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**50<sup>th</sup> U.S. Rock Mechanics/Geomechanics Symposium**

Houston, Texas USA  
26 – 29 June 2016

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## ***ARMA 50<sup>TH</sup> U.S. ROCK MECHANICS / GEOMECHANICS SYMPOSIUM***

### **COMPLETE PROGRAM AND TIMETABLE**

#### **TECHNICAL SESSIONS**

Monday, 27 June 2016				
Time	Track a - Mining & Civil Technical Session 1 – Galleria III Geomechanics in Geothermal Processes 1	Track B - Fracturing and Fractures Technical Session 7 – Woodway II Modeling Rock Mass Fracturing Processes	Track C – Petroleum Technical Session 11 – Woodway III Sand Control and Management	Track D – Interdisciplinary Technical Session 15 – Woodway I Laboratory and Field Measurements - Methods
08:00 am-08:15 am	825 R. Safari 3D Analysis of Thermo- poroelastic Processes on Fracture Network Deformation and Induced Micro-Seismicity Potential in EGS	93 J. Napier Application of a Fast Marching Method to Model the Development of the Fracture Zone At the Edges of Tabular Mine Excavations	197 A. Shabdirova Sample Preparation Method of Clay-Rich Sandstone Analogue of Sandstone Reservoirs in Kazakhstan	66 Y. Togashi A Method of Triaxial Testing for Determining Constitutive Parameters of Anisotropic Rocks Using a Single Specimen

08:15 am-08:30 am	368 S. Salimzadeh Thermal Effects during Hydraulic Fracturing in Low-Permeability Brittle Rocks	211 G. Meng Continuum/discrete numerical simulation of columnar basalt in large-scale underground excavations	251 H. Wang A 3-D Poro-Elasto-Plastic Model for Sand Production around Open-hole and Cased & Perforated Wellbores	75 A. Mitra Ultrasonic Velocity Measurement of Sidewall Cores for Different Stress Paths
08:30 am-08:45 am	391 C. Sherman Modeling Induced Microseismicity in an Enhanced Geothermal System	339 P. Cundall Considerations on Slope Stability in a Jointed Rock Mass	290 Y. Zeng Thermal Induced Sand Rate and Production	127 A. Mitra Measurement of Grain Compressibility of Fine-Grained Source Rock
08:45 am-09:00 am	828 M. Swyer Permeability Potential Modeling of Geothermal Prospects Combining Regional Crustal Strain Rates with Geomechanical Simulation of Fault Slip And Volcanic Center Deformation: A Case Study for Washington State Geothermal Play Fairways	621 J. Furtney Applications for Numerical Modeling of Blast Induced Rock Fracture.	330 E. Papamichos Well Strengthening in Gas Wells From Near Wellbore Drying	227 J. Dudley Experimental Characterization of Toughness Profile for Hydraulic Fracturing of Shales
09:00 am-09:15 am	257 S. Bauer Experimental and Numerical Investigation of Hydro-Thermally Induced Shear Stimulation	786 H. Zia Turbulent - Laminar Transition in the Propagation of Height-Contained Hydraulic Fractures	335 E. Gravanis A Hydro-Mechanical Erosion Analytical Model for Sand Prediction	276 B. Mehrgini Comparing Laboratory Hydraulic Fracturing and Brazilian Test Tensile Strengths
09:15 am-09:30 am	163 L. Zhuang Laboratory Study on Cyclic Hydraulic Fracturing of Pocheon Granite in Korea	49 P. Xing Experimental Study of Hydraulic Fracture Containment in Layered Reservoirs	683 L. Li Modelling Hole Failure Under Anisotropic Stresses Using Dem	371 D. Moronkeji Size Effects on Triaxial Strength Measurement and Brittle-Ductile Behavior of Carbonate Rock

Monday, 27 June 2016				
Time	Track a - Mining & Civil Technical Session 2 – Galleria III Geomechanics in Geothermal Processes 2	Track B - Fracturing and Fractures Technical Session 8 – Woodway II Fracture Mechanics - Physics and Models	Track C – Petroleum Technical Session 12 – Woodway III Drilling Geomechanics 1	Track D – Interdisciplinary Technical Session 16 – Woodway I Geology in Geomechanics
11:00 am-11:15 am	69 Q. Cheng Numerical Modeling of Newberry EGS Stimulation	32 S. Abbas Modeling Multiple Curved Fractures Connected through a Wellbore Using a Fluid-Coupled Xfem Algorithm	61 O. Oyedokun Theoretical Development on Morphology of Wellbore Toroidal Breakout	86 Y. Han Tensile Mechanical Behavior of Kerogen and Its Potential Implication to Fracture Opening in Kerogen-Rich Shales (KRS)
11:15 am-11:30 am	152 Q. Gao 3D Thermo-poromechanical Analysis of Reservoir Stimulation Using Damage Mechanics with Application to the Fenton Hill HDR Experiment	428 X. Hu Use of Coupled Geomechanics and Fluid Flow Model for Optimization of Multistage Hydraulic Fracturing and Horizontal Wells in Enhanced Geothermal System Applications	122 N. Brandao Modelling Cement Hardening in Pre-Salt Wells	437 K. Hull Modernized Mechanical Testing of Kerogen Rich Shales (KRS) by Monitoring in Situ
11:30 am-11:45 am	840 M. Plummer Primary Constraints on the Design of and Enhanced Geothermal System Reservoir	173 T. Hoeink Mechanisms-Based Fracture Model for Geological Materials	244 X. Li Numerical Modeling of Borehole Breakout in Ductile Formation Considering Fluid Seepage and Damage-Induced Permeability Change	545 B. Gao Stress and Porosity in Fold-and- Thrust Belt Systems
11:45 am-12:00 pm	841 P. Fu Revisiting Fenton Hill Phase I Reservoir Creation and Stimulation Mechanisms through the GTO Code Comparison Study	268 E. Dontsov Implementing a Universal Tip Asymptotic Solution Into An Implicit Level Set Algorithm (ILSA) for Multiple Parallel Hydraulic Fractures	318 J. Choi Effect of Non-linear Plasticity of Clay on Collapse Gradient for Deep Water Drilling	635 A. Ptaszynska Mineral and Organic Matter Constituents in Weak Interfaces in Shales
12:00 pm-12:15 pm	858 J. Bradford Application of Hydraulic and Thermal Stimulation Techniques at Raft River, Idaho: a DOE Enhanced Geothermal System Demonstration Project	531 R. Abedi Numerical Simulation of Rock Dynamic Fracturing and Failure Including Microscale Material Randomness	466 B. Wu An Experimental and Numerical Modelling Study on Stability of Boreholes with Pre-existing Breakouts	649 J. Avila Use of Borehole Images, Spectroscopy Data and Geology to Reduce Borehole Instability in Fractured Carbonates
12:15 pm-12:30 pm	860 J. Morris Parametric Study of Energetic Simulation for Geothermal Applications	792 M. Profit Applications of State of the Art Hydraulic Fracture Modelling Techniques for Optimized Design and for Enhanced Production	711 Y. Kang A Fast and Flexible Boundary Detection Algorithm for DEM Simulation	790 D. Roberts Investigation of the Coupled Mechanical-Thermal Evolution of Passive Continental Margins Incorporating Flexural Isostasy

Monday, 27 June 2016				
Time	Track a - Mining & Civil Technical Session 3 – Galleria III Rock Excavation, Breaking, Dynamic Loading	Track B - Fracturing and Fractures Technical Session 9 – Woodway II Rock Mass, Fault Zone, and Fractured Rock Characterization 1	Track C – Petroleum Technical Session 13 – Woodway III Subsurface Stress Modification	Track D – Interdisciplinary Technical Session 17 – Woodway I Coupled Processes - Flow and Thermal Responses
2:00 pm-2:15 pm	119 M. López Bendezú XFEM Simulation of Blast- Induced Crack Propagation in Rocks	88 R. Hunt Development and Application of a Site-Specific Rock Mass Classification Scheme for Wylfa Newydd New Build Nuclear Power Station in the UK	48 X. Ma Laboratory Investigation on Effective Stress in Middle Bakken: Implications on Poroelastic Stress Changes Due to Depletion and Injection	202 H. Yasuhara Predictions of Rock Permeability by THMC Model Considering Pressure Solution
2:15 pm-2:30 pm	393 M. Raffaldi Rock Mass Modeling Approach for Simulating Wave Propagation, Rock Fracture, and Rock Ejection	423 T. Ishibashi Exploring the Link between Permeability and Strength Evolution during Fracture Shearing	430 F. Rassouli A Comparison of Short-Term and Long-Term Creep Experiments in Unconventional Reservoir Formations	216 S. Broome Laboratory Gas Migration Experiments through Intact and Fractured Rock
2:30 pm-2:45 pm	424 B. Wu Influence of Hydrostatic Confining Pressure on the Dynamic Tensile Failure of Rock Material	476 A. Tsopela Hydro-Mechanical Modeling of Field Hydraulic Injection Inside a Fault Zone	35 M. Heidari Geomechanical Impacts of a Welding Salt Layer on Adjacent Sediments	517 J. Segura Estimating Drilling Conditions Based on Forward Modeling Along Wells, a Case Study including Mechanical and Chemical Compaction.
2:45 pm-3:00 pm	575 A. Adoko Developing the Ground Index (GI) for Rock Collapse Assessment in Tunneling	507 J. Park Creating a Digital Outcrop Model by using Hyper-Spectrometry and Terrestrial LiDAR	281 M. Davison The In-situ Stress Response of Reservoirs to Pressure Reduction followed by Pressure Increase: Depletion and Rebound Stress Paths from Two Case Studies	538 M. Ahmadi Feasibility Study of Heat Extraction from a Closed-loop Fractured Geothermal Reservoir; a Multiphysics problem
3:00 pm-3:15 pm	585 D. Deb Rock Failure Process in Indirect Tension using SPH Method	509 M. Petruzalek Fracturing of Migmatite Monitored by Acoustic Emission and Ultrasonic Sounding	385 y. wang Induced Stresses Around Staged Fractures and Impacts on SRV region in Low-permeability (Tight, Fractured and Shale) Formations	586 Q. Lei Influence of Stress on the Permeability of a Three- Dimensional Fractured Sedimentary Layer
3:15 pm-3:30 pm	758 N. Noraei Danesh Experimental Study of Impact of Creep on Coal Permeability	540 M. Bates Collecting Discontinuity Data at Kartchner Caverns Using LIDAR for the Purpose of Numerical Modeling	496 R. Holt Where Does the Stress Path Lead? Irreversibility and Hysteresis in Reservoir Geomechanics.	880 S. Elahi Geomechanical Simulation of Underground Coal Gasification

Monday, 27 June 2016				
Time	Track a - Mining & Civil Technical Session 6 – Galleria III Coal Mining Ground Control	Track B - Fracturing and Fractures Technical Session 10 – Woodway II Fracture Modeling of Initiation and Propagation	Track C – Petroleum Technical Session 14 – Woodway III In Situ Stress and Pore Pressure	Track D – Interdisciplinary Technical Session 18 – Woodway I Numerical Modeling of Salt and Soft Rock
04:30 pm-04:45 pm	182 P. La Pointe Mining Data in a Longwall Coal Mine to Predict Intersection Stability	412 J. Huang Hydraulic Fracture Growth and Containment Design in Unconventional Reservoirs	33 Y. Feng A Comparison Study of Extended Leak-off Tests in Permeable and Impermeable Formations	107 C. Zhu Damage and Healing Model of Stiffness and Permeability for Salt Rock: Microstructure Imaging, Fabric Processes and Continuum Mechanics
04:45 pm-05:00 pm	313 H. Maleki Application of Statistical and Computational Techniques for Analyses of Pre-Driven Longwall Recovery-Room Stability and Support Options	494 E. Gordeliy Modeling of Near-Wellbore Fracture Reorientation using a Fluid-Coupled 2D XFEM Algorithm	43 M. Nikolinakou Pore-Pressure Prediction Based on Seismic Velocities Coupled with Geomechanical Modeling	177 X. Shen Chemo-Mechanical Damage and Healing of Granular Salt: Micro- macro modeling
05:00 pm-05:15 pm	319 S. Sinha Analysis of Roof Control Plans for Improved Stability at Four- Way Coal Mine Intersections	534 F. Zhang Modeling of Hydraulic Fracture Initiation from Perforation Tunnels using the 3D Lattice Method	298 B. Sinha Determining Minimum and Maximum Horizontal Stress Magnitudes From Borehole Sonic Measurements in Organic Shales	239 C. Zhu Micro-Mechanical Analysis of Salt Creep Tests with a Joint-Enriched Finite Element Model
05:15 pm-05:30 pm	341 S. Mohanty Stability Evaluation of Two Parallel Declines Joining Multi- Seam Workings with Low Interburden Thickness	553 K. Das Multiple Intersecting Cohesive Discontinuities in 3D Reservoir Geomechanics	541 C. Chang Geomechanical characterization for the CO <sub>2</sub> injection test site, offshore Pohang Basin, SE Korea	581 J. Kemery Modeling of Time-Dependent Rock Failure in Abaqus and PFC3D
05:30 pm-05:45 pm	521 D. Burkhard Properties of Immediate Above Seam Strata and their Relationship to Ground Control At San Juan Mine	439 A. Lisjak Development of a Fully-Coupled, Hydro-Mechanical Model for Finite-Discrete Element Simulations of Fluid-Driven Fracturing	691 A. Agharazi Determination of Maximum Horizontal Field Stress from Microseismic Focal Mechanisms - a Deterministic Approach	670 T. Defoort The Effect of Heterogeneities on Damage and Fracture Propagation in Rock under a Spherical Indenter
05:45 pm-06:00 pm	183 U. Alkan Investigation of Beam Specimen Geometries Under Four-Point Asymmetric Bending for Shear Mode Fracture Toughness Measurement of Rocks	175 L. Jin Including a Stochastic Discrete Fracture Network into One-Way Coupled Poromechanical Modeling of Injection-Induced Shear Re-Activation	887 J. Andrews Use of Unique Database of Good Quality Stress Data to Investigate Theories of Fracture Initiation, Fracture Propagation and the Stress State in the Subsurface	101 M. Liu Sphere Indentation - the Hertzian Stress Field and the Effect of Far- Field Confining Stress

Tuesday, 28 June 2016				
Time	Track a - Mining & Civil Technical Session 19 – Galleria III Slope Stability, Foundations, and Dams	Track B - Fracturing and Fractures Technical Session 25 – Woodway II Hydraulic Fracturing Case Studies	Track C – Petroleum Technical Session 29 – Woodway III Near-Wellbore Processes 1	Track D – Interdisciplinary Technical Session 33 – Woodway I Geophysics in Geomechanics
08:00 am-08:15 am	9 B. Lukajic Intake Slope Stabilization and Spillway Cut in Rock for Hydropower Projects	85 M. Ingraham Laboratory Scale Hydraulic Fracture of Marcellus Shale	160 B. Park Three-Dimensional Bonded- Particle Discrete Element Modeling of Transversely Isotropic Rock: Verification and Application to Laboratory Test on Shale	448 E. Um Application of Electrical and Electromagnetic Geophysical Methods for Detecting Hydraulically-Active Fractured Zones
08:15 am-08:30 am	27 Y. Fujii New Techniques for Monitoring and Analyzing the Stability of Steep Cliffs Against Rock Falls	125 E. Ghazvinian Application of 3d Random Voronoi Tessellated Models for Simulation of Hydraulic Fracture Propagation Within the Distinct Element Formulation	449 E. Martinez Numerical Investigation of Potential Cement Failure Along the Wellbore and Gas Leak During Hydraulic Fracturing of Shale Gas Reservoirs	524 S. Goodfellow Acoustic Emission Geomechanics of Hydraulic Fracturing in the Laboratory
08:30 am-08:45 am	384 N. Bar Empirical Slope Design for Hard and Soft Rocks Using Q-Slope	136 D. Kumar 3d Poroelastic Simulation and Analysis of Multiple Fracture Propagation and Refracturing of Closely-Spaced Horizontal Wells	479 B. Orlic Numerical Estimation of Structural Integrity of Salt Cavern Wells	713 A. Bilal An Investigation of Static and Dynamic Data Using Multistage Tri- Axial Tests
08:45 am-09:00 am	527 S. Zamiran Modeling of Swelling Rocks for Group Pier Foundation Applications	843 G. Kampfer A Novel Approach to Mapping Hydraulic Fractures Using Poromechanic Principles	560 A. Lavrov Coupling a Fracturing Code to a Transient Reservoir Simulator: a Hands-On Approach	729 Z. Xu Modification of Fracture Geometry by Calcite Precipitation
09:00 am-09:15 am	848 M. George Mechanics of 3d Rock Block Erodibility	481 E. Papachristos 3D Hydro-Mechanical Modeling of Multiple Injections	611 F. Kwok DEM Modeling of the Propagation of Stress-Induced Borehole Breakout in Shale Sample	803 F. Pourahmadian Active Seismic Imaging and Interfacial Characterization of Fractures
09:15 am-09:30 am	889 G. Chen Stability Analysis of Toppling Slope Using the Extended NMM	546 M. Mack Microseismic Geomechanics for Refracturing	734 A. Najafi On the Finite Element Based Uncertainty Quantification of Thermal Fracturing Using Embedded Multiple-Site Cohesive Zone Elements	879 H. Knox Imaging Fracture Networks Using Joint Seismic and Electrical Change Detection Techniques

Tuesday, 28 June 2016				
Time	Track a - Mining & Civil Technical Session 20 – Galleria III Numerical Modeling in Mining	Track B - Fracturing and Fractures Technical Session 26 – Woodway II Fracture Mechanics - Diagnostics and Measurement	Track C – Petroleum Technical Session 30 -- Woodway III Integrated Reservoir Geomechanics 1	Track D – Interdisciplinary Technical Session 34 – Woodway I Laboratory and Field Measurements - Analysis
11:00 am-11:15 am	144 A. Yardimci Crown Pillar Optimization for Surface to Underground Mine Transition in Erzincan/Bizmisen Iron Mine	90 J. Hampton AE Investigation of Multi- Wellbore Hydraulic Fractures at the Laboratory Scale	114 P. Bhardwaj A New Reservoir Scale Model for Fracture Propagation and Stress Reorientation in Injection Wells	351 T. Lokajicek Enhanced Study of Rock Elastic Anisotropy
11:15 am-11:30 am	219 D. Adhikary Estimating the Height of Mining Induced Connective Fracturing	123 J. Bai Laboratory-Scale Hydraulic Fracturing: Experiment and Numerical Modeling	141 H. Roshan On Size-dependent Uniaxial Compressive Strength of Sedimentary Rocks in Reservoir Geomechanics	502 L. Frash Comparison of Pressure, Flow Rate, Stepped, and Oscillatory Control Methods for Fracture Permeability Measurements at Triaxial Stress Conditions
11:30 am-11:45 am	225 M. Fuenzalida Case Study: Mechanisms of Dilution at Henderson Mine	191 S. Falser Reducing Breakdown Pressure and Fracture Tortuosity by In- Plane Perforations and Cyclic Pressure Ramping	172 S. Sarmiento A Novel Approach to model DFNs Validating the Geological Evolution with Present Day Fracture Distributions	620 J. Labuz Failure Criterion with Intermediate Stress and Two Friction Angles
11:45 am-12:00 pm	346 I. Tulu Roof Collapse Modeling with FLAC3D	233 F. Wan Numerical Three-point Bending Test of Fracture Process Zone in Post-peak Deformation of Rock	252 N. Barton Non-Linear Shear Strength Descriptions are Still Needed in Petroleum Geomechanics, Despite 50 Years of Linearity	651 S. Brown Sensitivity of Roughness Algorithms to Sampling Frequency for the Characterization of Weathered Limestone Specimens
12:00 pm-12:15 pm	394 M. Raffaldi Framework for Simulating Fracture, Ejection, and Restraint of Rock around a Mine Drift Subjected to Seismic Loading	503 L. Frash Notched Specimen Hydraulic Fracturing Method for Conducting Mechanical and Hydrological Experiments at Triaxial Reservoir Conditions	794 A. Pirayehgar Hydraulic Fracture Well Interconnections in Anisotropic Stress Fields	809 S. Yumsak The Predictability of Physico- Mechanical Properties of Pyroclastic Rocks From the Needle Penetration Index
12:15 pm-12:30 pm	588 L. Karimi Sharif Simulation of Rock Bridge Failure At the Laboratory Scale Using a Combined Fdem Modeling and Discrete Crack Network Approach	626 S. Maxwell Calibrated Microseismic Geomechanical Modeling of a Horn River Basin Hydraulic Fracture	455 J. Lee Comparison of Different Methods to Estimate Uniaxial Compressive Strength in a Barnett Shale	811 K. Kaklis Experimental Determination of the Maximum Indirect Tensile Stress Parameters for Dionysos Marble



Tuesday, 28 June 2016				
Time	Track a - Mining & Civil Technical Session 21 – Galleria III Slope Stability in Mines	Track B - Fracturing and Fractures Technical Session 27 – Woodway II Rock Heterogeneity Across Length Scales	Track C – Petroleum Technical Session 31 -- Woodway III Drilling Geomechanics 2	Track D – Interdisciplinary Technical Session 35 – Woodway I Hazards, Risks, and Induced Seismicity
02:00 pm-02:15 pm	206 H. Stockhausen On the Application of Rockfall Risk Assessment Techniques From Field Observation and Quarry Experience	421 S. Busetti Branch Line Analysis of Faults and Fractures	321 K. Agapiou Influence of Recycled Rubber Tire Morphology on the Mechanical Properties of Well Cements	149 M. Boltz Effects of a Three-Dimensional Velocity Structure on the Locations of Coal Mining-Induced Seismicity
02:15 pm-02:30 pm	224 R. Kaunda Data Driven Approaches to Designing Large Open Pit Slopes – Lessons From Engineering Geology	571 P. Kaiser Role of Large Scale Heterogeneities on In-Situ Stress and Induced Stress Fields	513 V. Dokhani Influence of Sorptive Tendency of Porous Medium on Hydraulic Properties of Shale	523 Z. Khademanian Studies of Seismicity Generated by Unstable Failures Around Circular Excavations
02:30 pm-02:45 pm	354 P. Kulatilake 3-D Deformation Comparison Between Modeling and Field Data for An Open Pit Mine in Usa	682 J. Zhou Numerical Study of Critical Role of Rock Heterogeneity in Hydraulic Fracture Propagation	518 J. Segura Fault Stability Assessment for Well Planning: a Case Study Related to Salt Structures	525 D. Collins Use of Seismic Deformation and Stress Inversion Analysis to Help Improve the Understanding of Rock Mass Response to Excavation
02:45 pm-03:00 pm	373 D. Kumar A Fracture Mechanics Based Slope Stability Analysis with Application to Reclaimed Steep- Slopes	791 M. Bhuiyan The Influence of Rock Foliation on the Correlation Between Point Load Strength Index and Comminution Indices At Kinross Tasiast Mine	529 E. Pirayesh A Three-Dimensional Elastoplastic Finite Element Model to Determine Stress Distribution Around Boreholes Drilled in Compactible Rocks	279 F. Pereira Probabilistic Assessment of Casing Failure of a Typical Pre-Salt Wellbore Under Local Salt Dissolution Conditions
03:00 pm-03:15 pm	441 K. Andrews Improvements in Data Collection for Geotechnical Pit Slope Stability Assessment	890 N. Bahrani Strength Degradation Approach (SDA) for Estimation of Confined Strength of Micro-defected Rocks	643 S. Chen An Analytical Solution for Wellbore Stability Problem Using Strain Hardening Drucker-Prager Plasticity model	362 P. Papanastasiou Hydraulic Fracturing in CO2 Geological Storage
03:15 pm-03:30 pm	810 J. Silva Improved Signature Hole Analysis for Blast Vibration Control in Open Pit Mines	720 R. Thareja Parametric Analyses of Rock Support Design Parameters in Time Dependent Numerical Models	755 S. Elkatatny Application of Artificial Intelligent Techniques to Determine Sonic Time from well logs	169 A. Azhari Evaluating the Effect of Earthquakes on Open Pit Mine Slopes

Tuesday, 28 June 2016				
Time	Track a - Mining & Civil Technical Session 24 – Galleria III Numerical/Analytical/DEM Modeling in Geomechanics	Track B - Fracturing and Fractures Technical Session 28 – Woodway II DFN Fracture Characterization	Track C – Petroleum Technical Session 32 – Woodway III Waste Disposal and CO2 Sequestration	Track D – Interdisciplinary Technical Session 36 – Woodway I Coupled Processes: Chemical/Thermal/Biologic Influences on Geomechanics
04:30 pm-04:45 pm	99 X. Zhang Numerical Analysis of Borehole Breakouts with Size-Dependent Compressive Strength	40 M. Havaej Application of discrete fracture networks (DFN) in the stability analysis of Delabole Slate Quarry, Cornwall, UK	100 F. Pizzocolo Polymer-Gel Remediation of CO <sub>2</sub> Migration through Faults and Caprock: Numerical Simulations Addressing Feasibility of Novel Approaches	180 B. Lai Fracturing Fluids Effects on Mechanical Properties of Organic Rich Shale Mechanical Properties of Organic Rich Shale
04:45 pm-05:00 pm	587 Z. Bazant Vast System of Dense Intersecting Fractures: a Key Feature of Hydraulic Fracturing of Gas Shale	215 T. Hoeink Directional Permeability of Discrete Fracture Networks	410 W. Minkley Deep Borehole Disposal in Salt Rocks	300 W. Li Investigation of Thermal Effect of Fluid Injection into Unconsolidated Formation in Microscopic Numerical Modeling
05:00 pm-05:15 pm	113 M. Yetisir Up-Scaling DEM Simulations	625 D. Chorney Hydraulic Fracture Sensitivity Study with a Fully-Coupled Microseismic Geomechanics Model	495 Y. Fang Friction-Permeability Relationships for Reservoir Caprocks	710 T. Garipov Thermo-Hydro-Mechanical Model for Source Rock Thermal Maturation
05:15 pm-05:30 pm	142 D. San-Roman-Alerigi Evaluation of FEM and DEM Schemes to Model Thermal, Electromagnetic and Mechanical Effects in Laser-Rock Interaction – An Overview	777 D. Elmo Synthetic Rock Mass Modelling: Experience Gained and Lessons Learned	576 C. Wang Numerical Investigation of the Effect of Frictionally Weak Minerals on Shear Strength of Faults	267 Y. Gordin Ultrasonic Velocity and Anisotropy of Organic-Rich Chalks
05:30 pm-05:45 pm	647 A. Hedayat Stability of Circular Tunnels Excavated in Rock Masses Under Gravity Loading	878 M. Cottrell Deep Fluid Injection into Fractured Rock	120 S. Broome Laboratory Testing of Surrogate Nondegraded Waste Isolation Pilot Plant Materials	566 J. Carey Dynamic Triaxial Study of Direct Shear Fracturing and Precipitation- Induced Transient Permeability Observed by in Situ X-Ray Radiography
05:45 pm-06:00 pm	760 M. Rahjoo A Simplified Dilation Model for Modeling the Inelastic Behavior of Rock	882 S. Rogers DFN Modelling of Major Structural Instabilities in a Large Open Pit for End of Life Planning Purposes	583 Z. Sun Pore-scale Modeling of the Effect of Cementation on Rock Indentation Test	72 O. Shtrit Influence of Laboratory-Induced Maturation on Rock-Physics of Organic-Rich Chalks

Wednesday, 29 June 2016				
Time	Track a - Mining & Civil Technical Session 37 – Galleria III Mining Geomechanics	Track B - Fracturing and Fractures Technical Session 41 – Woodway II Fracture Mechanics - Fluid and Proppant	Track C – Petroleum Technical Session 45 – Woodway III Near-Wellbore Processes 2	Track D – Interdisciplinary Technical Session 49 -- Woodway I Induced/Triggered Seismicity
08:00 am-08:15 am	89 D. Dyk Open Pit Mining through Historic Underground Workings	38 K. Wu Numerical Study of Flow Rate Distribution for Simultaneous Multiple Fracture Propagation in Horizontal Wells	218 M. Tabatabaei Partial Annular Cracks Around Cemented Casing Interfaces	151 D. Castineira Uncertainty Quantification and Inverse Modeling of Fault Poromechanics and Induced Seismicity: Application to a Synthetic Carbon Capture and Storage (CCS) Problem
08:15 am-08:30 am	186 C. Palleske Expansion of Geotechnical Knowledge by Data Mining of a Geology Database	121 J. Bai Coupled Geomechanics and Fluid Flow Computational Algorithm for Hydraulic Fracturing Simulation: Case Studies	417 C. Liu N-Porosity and N-Permeability Generalized Wellbore Stability Analytical Solutions and Applications	217 D. Dempsey Density of Induced Earthquake Hypocenters As a Proxy for Pore Pressure Increase During Well Stimulation
08:30 am-08:45 am	407 W. Minkley Longwall Caving in Potash Mining – Geomechanical Assessment of Damage and Barrier Integrity	444 J. Park Importance of Fluid Compressibility and Multiphase Flow in Numerical Modeling of Hydraulic Fracture Propagation	457 A. Mehrabian Wellbore Geomechanics of Extended Drilling Margins and Engineered Lost Circulation Solutions	360 Y. Mukuhira Stress State Analysis of a Fault Plane with Large Induced Seismicity
08:45 am-09:00 am	416 A. Russo A Methodology to Select Valid Results From Lab Tests to Estimate Properties of Intact Rock with Microdefects.	652 I. Tomac Particle Image Velocimetry Analysis of Proppant Settling in a Narrow Slot	482 E. Fjaer How Creeping Shale May Form a Sealing Barrier Around a Well	492 A. Stroisz Monitoring of Fracture Reopening in Sandstones
09:00 am-09:15 am	445 T. Chikande Stability Analysis and Preliminary Support Design for Longhole Stopping Prefeasibility Study of a Greenfield Platinum Project	883 X. Li Permeability Evolution and Proppant Compaction in Artificial Fractures on Green River Shale	694 O. Razavi Initiation and Propagation of Drilling Induced Fractures	589 M. Grob Effect of Fault Orientation on Induced Seismicity Associated with Multi-Stage Hydraulic Fracturing
09:15 am-09:30 am	861 C. Lu Experimental Research on Shear-Slip Characteristics of Zigzag-Type Gouge of Simulated Fault	413 R. Medina Effect of Confining Stress on Sand-Fiber Proppant Placement in a Deformable Fracture	874 K. Xia A New Perspective on Multistage Stimulation of Multiple Horizontal Wells	787 P. Selvadurai Numerical Modeling of Heterogeneous Asperity Distributions Controlling the Growth of Shear Rupture on a Frictional Fault

Wednesday, 29 June 2016				
Time	Track a - Mining & Civil Technical Session 38 – Galleria III Computational Advances in Geomechanics	Track B - Fracturing and Fractures Technical Session 42 – Woodway II Interaction of Induced and Natural Fractures	Track C – Petroleum Technical Session 46 – Woodway III Numerical Modeling in Petroleum Geomechanics	Track D – Interdisciplinary Technical Session 50 -- Woodway I Laboratory and Field Measurements- Results
11:00 am-11:15 am	135 Y. Yanagimura Optimal Sample Size for Managing Uncertainty in Hoek- Brown Strength Parameters	886 J. Morris The Combined Influence of Stress Barriers and Natural Fractures Upon Hydraulic Fracture Height Growth	150 O. Omid Well Stimulation in Tight Formations: a Dynamic Approach	77 S. Read Geomechanics Properties From Laboratory Testing of Soft Rocks From Mount Messenger Formation, New Zealand
11:15 am-11:30 am	493 V. Baker Computational Advances and Data Analytics to Reduce Subsurface Uncertainty	363 J. Ter Heege Distribution and Properties of Faults and Fractures in Shales: Permeability Model and Implications for Optimum Flow Stimulation by Hydraulic Fracturing	237 E. Pirayesh An Algorithm for the Calculation of Material Tangent Stiffness Tensor using Extended Sandler- Rubin Cap Plasticity Model in Finite Element Analysis	108 T. Teklu Cyclic Permeability and Porosity Hysteresis in Mudrocks – Experimental Study
11:30 am-11:45 am	506 S. Nintcheu Fata Coupling Elasticity and Fluid Flow for a 3D Hydraulic Fracturing Solver	535 B. LEE Completion Optimization Using a Microseismically Calibrated Geomechanical Hydraulic Fracturing Simulation in a Naturally Fractured Formation	269 S. Akl Using Ellipsoidal Inclusion model to study shale gas mechanical anisotropy	261 J. Ding Mechanical Behavior and Microstructure Development in Consolidation of Nominally Dry Granular Salt
11:45 am-12:00 pm	516 O. Mahabadi Development of a new fully- Parallel Finite-Discrete Element Code: Irazu	582 R. Pramanik An SPH Approach to the Simulation of Hydraulic Fracture Propagation in Naturally Fractured Rock Medium	305 H. Florez A Novel Mesh Generation Algorithm for Field-Level Coupled Flow and Geomechanics Simulations	337 H. Zhao Laboratory Creep Strain Rate versus Deviatoric Stress for Sylvinitic and Halite at Room and Elevated Temperatures
12:00 pm-12:15 pm	679 A. El Matarawi Load and Resistance Separation for Reliability Based Design in Rock Engineering	769 H. Lee The Interaction Analysis of Propagating Opening Mode Fractures with Veins using Discrete Element Method	520 J. Segura Coupling a Fluid Flow Simulation with a Geomechanical Model of a Fractured Reservoir	498 P. Boyd Creep Experiments on Welded Nonlithophysal Topopah Spring Member Tuff - Atypical Crystalline Rock Behavior
12:15 pm-12:30 pm	739 J. Simulation of Hydraulic and Natural Fracture Interaction Using a Coupled DFN-DEM Model	829 Z. Moradian Shear Reactivation of Natural Fractures in Hydraulic Fracturing	820 I. Gil The Combination of Innovative Completion Hardware and 3D Non-planar Fracture/Reservoir Simulation in Shale Completion Optimization	686 M. Dessouki The Impact of CEC, Silt Content, and Salinity on Multistage Triaxial Tests of Reconsolidated Mudrocks

Wednesday, 29 June 2016				
Time	Track a - Mining & Civil Technical Session 39 – Galleria III Underground Storage and Structures	Track B - Fracturing and Fractures Technical Session 43 – Woodway II Fracturing and Brittleness	Track C – Petroleum Technical Session 47 – Woodway III Depletion Induced Surface Subsidence	Track D – Interdisciplinary Technical Session 51 -- Woodway I Subsurface Integrity
02:00 pm-02:15 pm	320 S. Sobolik Implementation of a Full-Dome, Sonar-Based Finite Element Geomechanical Model to Analyze Cavern and Well Stability at the West Hackberry SPR Site	369 H. Fernau Load-Rate Dependence of Rock Tensile Strength Testing: Experimental Evidence and Implications of Kinetic Fracture Theory	47 L. Louis Using Maximal Inscribed Spheres for Image-Based Compaction Forecasting	37 R. Schultz Critical Issues in Subsurface Integrity
02:15 pm-02:30 pm	345 B. Park Omission of Wellbore Block for Computational Efficiency in Big Hill Strategic Petroleum Reserve Model	782 T. Suppachoknirun Evaluation of Multistage Hydraulic Fracture Patterns in Naturally Fractured Tight Oil Formations Utilizing a Coupled Geomechanics-Fluid Flow Model – Case Study for an Eagle Ford Shale Well Pad	355 P. Kulatilake 3-D Discontinuum Numerical Modeling of Ore Extraction, Backfilling and Subsidence in An Underground Iron Mine in China	71 S. Li Numerical Studies of the Deformation of Salt Bodies with Embedded Carbonate or Anhydrite Stringers
02:30 pm-02:45 pm	632 P. Berest Thermomechanical Effects of a Rapid Depressurization in a Gas Cavern	429 H. Munoz Rock Brittleness Capacity Upon Compressive Fracture Energy Dissipation to Assess Drilling Efficiency	370 J. Roholl Translating Laboratory Compaction Test Results to Field Scale	365 I. Mohamed Accurate Forecasts of Stress Accumulation During Slurry Injection Operations
02:45 pm-03:00 pm	662 F. ARTHUR Pillar Stability Analysis at Missouri S&T Dolomitic Limestone Experimental Mine	181 V. Sesetty Numerical Modeling of Hydraulic Fracture Propagation from Horizontal Wells in Anisotropic Shale	409 G. Marketos Rocksalt Creep, Uncertainties, and their Implications for Surface Subsidence above a Producing Rocksalt-Capped Reservoir	614 S. Gheibi Stress Path Evolution during Fluid Injection into Geological Formations
03:00 pm-03:15 pm	837 H. Kheradi Numerical Analysis of Seismic Behavior of Existing Rectangular Underground Structure Enhanced with Ground Improvement	243 Y. Boneh Wear of Geo-Materials by Mechanical Impulse	434 H. De Waal Lessons From Larger Than Expected Subsidence Due to Production of Halite and Natural Gas in Fyris/An	658 B. Wassing Modelling of Fault Reactivation and Fault Slip in Producing Gasfields Using a Slip-Weakening Friction Law.
03:15 pm-03:30 pm	783 A. Seiphoori Microstructural Characterization of Opalinus Shale	168 W. Jin Simulation of Mode II Unconstrained Fracture Path Formation Coupled with Continuum Anisotropic Damage Propagation in Shale	680 J. Cornet Shear Enhanced Borehole Closure.	668 P. Roy Studying the Impact of Thermal Cycling on Wellbore Integrity During CO <sub>2</sub> Injection

Wednesday, 29 June 2016				
Time	Track a - Mining & Civil Technical Session 40 – Galleria III Rock Properties for Underground Excavation	Track B - Fracturing and Fractures Technical Session 44 – Woodway II Rock Mass, Fault Zone, and Fractured Rock Characterization 2	Track C – Petroleum Technical Session 48 – Woodway III Integrated Reservoir Geomechanics 2	Track D – Interdisciplinary Technical Session 52 -- Woodway I Coupled Processes - Mechanical Responses
04:00 pm-04:15 pm	117 K. Hashiba Factors Affecting the Loading Rate Dependence of Rock Strength	397 R. Goteti Evolution of Relay Zones in Normal Faulted Terranes: Integrating Field Geological Studies with Forward Geomechanical Models	200 B. Lin Evaluating Constitutive Models for Simulation of Water Injection in Land Facies Karamay Oil Sand Reservoirs	229 C. David Water Weakening Triggers Mechanical Instability in Laboratory Fluid Substitution Experiments on a Weakly-Consolidated Sandstone
04:15 pm-04:30 pm	411 W. Roggenthen Acoustic Velocities and Pillar Monitoring on the 4850 Level of the Sanford Underground Research Facility	648 P. Shi Rock Mass Grouting in Major Weakness Zones During Subsea Tunneling	205 H. Stockhausen Multidisciplinary Interpretation of a Tight Gas Reservoir to Understand Its Production Behavior, Northwestern Africa. a Change of an Old Paradigm Model	364 G. Ren Fully Coupled Geomechanics and Reservoir Simulation for Naturally and Hydraulically Fractured Reservoirs
04:30 pm-04:45 pm	475 W. Liang Study on Hydraulic Fracturing of Large-Size Coal Mass Containing Natural Macro- Fractures	678 W. Greenwood UAV-Based 3-D Characterization of Rock Masses and Rock Slides in Nepal	209 T. Berard 3D Geomechanics Completion Quality Mapping	419 J. Nopola Mitigation of the Thermo- mechanical Impacts of the Rock Melt Borehole Sealing System
04:45 pm-05:00 pm	613 S. Akutagawa On-Site Visualization methods of axial forces in ground supporting members without using electricity	705 A. Nolting Spatial and Temporal Characterization of Mechanical Rock Properties From West Caicos, British West Indies	294 y. wang Simulations and Case Studies for Enhancing Production in a Stress-sensitive Fractured Carbonated Reservoir	450 H. Yoon Rigorous Modeling of Coupled Flow and Geomechanics in Largely Deformable Anisotropic Geological Systems
05:00 pm-05:15 pm	688 S. Warren Empirical Ground Support Design Recommendations for Underground Gold Mines in Nevada	41 W. Hu The Effect of Smooth-Joint Parameters on the Macro Mechanical Behavior and Failure Modes	324 U. Prasad Integrated Evaluation of Haynesville Shale with Special Emphasis on Anisotropy	451 N. Thorp Characterization of a Pulsating Drill Bit Blaster
05:15 pm-05:30 pm	763 M. Rahjoo Stress-Induced Spalling Analysis of Extraction Level Pillars Using a 3-D Extensional Strain Failure Criterion	569 A. Modiriasari Monitoring Rock Damage Caused by Cyclic Loading Using Seismic Wave Transmission and Reflection	285 B. Crawford Incorporating Universal Scaling of Fracture Stiffness and Surface Roughness Effects for Improved Productivity Prediction in Naturally Fractured Reservoirs	864 S. Zhi A Parametric Study on Gas Outbursts Induced by Gas Desorption

## Short Courses

### Short Course #1

**Title:** Shale Gas GeoEngineering

**Instructor:** Maurice Dusseault, Professor, Geological Engineering, University of Waterloo, Ontario, Canada

**Venue:** The Westin Galleria Houston

**Date:** Two Day Course: Saturday, 25 June 2016; 8:30 am – 5:00 pm; Sunday, 26 June 2016; 8:30 am – 5:00 pm

Fundamental to the success of a shale gas project is knowing the quality and characteristics of the resource, choosing the best development approach, and evaluating the results in a science and economics framework. This two-day short course will cover the geoscience foundation of shale gas reservoir knowledge, giving the participant a broad knowledge of the geoscience models, essential information that must be collected, and the methods of collecting it to yield valuable engineering information. Then, the course will focus on developing a strong qualitative and semi-quantitative understanding of hydraulic fracturing mechanisms in naturally fractured rocks. Because the basis of a successful stimulation

design is understanding rock mechanics and hydraulics, this course will focus on the geomechanics aspects of fracturing using injection fluids such as slickwater or viscosified fluids to carry proppants.

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## **Short Course #2**

**Title:** Modeling of Coupled Hydro-Mechanical Deformation and Fracturing Processes in Geomechanics

**Instructor:** Dr. Andrea Lisjak, Geomechanica Inc.

**Venue:** The Westin Galleria Houston

**Date:** Sunday, 26 June 2016; 8:30 am – 4:30 pm

**Description:** The hybrid finite-discrete element method (FDEM) is an explicit numerical approach that combines continuum mechanics principles (FEM) with discrete element algorithms (DEM) to simulate multiple interacting deformable and fracturing bodies. With its ability to qualitatively and quantitatively reproduce failure processes in brittle materials, FDEM is gaining increasing acceptance in civil, mining, geological, and petroleum engineering applications, where fracture and fragmentation processes are key to fully understanding the rock mass behaviour. Recently, Geomechanica's FDEM software, Irazu, has been enhanced with full hydro-mechanical (H-M) coupling to model fluid flow and fluid-induced fracturing in unconventional plays.

This one-day course will combine theoretical lectures on the fundamental principles of FDEM with practical modeling sessions where participants will be guided through several simulation cases. The course will start with a general introduction to the FDEM modelling philosophy and its application to engineering geology, rock mechanics, and geophysics problems. After a quick review of the basic algorithms, such as finite element deformation, contact detection, and contact interaction, the fracture model will be discussed in more depth. More advanced features of Irazu, including: in-situ stress initialization, rock excavation, and the incorporation of rock-reinforcement and Discrete Fracture Networks (DFNs), and hydro-mechanical coupling will also be introduced. In the second part of the course, participants will gain valuable hands-on experience through a series of practical modelling exercises using Geomechanica's Irazu software to model practical H-M-coupled problems in oil & gas, geothermal, and civil engineering applications.

Highlights of this hands-on short course include:

- Numerical modeling of complex, non-linear, coupled rock engineering/geomechanics problems;
- Rock fracture and fragmentation;
- Fluid flow and fluid-induced fracturing in unconventional plays;
- Fundamental principles of the state-of-the-art Irazu finite-discrete element software; and
- Hands-on Irazu tutorials.

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## **Workshops**

## **Workshop #1**

**Title:** ARMA/AAPG Workshop on Advances in Reservoir Engineering Applied to Sedimentary Geothermal Energy

**Date:** Thursday and Friday, 23-24 June 2016, 8:00 am – 6:00 pm

**Venue:** The Westin Galleria Houston

This workshop will explore the benefits of recent developments in oil and gas, viz., horizontal drilling and massive hydraulic fracturing, and how these may be applied to elevate the viability of the recovery of geothermal energy from sedimentary reservoirs. The meeting is sponsored by the SedHeat initiative with support from NSF. The workshop is hosted by ARMA and the American Association of Petroleum Geologists (AAPG).

## **Workshop #2**

**Title:** Workshop on Hydraulic Fracturing

**Date:** Friday, 24 June 2016, 8:00 am – 4:00 pm

**Venue:** The Westin Galleria Houston

The objective of the workshop is to improve understanding of fundamental physics involved in hydraulic fracturing. This workshop will focus on three important fracturing processes: fracture initiation, propagation, and closure.

1. FRACTURE INITIATION, including near-wellbore complexity, fracturing criteria, plasticity, heterogeneity, fracture interference, etc.
2. FRACTURE PROPAGATION, considering discontinuities, natural fractures, brittle-ductile layers, multi-fracturing and branching, rock and fluid coupling, et.
3. FRACTURE CLOSURE, covering diagnostics, propped fracture, effective conductivity, fluid leak-off, SRV, etc.

Besides featuring three overviews and ten invited speakers, the workshop is specially designed to leave 50 minutes in each session for dialogue and audience participation in discussions.

## **Workshop #3**

**Title:** Geomechanics in Unconventionals Workshop for Asset Teams

**Date:** Saturday, 25 June 2016, 9:00 am – 5:00 pm

**Venue:** The Westin Galleria Houston

## **OilField Geomechanics LLC**

This one-day workshop will be comprised of seven, one-hour sessions on geomechanics-related subjects that are critical to the Asset Teams that characterize, develop, drill, complete, and refrac unconventional plays. Key topics will include the role of natural fractures, stresses, and pore pressure as well as key issues such as monitoring, stimulation design and design tools, and refracturing. The emphasis of each session will be on



geomechanics and be led by a single keynote speaker with 40 minutes of presentation and 20 minutes of facilitated discussion.

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#### **Workshop #4**

**Title:** How Laboratory Geomechanics Testing Adds Value to Exploration and Production

**Date:** Saturday, 25 June 2016, 12:30 pm – 6:00 pm

**Venue:** The Westin Galleria Houston

Starting from prevention of well blowout to designing effective hydraulic fracturing schemes to produce from ultralow permeability reservoir, principles of geomechanics have been used frequently in the past few decades. For geoscientists or reservoir engineers, typical practice involves extracting critical information from sonic logs and/or seismic data to construct pore pressure prediction model or detailed 3D earth models. However, the log measurements need to be validated against laboratory measured values to increase confidence in modeling exercise. This workshop aims at familiarizing the audience with various laboratory testing techniques, how to design a laboratory test program, to develop an understanding of good vs. bad data, and how to use the data subsequently. Following this, audiences will be taught how to construct a wellbore-centric mechanical earth model using laboratory data. As a final step, audiences will be given a tour to the laboratory where they will be shown up close how to set up a test and acquire data, common problems and troubleshooting. This workshop and laboratory visit is hosted by MetaRock Laboratories.

#### **Workshop #5**

**Title:** Microseismic Geomechanics from Laboratory to Field Scale Across All Industries

**Date:** Sunday, 26 June 2016, 8:00 am – 5:30 pm

**Venue:** The Westin Galleria Houston

This workshop covers microseismic geomechanics technology explained by experts across a wide range of industries who are studying the physics of rock deformation over a wide range of length scales.

#### **Workshop #6**

**Title:** Workshop on Petroleum Geomechanics Testing

**Date:** Sunday, 26 June 2016, 8:00 am – 4:00 pm

**Venue:** The Westin Galleria Houston

The last Workshop on Petroleum Geomechanics Testing took place in 2013, and in that time the ISRM Uniaxial-Strain Working Group has finalized the *ISRM Suggested Methods for Uniaxial-Strain Compressibility Testing for Reservoir Geomechanics*. A topic not fully addressed in the suggested methods is the impact of sample condition (cleaned vs. native-state, fluids used for saturation, etc.) and test conditions (e.g., temperature, true stress/pressure vs. effective stress approach) on the rock behavior. In prior workshops, we have touched only briefly on this topic. This workshop will focus on the effects of sample and test conditions (temperature, fluid type, true in-situ stress/pressure, etc.) on compaction/compressibility, triaxial compression and permeability vs. stress behavior. The

workshop will include test types other than compaction/compressibility, since they are also of high importance to petroleum geomechanics.

**Workshop #7**

**Title:** ARMA Future Leaders/Students Open Discussion: "What's Your Problem?"

**Date:** Sunday, 26 June 2016, 3:00 pm – 5:00 pm

**Venue:** The Westin Galleria Houston

This workshop is an open forum for students and early career researchers to discuss problems they are having in any aspect of their research in an open and positive environment. The ARMA Future Leaders will supply a group of researchers from all aspects of rock mechanics to help answer questions and solve problems you are having with your research. Example problems include, but are by no means limited to: instrument calibration, data validation, experimental techniques, code optimization, solution convergence, and model calibration.