main elements measured for iron ore are shown in figure 2. The chart shows typical results compared against 3m sampled reverse circulation (RC) holes assay data (column 2) across the range of values (columns 3 and 4)

	RMSD Validation 3 m	Min%	Max%
Fe	2	0	70
SiO2	2,5	0	90
Al2O3	1	0	35
TiO2	0,1	0	4
Mn	0,2	0	10
MgO	0,5	0	30
CaO	0,5	0	60
S	0,1	0	15
K2O3	0,15	0	10
Na2O	0,02	0	1
C	0,2	0	15
O	1	30	60
H	0,15	0	3
LOI	1,5	0	50
P	Not representative		

Figure 2: FastGrade™ vs RC sample assays

Minor elements can also be measured depending on ore grade – these include some of the base metals such as Cu or Ni, and also elements such as potassium and chlorine. The FastGrade™ is currently being scheduled to be demonstrated in a selection of base metal deposits that will show how the tool can provide value across a wide resource base.

A key component of the tool is the pulse neutron generator. In contrast to a chemical source used in conventional neutron and density logging tools, without power the tool does not produce radiation. This removes the risks associated with exposure at surface and mining issues in the unlikely event that the tool is lost in hole.

Measurement Theory

The FastGrade™ technology uses an electronic pulse neutron generator source to emit neutrons that penetrate the surrounding rock and lose their energy when colliding with nuclei. As they penetrate, they initiate interactions according to the formation, as fast inelastic collisions or neutron capture that result, nearly instantaneously, in the emission of gamma photons. Each element produces photons with a set of characteristic energies, which is the key to identifying and

quantifying them. A high resolution, scintillating material coupled with a photomultiplier converts the photons into electrical pulses and a fast processing, specialized circuit digitizer sorts and counts them to build their spectrum.

At this point a computer can extract element footprints out of the spectrum to determine the chemistry of the formation.

Figure 3: SODERN sealed Neutron Tube

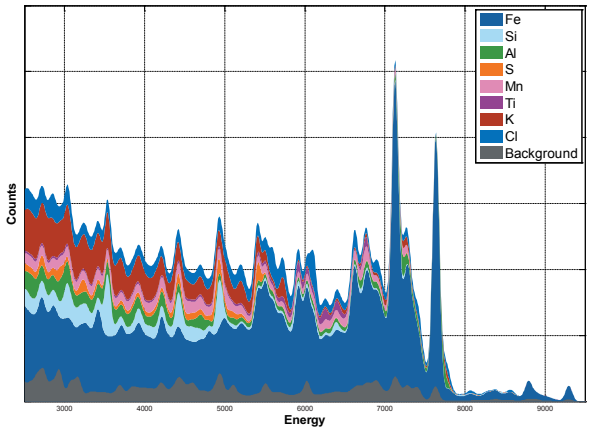

Figure 4: FastGrade™ Spectrum & individual elemental response

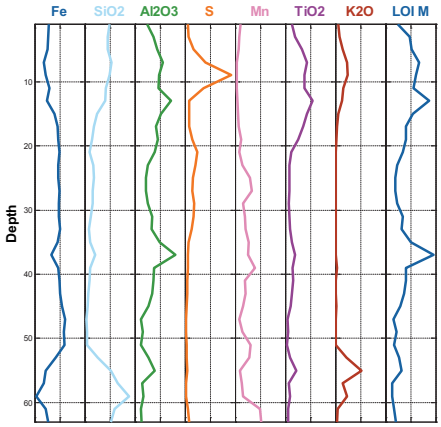

Figure 5: Multi elemental log

Measurement accuracy compared to conventional sampling

Using the FastGrade™ technology is fundamentally different to collecting a physical sample and sending it to the laboratory, and whilst there are limitations around the ability to accurately measure elements present in very small quantities the method of gathering data through this technique has many advantages when compared to physical samples gathered through the drilling process. These include:

- Accurate depth of sampling.
- No lost zones of data.
- No sample contamination.
- No damage to samples on surface.
- Almost immediate return of results.
- A large sample volume provided through the 30 – 50cm radius of investigation.
- The preservation of the natural profile variability when heterogeneous deposits are explored.

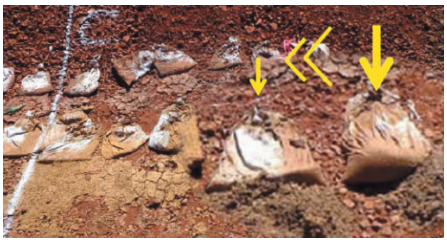

Figure 6. Damaged sample bags

Figure 7. Missing core

In figure 8, the accuracy of data from blasthole, RC and diamond drilling is shown versus the Fastgrade™ technology. It highlights the inherent accuracy deficiencies associated with the different methods of gathering physical samples. Whilst it can be seen that samples derived from diamond core drilling are superior to both RC and blasthole samples the method is still liable to core loss and the cost of diamond core drilling limits the amount of sampling that can be done within budget constraints. Therefore Fastgrade™ has the potential to replace all of these methods with a more cost effective, quicker and accurate way of gathering assay information in the correct geological environment.

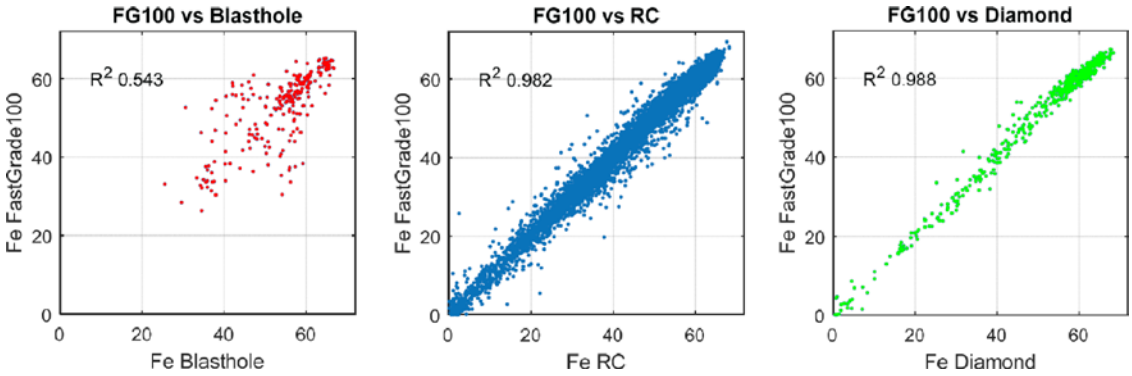

Figure 8. A comparison of FastGrade™ Fe% vs assay data from Blasthole, RC drilling and diamond drilling samples (Chi *et al.*, 2017).

RC drilling is often used in preference to diamond drilling due to the cost differential between the two techniques. Diamond drilled twinned holes drilled within 10m of an RC hole are commonly used to verify mineralisation identified by RC samples. The data is used to assess whether there is any sampling bias in the RC sampling technique (Chi *et al.*, 2017).

Figure 9, shows this technique can be flawed as the comparison of the data assumes the geometry of the geology is flat lying with consistent thickness, and that the inherent errors associated with both techniques are comparable.

In deposits where it is suitable, the use of the Fastgrade™ technology as an alternative to RC sampling would improve the accuracy of the data from the parent hole and remove the requirement for expensive twin hole drilling campaigns.

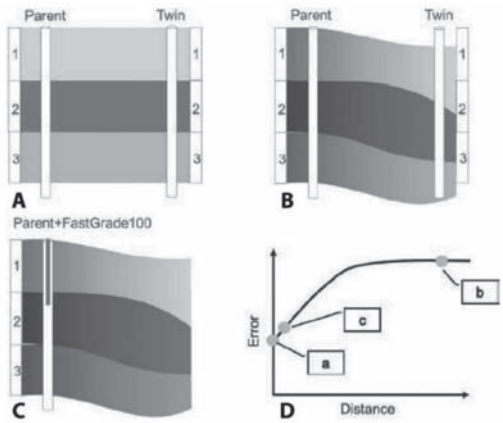

Figure 9. Flaw in twin hole pairing technique: (A) is the assumed case; (B) is a more realistic RC – diamond drilling case; (C) is the twinning case with a FastGrade™ tool under the same realistic conditions as (B); (D) demonstrates these concepts on a schematic semi-variogram type plot where we can see that as the distance between pairs increase, the error increase due to change in geometry and grade variability (Chi *et al.*, 2017)

Figure 10 shows how improving orebody knowledge through the use of Fastgrade™ to reduce the errors associated with sampling, can have major impacts on mining operations. The example which is based in an iron ore environment shows that reducing error associated with the grade assessment from 3% to 1% can have a significant impact on ore recovery.

The decrease in error leads to a reduction in stripping ratio and loss of ore, increasing the amount of ore that can be sold. This has the added benefit of reducing the environmental impact during operations through the reduction of waste at the minesite.

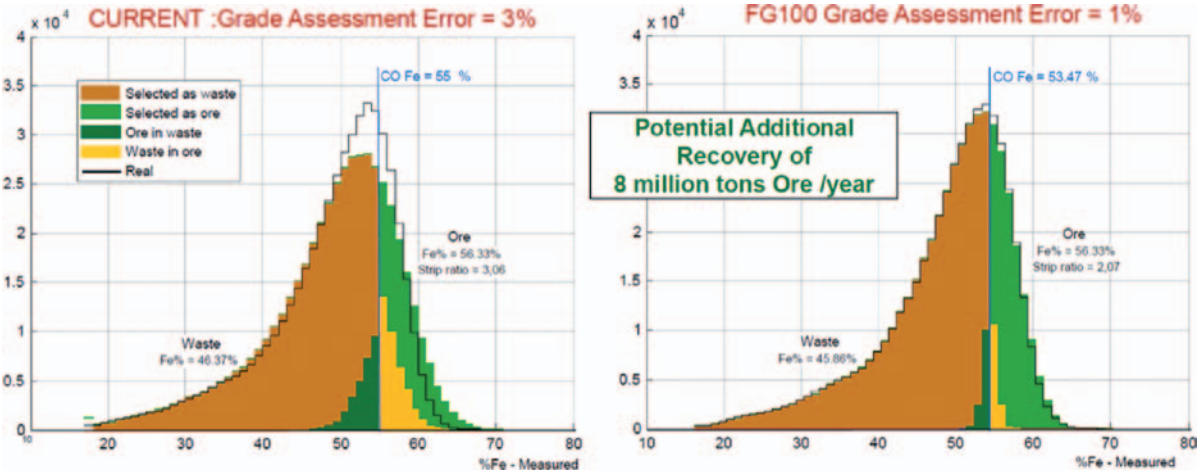

Figure 10. Showing how decreasing grade assessment error can lead to potential increased ore recovery

For more information please contact; Huw Rossiter, huw.rossiter@kinetic.group +61 8 9452 6800 013 or Vincent Flahaut, vincent.flahaut@sodern.fr +33 1 45 95 70 38

Reference:

Chi, B. *et al.* (2017) 'Near real-time assay with downhole assay tool (FastGrade™ 100)', in *Eighth World Conference on Sampling and Blending*. Perth: AUSIMM, pp. 137–144.

P059. CARBON ISOTOPE FINGERPRINTING PALAEO FLUID INCLUSION GASES USING A CRUSHING-TRAPPING TECHNIQUE

Se Gong, Stephen Sestak, Armand Stephane and Tania Vergara*
CSIRO Energy
*Se.Gong@csiro.au

Carbon isotope fingerprinting has been widely used to study gas origin and maturity, and gas-source correlations. However, natural gas accumulation in gas reservoirs could be affected by secondary alteration processes. In contrast, palaeo gases trapped in fluid inclusions (FIs) are free of any secondary alterations that may have occurred in the reservoir. It can also provide more gas geochemistry information in an area where no or little geochemistry data is available due to a low exploration degree.

FIs are formed when crystals grow, usually trapping fluids such as oil, gas or water. FIs are normally less than 10 um in diameter, hence the gases trapped are at trace level amounts. Due to the analytical challenges involved in obtaining carbon isotopic signatures from such trace levels of gases trapped in FIs, very few papers have been published regarding carbon isotopes of FI gases. An online crushing-trapping system has been developed in this study, which mainly comprises of a gas-tight crusher and a gas concentrator. The micro-trap is the key aspect of the gas concentrator, which results in sharp chromatographic peaks, enabling carbon isotope analyses of high molecular weight hydrocarbon gases which are normally in low concentrations.

Compound specific carbon isotope analysis of hydrocarbon gases (C_1-C_5 except nC_4) and CO_2 released from a FI sample from the Cooper-Eromanga Basin was achieved for the first time as a proof of concept of the technique. Subsequently, preliminary research on FI gases have been carried out in Australia's Browse Basin and China's Sichuan and Pearl River Mouth Basins.

P060. INTEGRATED EARTH DATA INTERPRETATION WORKFLOW – A RECIPE FOR SUCCESS IN ONSHORE FRONTIER HYDROCARBON EXPLORATION

*Lance Holmes**
Santos Ltd
*lance.holmes@santos.com

The interior of Australia plays host to a series of vast sedimentary basins spanning c. 2.5 billion years of the island continent's geological history. Many of these basins contain significant reserves of both conventional and unconventional hydrocarbons. In addition to being active offshore, Santos Ltd has a long history of hydrocarbon exploration (generally as Operator) in several of the onshore basins, which notably include the Bowen, Gunnedah, Cooper, Amadeus and McArthur Basins. Frontier exploration involves various regional geological studies, these being geared towards deriving an early assessment of hydrocarbon potential and directing the geographical focus of future exploration work. Due to the general lack of data in the early exploration phase, much effort is expended in maximising the interrogation and understanding of all available open source and proprietary datasets. These typically include surface geology, surface elevation, surface vegetation, Landsat, gravity, magnetics, radiometry, existing seismic and existing boreholes (including water bores). The key to extracting every ounce of useful geological information from these data is through data integration and co-visualisation. To this end, Santos has developed a tried-and-tested regional exploration workflow, which often involves some novel visualisation techniques (e.g. use of 3D anaglyphs). This presentation will include discussion of basic workflows, the various data types and principles of data integration and interpretation, illustrated with numerous real-world examples from Santos' extensive exploration experience in several of the aforementioned basins.

P061. VOLCANICS: A COMMONLY UNDERESTIMATED PART OF PETROLEUM EXPLORATION

Mosayeb Khademi Zahedi[1] and Shona Macdonald[2]*
[1]Rocca Energy
[2]Independent Geoscience Consultant
*m.khademi@roccaenergy.com.au

The presence of volcanics and their impact on sedimentary rocks may lead to complex overprints for oil and gas exploration. They can provide both positive and negative effects on the petroleum system.

Positively, impermeable volcanic rocks can act as a barrier, or seal, to lateral or vertical hydrocarbon migration. Alternatively, volcanics with some permeability can serve as reservoirs. Negatively, circulating hot fluids, in the presence of organic rich source rocks, or where hydrocarbons are accumulated in traps, lead to unsuccessful wells.

It is therefore important to understand the origin of the volcanics as well as their timing with respect to hydrocarbon generation and migration from source rocks, and reservoir traps.

In the North-West Shelf (NWS) of Australia, volcanics are quite common and some wells have penetrated them by hundreds of metres. 3D seismic images of these features can dramatically demonstrate their morphology including features like ring dyke complexes.

Sometimes the interpreter is lucky and they are simple and easy to interpret on seismic data, however it's not always the case. The visibility of volcanics in seismic data depends on their acoustic impedance contrast in comparison to the sedimentary layers. If this contrast is not high enough (such as when the volcanics are highly weathered), then it's a challenge to map their spatial extent.

The presence of volcanics is documented by several operators including Woodside and Inpex at NWS: Anhalt-1 penetrated volcanics at its TD and cutting descriptions from Dinichthys North-1 indicates the presence of volcanic material, as another example.

P063. ANALYSIS ON BRITTLENESS CHARACTERISTICS OF TIGHT OIL SILTSTONES

Wenhui Tan[1], Jing Ba[1], Haibo Zhao[2], Gang Fang[3], Wei Qian[1], Hao Chen[4], Ting Yu[1] and Chunfang Wu[1]*
[1]Hohai University
[2]Exploration and Development Research Institute of Daqing Oilfield Company Ltd
[3]Qingdao Institute of Marine Geology
[4]State Key Laboratory of Acoustics, Institute of Acoustics, Chinese Academy of Sciences
*guomq@hhu.edu.cn

We obtain the basic parameters of the rocks of Qingshankou Formation by performing rock uniaxial and triaxial compression mechanics experiments. Different brittleness indexes are

computed and we select the best brittleness index of $B2$ (E/υ, Young's modulus/Poisson's ratio) to evaluate rock brittleness characteristics. The coefficient of brittle stress drop is introduced to evaluate rock brittleness characteristics, which coincide with the selected brittleness index. The relationships between brittleness indexes and rock parameters such as elastic parameters, mineral components and reservoir physical properties (porosity, and density) are analysed. Results show that E and υ are the good indicators of rock brittleness, while shale content has no obviously influence on the elastic parameters. Quartz and carbonate minerals are considered as brittle components for evaluating rock brittleness. There is a good correlation between the brittleness index $B2$ and reservoir porosity, which is important for analysing rock brittleness characteristics in the study area.

P064. FULL SPECTRUM GRAVITY – HIGH QUALITY GRAVITY DATA FOR ALL APPLICATIONS

Chris van Galder, Mark Dransfield and Tianyou Chen*
CGG Multi-Physics
*christopher.vangalder@cgg.com

Over the last two years, CGG has introduced the Full Spectrum Gravity initiative. This merges the short to medium wavelength data from the Falcon Airborne Gravity Gradiometer (AGG) system and the medium to long wavelength data from the sGrav strap-down gravimeter. These complementary technologies allow for the delivery of sub-milliGal gravity data at resolutions from hundreds of meters up to hundreds of kilometers.

In this work, we demonstrate the acquisition and processing methods involved in Full Spectrum Gravity and the accuracy of the final data product. The long wavelength data is required first. The sGrav is used to create a free air anomaly gravity product. The accuracy of the data at various filter lengths (15–30 km) is evaluated to determine the optimal merging spatial wavelength for the sGrav and Falcon datasets. Using the sGrav data, free air anomaly differential curvature components are created.

Using the optimal wavelength as the cut-off frequency, a low-pass filter is designed to be applied to the sGrav curvature gradients and a high-pass filter is designed to be applied to the Falcon AGG curvature gradients. By combining these together, we create the Full Spectrum Gravity dataset.

In conclusion, we demonstrate the acquisition technologies and the processing methods to create the Full Spectrum Gravity data and demonstrate that it achieves sub-milliGal accuracy across the largest bandwidth of the gravity spectrum.

P065. A CLOUD-BASED WELL LOG DATABASE PROTOTYPE

Chitra Viswanathanr, Irina Emelyanov, Ben Clennell, Stacey Maslin and Jon Kelly*
CSIRO
*chitra.viswanathan@csiro.au

Geoscience data including seismic, well log, sensor and core measurements are fundamental for petroleum exploration. Due to recent advancements in sensor and computer technologies, the volume of this data is constantly increasing. Having a unified repository of this data of various types, structure and complexity is crucial for maintaining data integrity. This study addresses petroleum exploration data integrity issues. Current trends in data management technologies and current data practices in petroleum geoscience are explored and a practical data management solution to facilitate data access, storage and sharing is recommended. A prototype of a well log database was developed to demonstrate an example of a common repository for downloaded and sanitised data to avoid duplicate downloads from public websites by petrophysicists and make data use more efficient within a particular organisation. The prototype was developed using cloud-based technology and the PAWSEY supercomputing facility (a joint venture of CSIRO with Western Australian universities) for storing both the raw (.las and .DLIS files) and the sanitised well log datasets from Bonaparte Basin. PostgreSQL database was used to store the sanitised well log data, metadata and links to raw data. PostgreSQL architecture was selected for its ability to support advanced data types (arrays, JSON etc.), plug in to languages like Python, and link to PostGIS, a spatial database extender. A web-based graphical user interface was developed to view, upload and download well log data. In addition, meaningful metadata standards were established in collaboration with expert petrophysicists.

P066. EXPERIMENTAL AND THEORETICAL STUDY OF WATER RETENTION EFFECT ON ELASTIC PROPERTIES OF OPALINUS SHALE

Alexey Yurikov[1], Maxim Lebedev[1], Marina Pervukhina[2] and Boris Gurevich[1]*
[1]Curtin University
[2]CSIRO Energy
*alexey.yurikov@postgrad.curtin.edu.au

Understanding the elastic properties behavior of shales with saturation changes is important for the geological storage of nuclear waste and CO_2 sequestration as well as for development of conventional and unconventional shale oil and gas reservoirs. Existing data describing the effects of saturation on elastic properties of shales are sparse and contradictory. To improve understanding of the effects of changing water content on elastic properties in shales, we conducted an experimental study on Opalinus shale samples.

We measured vertical and horizontal ultrasonic P- and S-wave velocities on the same set of samples with controlled water content. The measured velocities were used to calculate components of elastic stiffness tensors in the shale at different saturations assuming its vertical transverse isotropy. Obtained results show increasing C_{11} and decreasing C_{33} with drying of the samples. Moreover, we observe 80% increase of shear moduli C_{44} and C_{66} with reduction of water content from 5.5% weight in the preserved state to 0.3%.

Conventional rock physics models are not designed to explain the observed dynamics. Here we develop a rock physics model suitable to describe these effects that takes into account (1) mechanical softening of the rock with substitution of saturating water with gas; (2) shrinkage of clay leading to reduction of microporosity and opening of interlayer fractures; (3) chemical hardening of clay particles; and (4) enhancing stiffness of contacts due to removing of water lubricant between clay particles.

P067. TIME-LAPSE SURFACE SEISMIC PROCESSING FOR STAGE 2C OF CO2CRC OTWAY PROJECT

D. Popik[1]*, *V. Shulakova*[2], *K. Tertyshnikov*[1], *S. Ziramov*[1], *M. Urosevic*[1] *and R. Pevzner*[1]
[1]Curtin University
[2]CSIRO
*Dmitry.Popik@postgrad.curtin.edu.au

Stage 2C of the Otway project aims to establish capabilities of economic and effective seismic monitoring of geological storage of CO_2. Over the past two years, we produced five vintages of high-quality 4D seismic images of the injected CO_2 plume. We have also built reference 4D synthetics that are used to validate workflows used in the processing of the field data. These tested workflows allow rapid time processing of the time-lapse data and allow fast monitoring of small incremental injections (about 5000 tonnes each) of a CO_2-rich mixture into a saline aquifer at ~1500 m depth. The results show plume stabilisation one year after injection has finished. The quality of the field data and obtained images suggests that these data can be processed in 'true amplitude' sense. Onshore time-lapse processing is a difficult task that requires good understanding of how processing routines affect time-lapse signal. Using model-guided approach to processing, we now address issues of amplitude restoration, prestack imaging, and cross-equalisation of the 4D seismic data acquired with a permanent geophone array during Stage 2C.

P068. THE SEISMIC SIGNATURE OF RAIN

*Tim Dean**
Curtin University
*tim.dean@curtin.edu.au

Rain has long been a problem for land seismic surveys. I measured the seismic signature of rainfall using both water dripped from height using a pipette, and natural rain in Winchester, England, over a three month period. My results showed that rain noise is concentrated at frequencies above 80 Hz with a detectable range of less than 1 m. Drops of water landing directly on a geophone result in events with amplitudes nearly 30 times larger than those landing next to the geophone. Items placed on the surface of the ground, such as cables, absorb the energy of the impact and reduce the level of the resulting seismic noise. Burying geophones results in attenuation of rain noise by between 7.7 and 8.6 dB/0.1 m. But, given the effort required to bury geophones, it is likely that data processing algorithms, or the placement of vibration absorbent matting, are likely to be the preferred strategies for dealing with noise.

P069. NOISE IN URBAN LAND SEISMIC SURVEYS

Tim Dean and Mus'ab Al Hasani*
Curtin University
*tim.dean@curtin.edu.au

Although most frequently conducted in remote areas, seismic surveys in urban areas, or other settings with high seismic noise levels, are becoming increasingly common. Examples of the most frequent sources of noise encountered in such settings include electrical installations, vehicles, the wind, and aircraft. In this paper we describe the results of a variety of experiments conducted that aim to characterise the nature of the different noise sources and their relative contribution to the overall noise level. We then describe the effectiveness of a range of noise mitigation measures and develop recommendations for seismic surveys conducted in urban environments.

P070. SEISMIC SIGNATURES OF FRACTURED RESERVOIRS: THEORY VERSUS NUMERICAL SIMULATIONS

Junxin Guo[1]*, *Stanislav Glubokovskikh*[1], *Boris Gurevich*[1,2] *and J. Germán Rubino*[3]
[1]Curtin University, GPO Box U1987, Perth, Western Australia
[2]CSIRO, Perth, Western Australia
[3]CONICET, Centro Atómico Bariloche – CNEA, San Carlos de Bariloche, Argentina
*junxin.guo@postgrad.curtin.edu.au

Seismic dispersion and attenuation are potentially important attributes for the detection and characterisation of fracture networks. A primary mechanism for these phenomena is wave-induced fluid flow (WIFF), which can take place between fractures and the embedding background, as well as within connected fractures. In this work, we propose a theoretical approach to quantify the related seismic attenuation and velocity dispersion for rocks containing two orthogonal sets of fractures. The approach is based on existing theoretical models for rocks with aligned fractures, and we consider three types of fracture geometries: periodic planar fractures, randomly-spaced planar fractures, and penny-shaped cracks. Synthetic 2D rock samples with non-intersecting and intersecting fractures are then studied by both numerical simulations and the proposed theoretical framework. The numerical simulations are carried out using an upscaling method based on Biot's quasi-static equations of poroelasticity. The results show that the theoretical predictions are in overall good agreement with the numerical simulations. For the seismic dispersion and attenuation caused by WIFF between fractures and the background, the theoretical model for penny-shaped cracks matches the numerical simulation results best. On the other hand, for representing the effects caused by WIFF within connected fractures, the theoretical model for periodic planar fractures turns out to be the most suitable. The proposed theoretical approach is easy to apply in practice, and is applicable not only to 2D but also to 3D fracture system. Hence, it has the potential to constitute a useful framework for the characterisation of fractured formations, especially in the presence of intersecting fractures.

P071. 3D INVERSION OF LARGE SCALE MARINE CONTROLLED-SOURCE ELECTROMAGNETICS

Eldad Haber[1]*, *Christoph Schwarzbach*[2], *Dave Marchant*[2] *and Mike McMillian*[2]
[1]University of British Columbia
[2]Computational Geosciences Inc.
*haber@math.ubc.ca

Three-dimensional controlled-source electromagnetic (CSEM) surveys can be a useful technique for oil and gas hydrate detection in marine environments. Electromagnetic waves are emitted from sources, and the ensuing electric and/or magnetic fields are recorded at one, or more receivers. The number, frequency and position of sources and the placement of receivers depends on the particular application. To recover the earth's conductivity, which can be either isotropic or anisotropic in nature, an inverse problem is solved.

A major issue with either an isotropic or anisotropic CSEM inversion is the computational cost associated with the solution of many linear systems of equations. This is a result of a large spatial domain with the potential presence of complicated bathymetry, as well as the existence of thousands of source and frequency combinations. Overall, there could be thousands or even millions of systems of equations to solve on expansive meshes. To assist with these numerical issues, we use ideas developed for airborne electromagnetic inversions. First, we incorporate a locally refined mesh for the forward problem, specifically optimised for a source and set of receivers. Second, we use stochastic programming techniques to solve the CSEM problem with many sources and receivers. These methods dramatically reduce the numerical cost of each forward model as well as the total number of simulations.

In this work we describe the methods used to overcome the computational difficulties and then demonstrate the techniques applied to field data sets.

P072. THE IMPACT OF WATER SATURATION ON THE ELASTIC ANISOTROPY DISPERSION IN THE WELLINGTON SHALE AT SEISMIC FREQUENCIES

Vassili Mikhaltsevitch, Maxim Lebedev and Boris Gurevich*
Curtin University
*M.Lebedev@curtin.edu.au

The anisotropic behavior of shales is commonly associated with the properties of a transversely isotropic (TI) medium, which are determined by five elastic constants such as five independent components of the compliance or stiffness matrix. In this study we utilise the laboratory low-frequency technique based on stress-strain relationship to measure the dispersion of five independent stiffness tensor components and Thomsen's anisotropy parameters of shale samples saturated with water at four different humidities in the range from 12% to 97.5% (12, 44, 72 and 97.5%). We have investigated three shale samples from the Wellington Formation cored along the horizontal, vertical and 45°-inclination directions with respect to the bedding plane at seismic frequencies between 0.1 Hz and 100 Hz.

The obtained experimental data show an increased softening of the samples, which manifests itself in reduction of the TI Young's moduli and Thomsen's parameters of elastic anisotropy ε and γ, no noticeable changes in parameter δ were found. We also found large reductions in normal and shear stiffness tensor components with saturation. When the samples were saturated at a relative humidity of 97.5%, the softening at the higher frequencies was partly compensated by the modulus dispersion.

We presume that the weakening of the elastic moduli and components of the stiffness tensor is caused by the significant percentage of water-swellable smectite in the Wellington shale.

P073. EFFECT OF AMPLITUTE ON WAVE PROPAGATION

Nazanin Nourifard and Maxim Lebedev*
Department of Exploration Geophysics, Curtin University
*Nazanin.nourifard@postgrad.curtin.edu.au

It is common to use ultrasonic techniques to measure elastic properties of porous media. However, conventional methods are unable to measure local strain in ultrasonic waves, and changes in velocity due to the different amplitudes. To fill this gap, in this work we, (1) measured the particle displacement using Laser Doppler Interferometry (LDI) and (2) measured changes of P-wave velocities with wave amplitude for pure elastic (aluminum), viscoelastic (Polymethyl methacrylate), and granular media (Gosford sandstone). We checked this phenomena using a conventional ultrasonic receiver and linked this changes to local strain in wave. The study indicated that for elastoplastic material local strain in wave increases from $7.2*10^{-6}$ to $1.9*10^{-5}$ for changing the voltage between 100 to 400 volts and the velocity increases by 0.85% for same sequences. The presented technique generates pulses by a conventional transducer and has a laser beam receiver. The main advantage of this approach is monitoring small changes of 0.03 mm^2 in particle size on the surface of the sample, which enables precise measurements of directional properties along with the different amplitudes.

P074. FORWARD AND INVERSION MODELLING OF THE ULTRASONIC WAVE IN A HOMOGENEOUS MEDIUM USING P-WAVE TRANSDUCERS

Michel M. Nzikou, Alexey Yurikov, Mahyar Madadi, Maxim Lebedev and Boris Gurevich*
Curtin University
*michel.nzikouma@postgrad.curtin.edu.au

Elastic properties of rocks are usually obtained from ultrasonic measurements using first break travel time picking or correlation approaches. The presence of factors such as boundary reflections, unwanted noise, and velocity dispersion can affect the estimates of elastic parameters from these methods, particularly when using shear wave arrivals. The problem becomes sophisticated in a viscoelastic medium. One way to improve the robustness of the interpretation is to use inversion of the entire wave train.

To this end, we build a robust forward and inversion model of the displacement waveforms using ultrasonic P/S-wave transducers which matches the experimental data. ABAQUS finite modelling software is used to estimate Poisson's ratio and Young's modulus of a homogeneous medium.

One challenge is to accurately represent the input displacement field emitted by the source transducer. We show that the measured displacement waveforms can be modelled assuming that the normal displacement is uniformly distributed over the entire surface of the transducer. In addition, we develop an inversion algorithm with python modules to search iteratively the elastic parameters. We show that to best model the elastic parameters, a minimum difference threshold can affect the results and has to be carefully selected. The results of both forward and inversion modelling show a great consistency with the experimental measurements. These results provide a new modelling workflow to estimate the elastic parameters of homogeneous and isotropic sample challenging traditional assumptions.

P075. PERMEABILITY AND SEISMIC-FREQUENCY ELASTICITY OF CRACKED GLASS

Abdulwaheed Ògúnsàmì, Yang Li and Ian Jackson*
Research School of Earth Sciences, Australian National University, Canberra, Australia
*abdulwaheed.ogunsami@anu.edu.au

Elastic properties of fluid-saturated crustal reservoirs are of key interest in exploration and production geophysics where the

role of cracks and pores on seismic properties is increasingly receiving more attention due to increasing economic significance of efficient seismic characterisation and time-lapse monitoring of crustal reservoir rocks in various contexts. These include petroleum production, geothermal energy production, carbon dioxide sequestration and efficiency of nuclear waste repositories. On a set of thermally cracked synthetic glass specimens - as simplified proxies for crustal rocks, *in situ* permeability and low frequency forced-oscillation measurements are being undertaken to investigate frequency-dependent seismic properties of a cracked media. We address some of the outstanding issues from a prior intensive study across a wide range of frequencies. Our preliminary results demonstrate the potential of improved methods for the measurement of the very low permeabilities of such cracked glass media, the feasibility of torsional forced oscillation measurements at longer oscillation periods and lower differential pressures, and the benefits of improved alignment of our specimen assembly for complementary flexural oscillation tests.

P076. INTERPRETATION USING EXPLICITLY ENCODED PHASE, AMPLITUDE AND FAULT DATA

Jacob Smith, Rachael Moore and Adrien Bisset*
GeoTeric
*jacob.smith@geoteric.com

Current horizon interpretation techniques are based primarily on the use of seismic reflectivity. While there have been robust algorithms developed to work with seismic data, there are limitations and trade-offs with each of these approaches.

In this presentation we investigate the merits of interpretation based on the use of a colour blend comprised of phase, amplitude and fault datasets. The colour blend used in this workflow is a Hue-Saturation-Value (HSV) blend. In this blend the hue/colour is controlled by the instantaneous phase, the saturation is controlled by the amplitude, and the value/blackness is controlled by a fault detect volume.

Combining these three datasets provides a greater level of explicit information when interpreting an event. In standard cases this information can be inferred by the interpreter using secondary attribute volumes, or an autotracking algorithm performing extra calculations in the background. However, both of these approaches add extra overhead to the work being performed, reducing efficiency. Explicitly encoding phase, amplitude and fault information allows:

- reduced incidence of cycle skipping,
- the ability to pick on a particular phase angle,
- honouring of faults in autotracking,
- increased visual information in manual interpretation.

These points will be reviewed through the interpretation of a number of 3D seismic datasets, with varying data quality and covering a range of geological settings.

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P077. BOREHOLE MEASUREMENTS WITHIN HIGHLY MAGNETIC BODIES – CORRECTIONS OF MEASURED MAGNETIC FIELDS AND GRADIENTS

*David A. Clark**
CSIRO Manufacturing and CSIRO Minerals
*David.Clark@csiro.au

Inside a magnetic body the magnetic field and gradients are modified by the self-demagnetising field and its gradients. For a homogeneous ellipsoidal body in a uniform applied field, the self-demagnetising field is uniform. However, a non-uniform applied field, due to external sources, results in internal field gradients and a non-uniform magnetisation. The perturbation of the internal gradient tensor components due to self-demagnetisation is shape-dependent, but differs from the effects of self-demagnetisation on field components. Non-ellipsoidal bodies and inhomogeneous bodies produce non-uniform demagnetising fields, i.e. they modify the applied gradient, particularly near edges, vertices, and surface irregularities, or in zones of rapidly changing properties. This paper gives explicit expressions for the internal field and gradient components for a layered earth, a dipping sheet, a sphere and a cylinder, that are exposed to an external field with a uniform gradient.

The internal field and gradient components cannot be measured directly, as magnetic sensors must be placed within a cavity in the magnetic medium. This modifies the measured field and gradients. For low to moderate susceptibilities, the cavity effect can be calculated assuming that the magnetisation of the surrounding medium is essentially unperturbed by the presence of the cavity. However this assumption is unacceptable when the surrounding medium has high susceptibility. This paper gives expressions that allow the true field and gradient components within a high susceptibility body to be calculated from measurements made in cylindrical cavities, such as boreholes, or in spherical or disc-like cavities.

P078. MAGNETIC FIELD SURVEYS WITH A SOURCE OF KNOWN MAGNETISATION

Clive Foss[1] and Keith Leslie[2]*
[1]CSIRO Mineral Resources, North Ryde
[2]CSIRO Manufacturing, Lindfield
*clive.foss@csiro.au

To develop new magnetic field analysis algorithms and software we generally use synthetic computed survey datasets, and then to establish their practical value we apply them to real test-case datasets. However, application to real data is hampered because we do not confidently know the total magnetisation of geological sources. To span the gap between synthetic computed fields and survey measurements we have surveyed small-scale magnetic fields due to a cylindrical palaeomagnetic core of measured magnetisation and magnetic susceptibility. A profile is acquired by drawing a 3 component fluxgate magnetometer along a carefully engineered track. The track is fixed and the sample

moved between measurement of successive profiles (the opposite of a conventional survey, but achieving the same relative sensor to source mapping of the field). Results show many similarities to typical aeromagnetic data, with the added benefit that we can directly measure the regional field by removing the source. We measure profiles of 60 to 100 cm length, moving the sample up to 15 cm to either side of the track centre. Our preferred sample has a Koenigsberger ratio >10, with a strong, stable remanence conveniently directed close to the cylinder axis (providing ease of orientation to set a desired source magnetisation direction). We have used data from these surveys extensively in our research to improve determination of magnetisation direction from magnetic field data.

P079. PETROPHYSICAL CHARACTERISATION OF SOUTH EAST DOME COPPER GOLD DEPOSIT, NORTHWEST ZAMBIA

*Adouley Guirou**
FQML
*adouley.guirou@fqml.com

The Katangan sequence of the Domes region in Northwest Zambia has delivered major copper-gold mines such as Kansanshi, Lumwana and Kalumbila, making it a prime area for exploring for sediment hosted copper. Kansanshi with its 750 Mt @ 0.74% Cu and 0.13 g/t Au is among major copper-gold producer in Africa. SE Dome, a satellite deposit of Kansanshi, was recently explored and drilled out with a significant input from both surface and borehole geophysics surveys including airborne magnetic and radiometric, airborne electromagnetic (AEM), natural source audio-magnetotelluric (NSAMT), Sub audio magnetics (SAM), induced polarisation (IP) and 2D seismic profiles and downhole acoustics and radiometric. Systematic physical property data such as magnetic susceptibility, specific gravity, resistivity and IP have been measured on cores. This paper intends to integrate and visualise the data in order to fully characterise the deposit.

P080. DEPTH ESTIMATE OF A REMNANTLY MAGNETISED SOURCE USING MULTI-LEVEL MAGNETIC DATA

*Matthew Hutchens**
Hutchens Geophysics/Geological Survey of South Australia
*matthew.hutchens@sa.gov.au

The depth to the top of a remanently magnetised source near Teetulpa in South Australia is estimated using multi-level (airborne and ground) magnetic data.

Remanently magnetised sources are considered challenging to interpret, mainly because the shape of the anomalism is a product of both the dip of the source and the magnetisation vector, with the two indistinguishable if both are unknown.

It is shown here that by interpreting the source geometry, in this case a sub-vertical pipe, the appropriate formula to calculate the magnetic response can be integrated with respect to z (vertical separation of source and sensor) irrespective of the dip or magnetisation vector, and when data exists at multiple z levels the z values can be estimated by solving a system of linear equations.

P081. DEPTH ESTIMATION OF SOURCE BODIES USING 2D MAGNETIC GRADIENT RATIOS

*Matthew Hutchens**
Hutchens Geophysics/Geological Survey of South Australia
*matthew.hutchens@sa.gov.au

Depth estimation remains an important interpretation goal of the exploration geophysicist, especially when cover of uncertain thickness is present. There are many methods of estimating depth using magnetic data ranging from simple 1D (profile) analysis to complex 3D inversion, each with respective strengths and weaknesses. The method discussed here involves analysis of standard 2D magnetic grids.

The dipolar nature of magnetic anomalies is exploited, with the location of the nearest pole in relation to the magnetic sensor the parameter estimated. For sphere-like sources the result plots the centre of the body, where-as for bodies with extensive strike in 1D (pipe) or 2D (dyke) the result plots at the pole nearest the sensor (the depth to top).

Reduction to pole (RTP) filtering is performed on the standard 2D total magnetic intensity grid to make the anomalies symmetrical and centred over source bodies (assuming induced magnetism). The 1st order total horizontal gradient (THG) and vertical gradient (1VD) of the RTP grid are then generated. The ratio of 1VD/THG is then calculated and gridded with contouring used to highlight the isograd with a value of 1 (THG=1VD). The depth estimate is calculated by dividing the shortest diameter of this isograd by 2 and subtracting the ground clearance. Dip information can also be interpreted.

Forward modelling of simulated data illustrates the method, proves the concept and discusses weaknesses. Several different scenarios identify the role of source topology. A real world example using open file magnetic data with known depths from drilling is then presented.

P082. GEOPHYSICAL SIGNATURE OF THE SOUTHERN-GURUBANG BASE METAL OCCURRENCE IN SOUTHEASTERN NSW

Harrison Jones[1], *Mark Lackie*[1]*, *Mike Smith*[2] *and Thusitha Nimalsiri*[1]
[1]Macquarie University, North Ryde, Sydney, Australia
[2]Smith Engineering Systems Pty Ltd, Sydney, Australia
*mark.lackie@mq.edu.au

Ground-based, time-domain electromagnetic, magnetic and gravity data were obtained for the southern-section of the Gurubang base metal deposit, in southeastern NSW. The aim was to ascertain the usefulness of high-resolution geophysical techniques in targeting and evaluating a small-scale polymetallic massive suphide deposit. Acquired data were analysed using a forward modelling approach. Due to the deposit's high concentration of conductive material, a coincident loop time-domain electromagnetic 2D survey effectively delineates the sulphide mineralisation, and is useful in interpreting and adapting deposit parameters such as the azimuth, dip and strike length. Based on the target deposit, it was determined that a high-resolution magnetic and gravity survey was not an effective method in directly targeting the mineral deposit, due to the nature of the mineralisation. However, these methods were effective in delineating the surrounding geology, such as intrusive volcanic plugs and basement geologies and structures.

P083. INTEGRATION OF BOREHOLE DATA IN GEOPHYSICAL INVERSION USING FUZZY CLUSTERING

Duy Thong Kieu and Anton Kepic*
DET CRC, Curtin University
*duythong.kieu@postgrad.curtin.edu.au

Geophysical inversion problems are non-unique solutions and multiple physical models can adequately fit the data to the desired degree. To choose a reliable model extra information such as borehole data is essential. In fact, we may have many boreholes, but the parameter used in the inversion model is only valuable in a few holes. Thus, the question is how we can exploit other borehole features to assist the inversion. We present the application of fuzzy clustering to incorporate multiple borehole features such as lithological, assay and wireline logs in the geophysical inversion. In this approach, we utilise the ability of fuzzy logic to resolve 'unclear' classification situations common in geology. Hence it is better than a 'hard' clustering technique such as the K-means method. The integration of this extra information produces physical parameter distributions that fit surface geophysical data and simultaneously honour the prior information. Consequently, the model likely resembles the true rock units. We have applied this technique to a case study over the Kevitsa deposit within the Kevitsa ultramafic intrusion in northern Finland. Our inversion process can produce a 'cluster' model defined by similarity of the model attributes. The cluster model can help the interpretation process better than using geophysical models.

P084. CONTINUOUS HYDROGEOLOGICAL CHARACTERISATION IN IRON ORE DEPOSITS USING BOREHOLE MAGNETIC RESONANCE

Kazimierz Trofimczyk[1], Mark Downey[2], Tim Hopper[3], Tom Neville[3] and Benjamin Birt[4]
[1]BHP Billiton Limited
[2]Downey Data Analysis Pty Ltd
[3]NMR Services Australia Pty Ltd
[4]Kinetic Logging Services

In situ dewatering of iron ore deposits is essential for safe and efficient mining operations, as well as reducing requirements for subsequent moisture removal for processing and transportation. Evaluating porosity, residual moisture content, and hydraulic conductivity is key to designing effective dewatering schemes.

Modern borehole magnetic resonance has been used in the oil and gas industry for over twenty years to provide continuous evaluation of porosity, bound and free fluid volumes, and permeability. As such, it is uniquely suited to provide subsurface characterisation data for dewatering scheme design. However, applying these methods in iron ore settings introduces complications that are not observed in typical oil and gas environments due to the high concentrations of ferromagnetic iron-containing compounds making up the ores. This requires modification of standard approaches for estimating fluid volumes and permeability from magnetic resonance measurements.

Using an extensive data set of both core and log measurements, optimised workflows and algorithms for evaluating porosity, residual moisture content, and hydraulic conductivity from borehole magnetic resonance measurements in iron ore deposits have been developed. This allows the practical application of borehole magnetic resonance measurements in iron ore settings, providing continuous and cost effective hydrogeological characterisation.

P085. CONTINUOUS DRY BULK DENSITY EVALUATION USING BOREHOLE MAGNETIC RESONANCE AND DENSITY MEASUREMENTS

Tim Hopper[1], Tom Neville[1] and Benjamin Birt[2]*
[1]NMR Services Australia Pty Ltd
[2]Kinetic Logging Services
*tim@nmrservices.com.au

Dry bulk density is a key parameter in resource estimation and mine and process planning. Ore bodies are mapped as volumes, whereas mineralisation grade is reported as mass fractions, requiring rock density to complete the reserves calculation. Similarly, although a volume of rock is to be excavated, planning for the transport and processing of this material takes place in terms of the mass of ore to be handled, again requiring rock density information to convert between the two.

Although many different densities can be defined based on the underlying mass and volume definitions, the one of most interest to the mining industry is dry bulk density, or the dry mass per unit volume of *in situ* rock. This contrasts with the *in situ* bulk density, which includes the mass of any fluids in the pore space of the rock. *In situ* bulk density can be accurately measured using borehole geophysical techniques, but no direct downhole measurement of dry bulk density is possible. Therefore, common practice is to determine mass, after drying, and volume of core samples for calculation of dry bulk density. However, this process can be time consuming and problematic with porous or unconsolidated samples.

Another approach to estimate dry bulk density, amenable to downhole application and therefore avoiding many of the complications related to core measurements, utilises *in situ* bulk density and magnetic resonance porosity measurements. Combining these two measurements allows for continuous dry bulk density evaluation without the need for coring.

P086. DIGITAL OPENCAST MINING ECOSYSTEM (DOME) FOR MANAGING THE AUSTRALIAN MINING INDUSTRY IN A BIG DATA SCALE

Shastri L. Nimmagadda, Torsten Reiners and Amit Rudra*
Curtin University, Perth, WA, Australia
*shastri.nimmagadda@curtin.edu.au

Many opencast mines inhabit thousands of square kilometres, which are productive and commercial Australia wide. Hundreds of volumes and varieties of data dimensions and facts exist in the opencast mining areas. The data sources linked with various opencast mines are often heterogeneous and multidimensional. Data modelling is challenging in a Big Data scale, at times precluding the data integration process. The mineralisation connected to opencast mines occurs in shafts, pit slopes, ramps and benches with varying geometries and configurations in large-scale geographic and periodic dimensions. The limits of the mineralisation at places are either unknown and or ambiguously interpreted. The Big Data, in the context of the Australian mining industry, are due to the explosive growth of data sources and their uncontrolled management in many national and multinational companies. New knowledge is

required for interpreting new opencast mining areas and their mineralisation. For sustainable production, the knowledge of the connectivity between mineralisation and its associated opencast mines is constrained. We propose an empirical modelling, analysing hundreds of attribute dimensions and fact instances of geological and geophysical vintages in the mining areas. Different data constructs and models are built for logical metadata, accommodating it in a multidimensional warehouse repository, as a DOME solution. It is an innovative solution to the mining industry's Big Data problem including the opencast mine planning and design, adding values to the existing domain knowledge with new interpretations. Various geological events attributed to the interpretation and distribution of mineralisation are useful for the opencast mine managers.

P087. EFFECT OF FINELY-LAYERED STIFF CARBONATES ON A SEISMIC RESPONSE, CARNARVON BASIN SYNTHETIC STUDY

Anastasia Pirogova[1], Roman Pevzner[1], Boris Gurevich[1,2] and Sergey Vlasov[3]*
[1]Curtin University
[2]CSIRO
[3]Santos
*a.pirogova@postgrad.curtin.edu.au

Fine layering is known to cause both attenuation and VTI-anisotropy of seismic waves. In typical geological environments the contrast in elastic properties of adjacent layers rarely exceeds 30% so that the layer-induced effects are negligible. However, it's not true for the overburden of Carnarvon basin (Northern shelf of Western Australia) that is characterised by thin interlayering of very stiff carbonates and soft porous sands.

In this paper we present a workflow for preliminary analysis of a seismic wavefield and, in particular, effects of layer-induced scattering attenuation and anisotropy in the target area. The workflow is based on the walk-away VSP full-wave modelling (5–100 Hz) for a flat-layered elastic model that is constructed using logs of four wells, namely, Dampier 1, Withnell 1, Wilcox 2 and Parker 1.

We show that particular sequences with stiff carbonates produce significant amplitude loss and degradation of spectrum of a transient seismic pulse. Maximum attenuation is observed for Withnell 1 borehole and is characterised by the drop of 35% in the centroid frequency in the 200 m interval. Anisotropy anellipticity parameter η is estimated by fitting the moveout curves and varies from 0.3 to 1.5. In addition, the modelling reveals very complex wavetrain with energetic reflected and converted waves at large offsets. All these effects should be taken into account in seismic processing and imaging.

P088. APPLICATION OF IMAGE PROCESSING METHODS IN EDGE DETECTION OF POTENTIAL FIELD DATA

Tan Xiaodi, Ma Guoqing and Zhang Dailei*
College of Geo-exploration Science and Technology, Jilin University, Changchun, China
*tanxiaodi@hotmail.com

On the basis of conventional methods for edge detection on potential field data, various source edge enhancement techniques have been studied to improve signal-to-noise ratio and localisation accuracy. But problems such as low resolution, noise interference and false edge information introduced still exist. In this paper, three image processing methods are introduced, which are Canny, LoG and Sobel operators. We describe briefly the principle of the methods and apply them to edge detection of geological bodies. And three typical numerical calculation methods of edge detection are selected and compared with image processing methods on edge detection effect. The results show that image processing methods can effectively identify the edge of geological bodies, especially for Canny operator, which can prevent introducing error information and is insensitive to noise. To verify practical application effects of image processing methods, the data in gravity anomaly of Sichuan basin and magnetic anomaly of Zhurihe area are processed in this paper. The results indicate that Canny operator is capable of detecting the edge position of geological bodies in the study area more clearly, which corresponds to known information. Therefore, image processing methods can be used in edge detection and satisfactory practical application effects can be achieved.

P089. FAST THREE DIMENSIONAL DENSITY INVERSION BASED ON MULTI-SCALE ANALYSIS OF WAVELET

Zhang Dailei, Ma Guoqing and Tan Xiaodi*
College of Geo-exploration Science and Technology, Jilin University, Changchun, China
*zhangdailei@hotmail.com

Low calculation efficiency and insufficient resolution in depth direction exist in inversion of underground 3D density distribution. In this paper, we proposed a fast inversion algorithm. It decomposed the gravity anomaly on multi-scale with wavelet, represented the original data sparsely with wavelet coefficients on each scale and carried on the inversion in wavelet domain. An appropriate threshold is set to process the coefficients in order to enhance the sparsity of coefficient matrix. This would furthermore improve the compressed ratio of data and save calculation time. Gravity anomalies on each scale represent responses of sources at different depths as an inverse relation exists between scale and frequency. So the inversion results would mainly reflect density distribution at the corresponding depth and the final inversion could be achieved by summing up results at all scales. It is not necessary to set the range of depth related to anomalies at each scale and besides, the inversion scheme is applied without depth weighting. The method could increase the resolution in depth direction of inversion results effectively and provide more detailed deep density distribution. As an iterative algorithm, which can take advantage of sparse matrix to improve calculation efficiency, conjugate gradient was used for inversion. The proposed method will be applied to inversion of synthetic model data and real gravity anomaly to demonstrate its effect.

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P090. THE NEW GENERATION TEMPEST SYSTEM

Teo Hage, Ray Lockwood and Eric Steele*
CGG MultiPhysics
*Teo.Hage@cgg.com

The development of the new Generation TEMPEST system was driven by an expectation that TDEM data would find increased utility, at regional scale, for both geological mapping and regolith characterisation. Achieving the correct balance of affordability and technical capability was determined to be a key component to the success of this endeavor.

Designed as a system suited to contemporary demands for high quality calibrated data whilst maintaining a good depth of penetration, a number of new innovations were necessary. These include the development of a 'low frequency bird' (12.5 Hz and below) in conjunction with UWA, a faster switching higher power transmitter and new signal processing algorithms to accommodate these changes. Additionally, continuous measurements of system geometry, transmitter/receiver orientation etc. for use in modern inversion codes enables the potential for both improved results and better quantified data and associated uncertainty.

Historically the cost of operating a TDEM system also limited the widespread use of quality EM data for mapping purposes. In order to contain these operational costs an inexpensive and robust platform, the Cessna C208B, albeit with an upgraded engine, was selected as being most suitable. CGG embarked on a certification journey with the Civil Aviation Australia (CASA) for the issue of a Supplemental Type Certificate. This 2.5 year endeavor provides a unique insight into the trials and tribulations of equipment development in an increasingly legislated environment.

In this paper we present both the development path and technical achievements of a project designed to improve the accessibility of quality Airborne EM data.

P091. RAPID ESTIMATION OF VOLUMETRIC GROUNDWATER RECHARGE IN THE VADOSE ZONE VIA GROUND PENETRATING RADAR

Alexander R. Costall and Brett Harris*
Curtin University
*alex.costall@curtin.edu.au

Rapid bulk estimation of the stored water content in a high-permeability sandy vadose zone at the coastal margin is made using velocity corrections for time-lapse ground penetrating radar measurements.

Ground Penetrating Radar (GPR) is an invaluable tool for shallow high-resolution geophysical investigation. It is applicable to a wide range of near-surface problems, such as archaeological investigation, engineering assessments, and medical imaging. The speed and simplicity of acquisition and processing lends itself to the rapid detection and evaluation of subsurface features.

Shallow hydrogeological applications, such as delineation of stratigraphy mapping (Davis and Annan, 1989), soil water content definition (Huisman et al., 2003), porosity estimation (Bradford et al., 2009; Turesson 2006), and water table/vadose zone depth evaluation (Strobach, 2013; Strobach et al., 2010) are well-suited towards GPR investigation due to the shallow nature and large contrasts in the physical properties of the target.

Volumetric water content stored in the vadose zone will reduce the electromagnetic wave velocity of a ground penetrating radar signal. We demonstrate the effect of increased volumetric water content through repeat acquisition of GPR data in a highly-permeable dune system in the coastal margin of Perth, Western Australia.

The increase in bulk stored water content between successive transects is estimated through manipulation of the topographic correction velocity to achieve a flat, or near-flat water table consistent for both datasets. The flat water table assumption is validated via nearby well logs and the highly permeable sandy environment. The changes in velocity allows for the estimation of saturated water increase over the elapsed time period, which can be correlated with rainfall and evapotranspiration to estimate the total stored water in the vadose zone.

P092. ASSESSING AQUIFER COMPARTMENTALISATION IN THE DALY RIVER BASIN, NORTHERN TERRITORY: A HYDROGEOPHYSICAL APPROACH

Laura Gow[1], Niels B. Christensen[2], Steven Tickell[3], Ken Lawrie[1], Donna Cathro[1], Sam Buchanan[1], Martin Smith[1] and KokPiang Tan[1]*
[1]Geoscience Australia
[2]Aarhus University
[3]Northern Territory Department of Environment and Natural Resources
*laura.gow@ga.gov.au

The presence of Neogene fault systems can have a significant impact on hydraulic connectivity of aquifers, juxtaposing otherwise disconnected aquifers, enhancing recharge and/or discharge or acting as barriers to flow and consequently compartmentalising groundwater resources. Previously, regional airborne electromagnetics (AEM) transects allied with groundwater investigations have pointed to the potential for localised compartmentalisation of the Daly River Basin groundwater systems. However, existing data is sparse, and equivocal.

In this context, the main aim of the Daly River Basin Project is to determine if compartmentalisation of the aquifers is a significant factor and thus should be explicitly considered in groundwater modelling and water allocation planning. The objectives of the project main goals of the project are to: (1) map Neogene faults through the use of airborne electromagnetic (AEM) and morphotectonic mapping, and (2) assess the permeability and transmissivity of mapped fault zones and their role in potential groundwater system compartmentalisation. Data acquisition includes 3325 line-km of new AEM and airborne magnetics, ground (ground magnetic resonance (GMR)), and borehole geophysics, drilling, groundwater sampling and hydrochemical analysis, geomorphic and morphotectonics mapping. Hydrogeophysical, geomorphic and hydrogeological data will also be used to better understand groundwater-surface

water connectivity and the potential for managed aquifer recharge schemes to replenish extracted groundwater resources. The outcomes of this project will inform decisions on water allocations and underpin effective and efficient groundwater use. This paper specifically reports on the ability of AEM and morphotectonics mapping to identify Neogene fault systems in the Daly River Basin.

P093. DEVELOPING REGIONAL-SCALE HYDROGEOLOGICAL FRAMEWORKS FOR REMOTE PARTS OF AUSTRALIA – THE ROLE OF DIGITAL TERRAIN DATA COUPLED WITH FINE-SCALE GEOPHYSICAL AND GEOLOGICAL DATA

Tania Ibrahimi, Tim Munday, Camilla Soerensen and Mat Gilfedder*
CSIRO
*Tania.Ibrahimi@csiro.au

Securing water resources in central Australia for isolated communities and environment is a challenge for both State Governments and industry. The G-FLOWS projects of the Goyder Institute for Water have developed a scalable approach to help better understand water resources of arid inland regions of Australia. It employs digital terrain data and a terrain index - MrVBF to delimit contemporary valleys or low points in the landscape. This index is designed to identify areas where alluvial/colluvial material might be deposited at a range of scales based on the observations that valley bottoms are low and flat relative to their surroundings and that large valley bottoms are flatter than smaller ones. This index has been tested with airborne electromagnetic and airborne magnetics data datasets in data poor, arid parts of South Australia where spatial associations between surface topography and materials, and observed subsurface character were identified. A hydrogeological framework model was then developed with five hydrogeological units defined, categorising the landscape as comprising alluvial aquifers with buried palaeovalley systems, alluvial/colluvial aquifers, colluvial aquifers, aquifers in saprolite and weathered fractured rock, and fractured rock aquifers in fresh rocks. The hydrogeological framework model has also been tested in other areas, and can be scaled depending on the resolution of available terrain data, but also an understanding of the basement geology. The framework can help target locations and determine approaches for finer-scale groundwater resource assessments by Government or industry, and in future can be modified and applied to other areas in Australia as needed.

P094. STRUCTURAL ANALYSES AIDING IDENTIFICATION OF WATER CONDUCTIVE FRACTURE ZONES IN CRYSTALLINE ROCKS

K. H. Morgan
khmorgan@iinet.net.au

Development of hydraulic conductive zones in crystalline rock can result from a wide range of geological conditions, which include primary structures, post crystalline tectonics, fluid solution and movement within a developing and eroding regolith.

Crystalline rock areas mostly have low water resource potential due to inherent extremely low storage and water conductive properties. Therefore, fracture zones of high hydraulic conductivity have an important role in developing groundwater resources in these areas.

Mechanisms for development of open tension or pull-apart fractures in brittle rocks are similar to those involving development of mineralised veins. The same structural analytical techniques can be applied.

Crystalline rock fracture zones can be amenable to rapid recharge through rainfall runoff. They are also significant in that they provide a mechanism for underdrainage through 'delayed yield' of surrounding or enclosing low conductive rocks such as saprock/saprolite, pelite and phyllite.

In addition to brittle rocks, open tension fracture zones of enhanced hydraulic conductivity may also occur in more fissile pelitic rocks such as slate and phyllite. These zones are often associated with crestal zones of folds and along saddles in cross-folds and in strike deviations produced by conjugate shears.

The development of conjugate joint sets in a region also provides a significant basis for this type of fracture analyses.

This presentation provides examples of water supplies developed from crystalline rock structures in a range of geological and earth environments.

P095. MAGNETOTELLURIC, BASIN STRUCTURE AND HYDRODYNAMIC; SOUTH WEST OF WESTERN AUSTRALIA

Bibirabea Sedaghat[1], Ralf Schaa[1], Brett Harris[1], Andrew Pethick[1], Alex Costall[1], Jingming Duan[2] and Wenping Jiang[2]*
[1]Curtin University, Exploration Geophysics
[2]Geoscience Australia
*bibirabea.sedaghat@postgrad.curtin.edu.au

An MT transect was collected over a hypersaline aquifer along a west-east profile almost perpendicular to the Darling fault and Indian Ocean coast in a rural/semi-rural area proximal to Harvey, Western Australia. AMT/MT data were recorded during periods between 10 h and 24 h simultaneously at multiple stations. Some stations were influenced by power line high noise, and remote reference processing was applied to improve data quality. First 1D forward modelling was completed to get a sense of conductivity distribution, then 2D inversions was completed using Mare2DEM. Clear and significant splitting in TE and TM mode apparent resistivity and phase occurred at low frequencies (less than 0.1 Hz) for all stations. The mode splitting could be related to the proximity of the MT transect to the narrow deep Perth Basin near the Darling fault, combined with the presence of the Indian Ocean several kilometres to the West. The 2D inversion result shows some thick sand formations containing high salinity where resistivity appears to be strongly connected to reduction in porosity with depth.

P096. APPLICATION OF MAGNETIC RESONANCE DATA FOR GROUNDWATER PROSPECTIVITY IN THE FITZROY BASIN, WESTERN AUSTRALIA

KokPiang Tan[1], Neil Symington[1], Ken Lawrie[1], Alastair Hoare[2], Elliot Grunewald[3] and Larysa Halas[1]*
[1]Geoscience Australia
[2]Western Australia Department of Water
[3]Vista Clara
*kokpiang.tan@ga.gov.au

In northern Australia, groundwater investigations in remote areas face challenges including the cost and difficulty in obtaining

drilling permit due to lengthy heritage and environmental approvals processes. Non-invasive geophysical techniques, including airborne electromagnetics (AEM), Ground Magnetic Resonance (GMR) and borehole Nuclear Magnetic Resonance (NMR), are particularly attractive in these circumstances, as key hydrogeological parameters including depth to water table, porosity and transmissivity can be obtained with limited clearance approvals required.

In the Fitzroy Basin of Western Australia, both surface and borehole MR have been applied to groundwater prospectivity assessment of the Cenozoic sediments, and the Palaeozoic and Mesozoic sandstone aquifers. Eight GMR sites were acquired across the basin, which include Mowanjum, Willare – lower Fitzroy, Mount Anderson, and May – Lennard River areas. These sites were selected based on interpretation of the AEM data.

The GMR results with good resolution to 100 m depth were compared against borehole NMR and lithostratigraphic information, and found to be consistent. Both sets of MR data support that the Palaeozoic (Grant Group and Poole Sandstone) are excellent aquifers. At other sites, the lack of water content in some of the water profiles indicates the presence of aquitards such as Blina Shale and Jarlemai Siltstone.

GMR data indicates that the floodplain alluvium of the intermittent Fitzroy River contains little 'mobile', or free-draining, water (~3 vol %) at the end of the dry season. The water table at the site was ~30 m depth, most likely beneath the alluvium in the Mesozoic sedimentary rock.

P097. UTILISATION OF AEM METHODS FOR COST-EFFECTIVE MAPPING OF SHALLOW NEOGENE INTRA-PLATE FAULT SYSTEMS IN EASTERN AUSTRALIAN COAL SEAM GAS BASINS

Ken Lawrie[1], *Donna Cathro*[1*], *Neil Symington*[1], *Niels B. Christensen*[2], *Chris Harris-Pascal*[1], *KokPiang Tan*[1], *Andrew McPherson*[1] *and Laura Gow*[1]
[1]Geoscience Australia
[2]Aarhus University
*donna.cathro@ga.gov.au

Neogene fault systems are increasingly recognised as an important control on hydraulic connectivity in some of Australia's energy rich basins. However, accurate delineation of these faults systems is challenging and expensive. In this context, the main objective of the Exploring for the Future (EFTF) Surat-Galilee Basin (Phase 1) Project is to test novel methods for more cost-effective mapping of Neogene fault systems in the Coal Seam Gas (CSG) basins of eastern Australia. Methods assessed in this project include morphotectonic mapping using temporal remote sensing data and high-resolution terrain mapping techniques, airborne electromagnetics (AEM), and the use of earthquake databases to inform active tectonic and geomechanical analysis.

The project is funded by Geoscience Australia (GA) as part of its EFTF Program, and is focussed on exemplar areas in the Surat and Galilee Basins where Neogene fault activity has been interpreted on high-resolution 2D and 3D seismic reflection surveys. This paper reports on the use of airborne electromagnetics (AEM) for detecting near-surface (<50–150 m) Neogene faults in both basins. Approximately 4500 line km of AEM data were acquired in a number of smaller acquisition blocks where Neogene faults had previously been identified. The AEM inversion results are compared with interpretation of seismic reflection data, morphotectonic mapping, and other hydrogeological and tectonic/geomechanical data. The utility of AEM to map the broader hydrogeological system in these basins, including groundwater-surface water connectivity (springs and rivers), is also assessed.