Workshop Summary: "Large Block Hydraulic Fracturing in the Laboratory"

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Preceding the 59th US Rock Mechanics/Geomechanics Symposium

Egor Dontsov, Thomas Finkbeiner, Roberto Suarez-Rivera

The workshop titled **"Large Block Hydraulic Fracturing in the Laboratory"** was held on June 8th, 2025, in Santa Fe, immediately prior to the 59th US Rock Mechanics/Geomechanics Symposium. This was a truly international gathering, drawing speakers and participants from the United States, Canada, Saudi Arabia, Switzerland, China, and beyond.

Objectives and Access to Materials

The primary goals of the workshop were to:

- Review key accomplishments to date,
- Assess the technical value of large block testing,
- Discuss challenges and future directions for experimental programs.

All presenters agreed to make their presentations available, which can be accessed on the ARMA HFC website. The agenda is available there as well. This ensures that those who were unable to attend may still review the content and benefit from the discussions. Also, a list of useful references is provided at the end of the document.

Highlights and Themes

1. The Purpose of Large Block Experiments

The first session addressed the central question of why conducting large block laboratory experiments. The audience identified several compelling reasons:

- **Model and Theory Validation**: These experiments validate key hydraulic fracture regimes, such as viscosity- versus toughness-dominated propagation. By selecting appropriate fluid viscosities, researchers may replicate fracture propagation akin to field-scale behavior, despite the lab's reduced dimensions. Experiments helped validating fracture propagation in anisotropic rocks and the effect of fracture toughness anisotropy on hydraulic fracturing.
- **Monitoring Technology Testing**: Large blocks offer a controlled setting ideal for testing active/passive acoustic monitoring and distributed acoustic sensing (DAS) via fiber optics. Researchers can evaluate event detection thresholds, localization accuracy, reliability, and repeatability of these techniques.

2. Influence of Rock Type and Fabric

Many presentations emphasized the critical role of rock fabric on hydraulic fracture propagation. While unconventional rocks are often considered elastically anisotropic with toughness anisotropy, they also exhibit bedding-plane delamination due to weak interlayer bonding. Examples are interfaces in thinly laminated shales and in shale/carbonate stacked systems, which are abundant in mudstone reservoirs. The presence of weak interfaces introduces tensile strength anisotropy, which can lead to preferential fracture propagation along weaker planes. Thus, when the vertical to horizontal stress contrast is smaller than the vertical to horizontal tensile strength contrast, horizontal fractures can develop along these interfaces, despite the presence of higher vertical stress. Several experimental results confirmed this concept. Moreover, weak interfaces in layered rock can create localized fracture complexities, such as step-overs and fracture branching, which hinder proppant transport.

3. Limitations of Small-Scale Testing and Scaling Challenges

A prominent theme was the difficulty of scaling laboratory results to field conditions. Although simple fracture geometries can be scaled well, the scaling of more realistic fractures that develop in the presence of complex rock structures is still not possible. Additional complications include:

- **System Compressibility**: Rapid pressure drops during fracture growth can cause a discrepancy between planned and actual injection rates.
- **Boundary Effects**: Fractures often reach the specimen's edge, limiting experimental utility for both theoretical validation and field analogs. This is particularly problematic when using smaller size blocks (1 ft x 1ft x 1ft)

- **Initiation Techniques**: Methods to initiate fractures—such as pre-cut notches, perforations, or thermal cracks via liquid nitrogen—were explored for their pros and cons.

4. Initiation of Multiple Fractures
It remains nearly impossible to replicate perforation friction in the lab, leading to unrealistic fluid distribution among fractures. An innovative workaround was presented using separate injection lines for each cluster, which was used to mimic field-scale diversion and pressure control.

5. Looking Forward: Practical Relevance and Research Frontiers
Perhaps the most thought-provoking discussions centered on the future of large block experiments. Two major challenges emerged:

1. **Field Relevance and Upscaling**: Although scaling issues have been discussed for decades, no universal solution has emerged. One perspective suggests acknowledging that full replication is unattainable. Instead, we can history-match small-scale models to laboratory results and then extrapolate to field conditions via simulation. This approach shifts the burden of scaling from the experiment to the model itself.

2. **Industry Engagement**: Another concern is that the industry may have ceased incorporating laboratory findings into field practices. This disconnect invites a fundamental question: *How can we make large block experiments directly useful to practitioners?*

Other questions that were discussed are as follows:

- Q: Could additional modeling, imaging, and simulation add more value?
  A: Yes, but it has mostly an academic value.
- Q: Can we better image crack tip initiation and fracture front propagation to improve our understanding of breakdown, propagation, and closure?
  A: This is considered an interesting direction, but probably mostly of academic nature.
- Q: Can we actually simulate proppant transport?
  A: This is difficult to achieve since proppant will have to be scaled accordingly and will be so small that suspension and fluids mechanics may change. Perhaps it is possible to do this in gelatin, where fracture openings are larger/ Also, if viscosity is scaled to ~1000 cp then we cannot expect any proppant settling.
- Q: What new questions can be answered?
  A: Three topics came to mind: what is the impact of pore pressure, temperature, and multiple wells/stages? Also, what is the actual viscosity through the perf (sometimes referred to as dynamic/shear viscosity)?
- Q: Why is industry moving away from laboratory testing and trying to rely solely on log-derived correlations?

A: Industry stopped learning and, thus, unwilling pay for such experiments anymore, Often, a relation to the field is missing, thus these experiments do not affect the decision making process.

- Q: How can we leverage what we learn in the laboratory for field applications OR how can we understand what "Completions Engineer" look for onsite in the field and try to replicate that in a laboratory to understand the phenomena in a more controlled environment?
  A: Onsite in the field the injection rate is monitored and controlled so that the maximum allowable pressure in the system is not exceeded. Further, their task and goal are to pump and dispose downhole into the created fracture(s) all material (fluids and proppants) provided and planned for. In this context rock mechanical aspects in the field seem irrelevant. It is the engineers designing and planning the stimulation in their offices who have an interest to understand rock mechanics better. Thus, one way to influence them is with the design software that they use. So, any knowledge gained in the laboratory should be utilized to update software code for such design packages. In short, one potential way to influence the field is to discover/study a new phenomenon in the lab and turn it into a programmable model, which is then used by completion engineers.

In summary, the current opinion is that for now, large block tests may best serve mostly the academic and research community by providing an arena for testing emerging models, improving imaging methods, and training future geomechanics professionals. Promising research directions include:

- Studying saturation effects,
- Evaluating the effect of temperature on fracture propagation (particularly for geothermal applications),
- Designing experiments involving multiple wells or stages.

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