## Workshop makes headway on naturally fractured reservoirs

The 3rd EAGE Workshop on Naturally Fractured Reservoirs themed as 'Calibration Challenges' was held in Muscat, Oman on 5-7 February. Prof Sebastian Geiger (Heriot-Watt University) and Bertrand Gauthier (Total), co-chairs of the Technical Committee, report.



Following the successful EAGE Workshops in Nafplio, Greece (2011) and Muscat, Oman (2013), the third instalment of the series took place again in Muscat. It was delayed until 2018 due to the downturn in the industry. However, this delay allowed EAGE to ensure that, once again, a strong and diverse group of delegates was able to attend. In total 61 delegates from 32 different institutions and 17 countries, including six students, attended, and the workshop was generously supported by Saudi Aramco.

The theme of the workshop 'Calibration Challenges' was recognition of the significant difficulties that are encountered when calibrating static and dynamic models of naturally fractured reservoirs to reduce uncertainties at any stage of the field life. Excellent oral and poster presentations explored what kind of analogue data could be used to calibrate reservoir models, at what scales reservoir models need to be built to ensure efficient calibration, and how to best use dynamic data to calibrate reservoir models.

The workshop began with an inspiring field trip to Jebel Madmar, organized by Loic Bazalgette and Pascal Richard. These world-class outcrop analogues of a fractured reservoir allowed the delegates, forming syndicate teams to stimulate discussion, to observe 2D and 3D geometries of fractures and fracture corridors, debate which scales and geological features could be observed in wells and represented in reservoir models, and explore the practical aspects and challenges of characterizing, modelling, calibrating and drilling naturally fractured reservoirs.

Back in Muscat, the first session on the use of analogue models for calibration welcomed Kevin Bisdom (Shell) as a keynote speaker. His intriguing talk reviewed the good, the bad, and the ugly in the practice of fractured reservoir characterization, a talk which not only linked back to the field trip but set the scene for the rest of the workshop.

Key challenges are still the use of 1D data (e.g., fracture spacing) to characterize 3D fracture networks in the subsurface, and the fact that high-resolution 3D outcrop models are still reduced to 1D data to populate reservoir models. Yet, modern data collection methods (e.g., drone imagery) and simulation approaches (e.g., unstructured grid reservoir simulation) now allow us to generate detailed 3D outcrop models and compute effective properties (e.g., permeability), which can be used as input to, or constraints for, the calibration of 3D reservoir models.

Presentations by Giovanni Bertotti (TU Delft), Juliette Lamarche (University Aix-Marseille), Claire Bossennec (Universite de Lorraine) and Pierre Bruna (TU Delft) all reiterated the value of detailed outcrop analogue studies for identifying the drivers that form fracture networks and predicting subsurface fracture patterns more reliably. However, they also emphasised that outcrop data are not always conclusive and should hence be used to define end-members of fracture network types, which can then be linked to the tectonic stress evolution to obtain more valuable information for the calibration of reservoir models.

The second session on the scales of models was highlighted by the excellent keynote lecture from Steven Laubach (UT Austin), who provided clear evidence for the need to include the role of diagenesis for understanding the formation and growth of fractures, as well as the creation and destruction of mechanical fracture apertures.

Presentations by Michael Welch (DTU), Mochel Garcia (KIDOVA) and Bertrand Gauthier (Total) discussed how discrete fracture network (DFN) models could be improved to account for geomechanical effects and how geological constraints observed in wells can be used to improve the uncertainty quantification in DFN models. Romain Plateaux (Schlumberger) showed how the likelihood of fracture reactivation is influenced by the local stress regime and fracture orientation, valuable insights which could be used in conjunction with DFN modelling. Stephan Matthai (University of Melbourne) and Hamid Nick (DTU) both revisited the challenges constraining and quantifying fracture apertures, as these are first order controls on single- and multi-phase flow in fractured formations, and strongly impact the estimation of effective permeability tensors. Daniel Wong (Heriot-Watt University) offered a new workflow based on effective medium theory, which not only allows us to compute effective fracture and matrix permeabilities efficiently and accurately, it also enables us to quantify the impact of upscaling smaller-scale fractures.

The last session, on using dynamic data for calibrating fractured reservoir models, began with an inspiring keynote presentation from Hussein Hoteit (KAUST). He reviewed the state-of-the-art of fractured reservoir simulation methods that aim to represent fractures explicitly, emphasising the opportunities that advanced gridding methods and simulation algorithms offer for overcoming long-standing problems in the dynamic simulation of naturally fractured reservoirs, presenting the Tengiz field as an interesting case-in-point.

Dan Bonter (Hurricane Energy) gave a detailed review of the characterization and appraisal of the Hurricane Field, a recently discovered fractured basement reservoir offshore UK, while Lingli Wei and Keith Ranswley (both Shell) discussed a case study that demonstrated how they were able to represent multi-scale fracture networks in a reservoir model that was used to manage a steam flood project in Oman. Pascal Richard (Shell) and David Egya (Heriot-Watt University) presented case studies which emphasized the value of linking pressure transient data with geological insights, fracture properties, and conceptual fracture models to improve the calibration of fractured reservoir models rather than

relying upon classical pressure transient analysis. The session was concluded by a presentation by Victoria Spooner (Heriot-Watt University), who demonstrated how fast numerical screening methods, so-called flow diagnostics, can provide insights into the dynamic properties of different fractured reservoir models, before selected models are deployed for subsequent reservoir simulation.

As with the previous EAGE workshops in the series, ample discussions accompanied the interesting talks and around the posters, ranging from detailed technical aspects such as the role of geomechanics for constraining fracture networks, the challenges surrounding uncertainty in data, or the need to build models that are approximately right, not precisely wrong. The delegates also agreed that there are key problems that still need to be solved, namely how to include and preserve uncertainties in reservoir modelling throughout all stages of field life to make informed reservoir management decisions, how to take the knowledge generated in academia to identify and make viable short cuts in every-day workflows, how to generate fully integrated models that include geomechanical effects and not only focus on the fractures but the reservoir as a hole, how to accurately model relative permeability in fractures, and how to generate shared datasets that can be used by the entire community as a resource to drive R&D and innovation.

Overall, the workshop highlighted the excellent progress that is being made, and has been made, in the challenging field of naturally fractured reservoir characterization, modelling, and simulation. Industry and academia alike share the same struggles and need to continue to share ideas and exchange data in order to further advance our knowledge.

Hussein Hoteit's keynote talk asked the question 'Are we there yet?'. The answer was: 'We continue to move in the right direction and covered significant ground, but our journey is far from over'. Hence we all look forward to meeting again in 2020 for the 4<sup>th</sup> EAGE Workshop on Naturally Fractured Reservoirs.



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