EAGE

EUROPEAN ASSOCIATION OF GEOSCIENTISTS & ENGINEERS

Fifth EAGE Workshop on Naturally Fractured Rocks

NATURALLY FRACTURED ROCKS FOR SUSTAINABLE ENERGY - CAN VIRTUAL REALITY AND OTHER EMERGING TOOLS HELP IMPROVE OUR UNDERSTANDING OF SUBSURFACE FLUID MOVEMENTS?

6-8 OCTOBER 2024 • MUSCAT, OMAN

- **Programme**

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WORKSHOP OVERVIEW

Please join us for the much anticipated continuation of the successful workshop series under a slightly different name Naturally Fractured Rocks (NFR) to be held in Muscat (Oman) in October 2024 under the theme "Naturally Fractured Rocks for Sustainable Energy - can virtual reality and other emerging tools help improve our understanding of subsurface fluid movements?"

The 3-day event will feature a 1-day field trip to Jebel Madar to characterize and understand the fracture systems in this structure, which is considered an unaltered analogue to nearby subsurface field developments.The ensuing 2-day long technical sessions will then cover the key topics of the workshop.

TOPICS

New insights into NFR

- Recent progress in the understanding of NFR in geological formations
- Linking NFR from outcrop observations with sub-surface characterisation
- Structural diagenesis
- Optimizing NFR representation in numerical models

Application domains

- Geothermal systems (e.g., EGS)
  - natural and induced fracture transmissivity, thermal short circuiting
- Carbon Capture, Utilisation and Storage (CCUS)
  - caprock integrity
  - storage
    - mineralization
- Static and dynamic characterisation of fractured aquifers
- Geoenergy storage
- Old and new knowledge - using expertise from Oil & Gas in new energy - what could be learned, what is not applicable and why

Tools & Methods

- Use a virtual reality (VR) data set from Jebel Madar to compare observations and conclusions from the field trip with this outcrop seen in virtual reality and address the following topics
  - VR and how it is used as an emerging technology to characterize subsurface system
  - advances and limitations
- Data science approaches for uncertainty evaluation

FIELD TRIPS IN NATURALLY FRACTURED ROCKS

Field Trip to Jebel Madar

Date: Sunday, 6th October 2024; 08:00 - 16:00

Trip Leaders

Pascal Richard[1], Juliette Lamarche[2], Thomas Finkbeiner[3], François Civet[4]
[1]PRgeology; [2]Aix Marseille University – CEREGE; [3]King Abdullah University of Science & Technology; [4]VR2Planets

Objectives

The 1-Day excursion will take place as part of EAGE's Naturally Fractured Rocks taking place from 6-8 October 2024, in the foothills of the Oman mountains where the absence of vegetation provides world class outcropping conditions. We will visit Jebel Madar, a salt core anticline developed in the Tertiary as the result of the collision between the Arabian and the Eurasian plates, which has shaped the present-day geometry of the Oman Mountains. The outcrops of interest are carbonate formations (e.g. Natih and Shuaiba), which are important reservoirs for Oman.

The main objectives of the excursion will be two-folds. First, we aim to observe faults and fractures corridors in carbonates, with a strong focus on geometry, timing of development, impact of mechanical stratigraphy.

Jebel Madar South West corner overview from drone survey. (picture from Drone survey, KAUST).

Fracture pavement.

Small scale fracture corridor on pavement

We will make outcrop observations both in sections and on pavements. We will link the observations to the known regional phases of deformations. We also want to link the understanding of their development and the geometries observed to the strategy we would used to capture them in sub-surface models. We hope to have a mix of discipline experts on the field trip in order to have integrated discussions. Secondly, participants will experience collaborative virtual geology from the same outcrop utilizing state of the art 3D visualization tools. This provides an opportunity to trial the added value of virtual field trips after having seen the real fractured rocks in the field.

This enables participants to better handle both field work and analysis. In the field, we will observe a complex structural pattern of faults (e.g. normal faults, transtensional faults, grabens) and natural fractures (e.g. layer bound fractures and fracture corridors) that deformed the carbonates. Along the day, we will switch from large-scale faults down to small fractures. In combination with the virtual field, we will understand their 3D geometry and imbrication, the relations to the mechanical stratigraphy and the timing of deformation. Participants will appreciate how field and virtual geology help to up-scale when creating reservoir-size geological models.

Logistics

The outcrops are located only a 2 ½ hours drive away from the workshop venue. Safe transportation is assured by high standard 4 wheel vehicles with professional, experienced and well trained drivers from the Omani tour organizer Shuram. The field trip will consist of a ~ 3 km long hike, with several stops. We will have lunch half way through the day in the middle of the Jebel (note, you will not need to carry your lunch). On each location, we will have plenty of time for observations, exercises, and numerous discussions. We look forward to your active contribution in the field! Importantly, temperatures in Oman in October are expected to be mild for the country. However, the hike will be on rocky terrain and in the sun. It will be important to wear adequate clothing and footwear and to be in good physical conditions.

TECHNICAL PROGRAMME

Oral Presentations | Monday 7 October 2024

AFRAH BALLROOM 2	
08:00	**Registration and Welcome Coffee**
08:30	**HSSE by Hotel**
08:35	**Welcome by Co-Chairs Thomas Finkbeiner (KAUST) & Mandefro B. Woldeamanuel (Aramco)**
08:50	**Opening Address: Shadia Farsi (PDO)**
09:05	**Opening Keynote: Munahi Otiebi (Aramco)**
SESSION 1: New insights into NFR - (Part I) Session Chairs: Thomas Finkbeiner & Mandefro B. Woldeamanuel	
09:35	**Keynote 1: Carbon Mineralization - Mouadh Addassi (KAUST)**
10:05	**Natural fractures and hydrothermal alteration in the Brazilian Pre-salt - an example from Santos Basin -** R. Correa, Petrobras S.A.
10:25	**Fracture Sequence and Loading Path in Folded Carbonates of Albania Foreland -** J. Lamarche, Aix Marseille University
10:45	**A New Methodology for Integrated 3D Geologic Reconstruction and Fracture Network Modelling using Outcrop Scan Datasets -** J. Van Dijk, OCRE Geoscience Services
11:05	**Discussion Session - This session will cover additional Q&As / Discussions around all the papers presented in Session 1 in the morning**
11:20	**AM Coffee Break**
11:50	**New insights into fracture-modelling of naturally fractured basement reservoir - A case-study from Norwegian North Sea -** S. Ahmad, Halliburton
12:10	**Comparing fracture networks across scales: The Minkowski Fingerprint Distance -** R. Prabhakaran, FAU Erlangen-Nürnberg
12:30	**Modelling the uncertainties in reservoir properties distribution of a diagenetically overprinted fractured carbonate field -** S. Quental, DNO ASA
12:50	**Discussion Session - This session will cover additional Q&As / Discussions around all the papers presented in Session 1 in the afternoon**
13:00	**Lunch Break**

Oral Presentations | Monday 7 October 2024

SESSION 2: Application Domains
Session Chairs: Juliette Lamarche & Michael Welch

14:00	**Fractured Reservoirs of Oman: Learnings, Challenges & Opportunities in Reservoir Development and Management -** D. Repol, Petroleum Development Oman
14:20	**De-risking Faults and Fractures for Subsurface Storage Applications: An Integrated Workflow -** K. Bisdom, Shell Global Solutions International BV
14:40	**Numerical Analysis of Foam-Assisted and Continuous CO2 flooding for Utilization and Storage in an oil reservoir -** A. Bello, Skolkovo Institute of Science and Technology
15:00	**Critical Role of Fracture Characterization in Geothermal Exploration: A Case Study in Western Saudi Arabia -** I.S. Abu-Mahfouz, King Fahd University of Petroleum & Minerals (KFUPM)
15:20	**Discussion Session - This session will cover additional Q&As / Discussions around all the papers presented in Session 2**
15:40	**PM Coffee Break**

SESSION 3: Exploring Jebel Madar: An Immersive VR Experience

16:10	**Keynote 2: - Discovering Jebel Madar: How Virtual Reality Technology Unveils New Insights - Pascal Richard**
16:40	**Introduction to Jebel Madar Poster Session by Pascal Richard**

Jebel Madar Poster Session

16:45	**Fracture characterization from field-scale reservoirs outcrop analogue: perspective from Jebel Madar -** Y. Panara, King Abdullah University Of Science And Technology
16:55	**Digital Outcrop Modelling of faulted and fractured salt-cored anticline of Jebel Madar (North Oman) -** N. Menegoni, King Abdullah University of Science and Technology
17:05	**Fracture network heterogeneity analysis in Jebel Madar, Oman -** M. Meha, King Abdullah University Of Science And Technology
17:15	**Closing Remarks**
17:25	**Close of Day 2**

Oral Presentations | Tuesday 8 October 2024

AFRAH BALLROOM 2

08:00	**Registration and Welcome Coffee**
08:30	**Welcome by Co-Chairs Thomas Finkbeiner (KAUST) & Mandefro B. Woldeamanuel (Aramco)**

SESSION 4: Tools & Methods
Session Chairs: Israa Salem Ali Abu Mahfouz & Mandefro B. Woldeamanuel

8:40	**Keynote 3: Nicolas Beaudoin (University of Pau)**
09:10	**A Framework for Life-cycle Subsurface Uncertainty Quantification -** L. Wei SubsurfaceLab
09:30	**Fracture Network Connectivity and Heterogeneity Evaluation Using Flow Diagnostics on a Graph Theory-Based Fracture Model Database -** J. Li Dimue Technologies; School of Earth Resources, China University of Geosciences (Wuhan)
9:50	**Discussion Session - This session will cover additional Q&As / Discussions around all the papers presented in Session 4**

Poster Session - New insights into NFR & Application Domains

10:00	**Lightning Session**
	Python toolbox for fracture stratigraphy quantification and mechanical interface characterization - P.J.F. Namongo Soro Aix-Marseille University
	Quantitative Fracture Characterisation from UAV Photogrammetry in Irish Mississippian Carbonates - S. Vokes University College Dublin
	Characterising fracture network analogues for subsurface geothermal modelling - Insights from Northern Bavaria - R. Smith Geozentrum Nordbayern, Friedrich-Alexander Universität Erlangen-Nürnberg
	Fracture network characterization of the Lower Cretaceous Shu'aiba outcrops in central Oman, Wadi Baw - R. Iakusheva KAUST
	Extending the Limit of High resolution LWD Borehole Imaging Technology in Challenging Drilling Environments - M. Fouda Halliburton
10:10	**AM Coffee Break**

SESSION 5: New insights into NFR - (Part II)
Session Chairs: Béatrice Ledésert & Thomas Finkbeiner

10:40	**Modelling fracture propagation across layer boundaries using Linear Elastic Fracture Mechanics -** M. Welch DTU
11:00	**An Insight into Fracture Pattern and Characterization in Salt Dome Area -** S. Zhang
11:20	**Advance Modelling of Subsurface Flows in Complex Fracture Network Systems using Discrete Fracture Networks Modelling Approach -** M. Pal KTU
11:40	**Quantification of Diagenesis in Carbonate Rocks using Borehole Image Logs -** M. Belayneh Woldeamanuel
12:00	**Discussion Session - This session will cover additional Q&As / Discussions around all the papers presented in Session 5 in the morning**
12:20	**Lunch Break**
13:20	**Inertia-driven fluid flow in natural fracture networks -** C. Bui University of Melbourne
13:40	**Carbonate fractured reservoirs comprehensive wellbore imagers and core analysis for DFN model calculation -** N. Evdokimov
14:00	**Faults in Enhanced Geothermal Systems : Soultz-sous-Forêts site and its analogue in the Upper Rhine graben -** B. Ledésert Cy Cergy Paris Université
14:20	**Impact of Poroelasticity and Thermoelasticity on Hydraulic Properties of Natural Fractures -** Q.Li, M. Belayneh Woldeamanuel Aramco
14:40	**Discussion Session - This session will cover additional Q&As / Discussions around all the papers presented in Session 5 in the afternoon**
15:00	**PM Coffee Break**

SESSION 6: Final Discussion

15:30	In this final session, we will collectively reflect on the highlights, key takeaways, and transformative moments that have defined our time together. It's an opportunity to distill the essence of our discussions, celebrate the shared knowledge, and chart a course forward.
16:30	**Final closing remarks by co-chairs**
16:40	**Close of Workshop**

VENUE

Grand Hyatt Muscat

Shatti Al Qurm, P.O. Box 951 Muscat, Oman
For room rates for event attendees at this venue please check the event website for more information.

SPONSORS

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CONTACT

For more information on the workshop, please get in touch with the EAGE MEA team via middle_east@eage.org or +971 4 369 3897.

REGISTRATION FEES

REGISTERED AND PAID	Early Registration - 13/4/24 - 25/8/24	Regular Registration 26/8/24 - 23/9/24	Registration 24/9/24 - 8/10/24
EAGE Green Member	1090	1290	1540
EAGE Bronze/Silver/Gold Member	940	1140	1390
EAGE Platinum Member	940	940	940
Non-member	1190	1390	1640
EAGE Student Green Member	545	595	645
EAGE Student Bronze/Silver/Gold Member	470	520	570
Student Non-member	570	620	70

1 Members please note: To qualify for the member registration fee, your EAGE membership dues for 2023 must have been paid and confirmed. The processing time for membership applications or renewals is 10 working days.
2 To qualify for the reduced student registration fee:
- Students must be enrolled in a full time study programme at a recognized university or institute
- The registration must be accompanied by a copy of a student ID card and/or official proof of enrolment

3 The Non-member fee includes EAGE membership for the remainder of 2024 (31/12/2024). This membership will be activated shortly after the event.
4 Student Non-members cannot be older than 34 years of age (when registering).
5 Green membership status gives you a USD 50 discount (USD 25 for students) on the Non-member fee for each EAGE event registration; starting from the Bronze status, you can benefit from an even greater reduced EAGE member registration fee. Find here for more information on the recognition programme.
All fees are in USD. One US Dollar of your total registration fee is donated to the EAGE Green Fund.

UPCOMING EVENTS 2025

INNOVATIVE TECHNOLOGY FOR RESERVOIR OPTIMIZATION: FIFTH EAGE WELL INJECTIVITY & PRODUCTIVITY IN CARBONATES (WIPIC)

14-16 April 2025 • Doha, Qatar

FIRST EAGE ATLANTIC GEOSCIENCE RESOURCE EXPLORATION & DEVELOPMENT SYMPOSIUM

5-7 May 2025 • Marrakech, Morocco

SIXTH EAGE BOREHOLE GEOLOGY WORKSHOP

22-24 September 2025 • TBC

SECOND AAPG/ EAGE MEDITERRANEAN AND NORTH AFRICAN CONFERENCE (MEDINA)

22-24 September 2025 • Tunis, Tunisia

EIGHTH EAGE BOREHOLE GEOPHYSICS WORKSHOP

29 September - 1 October 2025 • Al Khobar, Saudi Arabia

NINTH EAGE HIGH PERFORMANCE COMPUTING WORKSHOP

October 2025 • Barcelona

SECOND GEO 4.0: DIGITALIZATION IN GEOSCIENCE SYMPOSIUM

20-23 October • Riyadh, Saudi Arabia

EAGE/AAPG WORKSHOP ON TECTONOSTRATIGRAPHY OF THE ARABIAN PLATE: STRUCTURAL EVOLUTION OF THE ARABIAN BASINS

3-5 November • Riyadh, Saudi Arabia

SEVENTH EAGE ROCK PHYSICS WORKSHOP

10-12 November • Cape Town, South Africa

THIRD EAGE SEABED SEISMIC TODAY WORKSHOP

24 - 26 November • Manama, Bahrain

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