Design and Implementation of a Novel Multi-frac Stimulation Concept in Utah FORGE EGS

1. **Design and Implementation of a Novel Multi-frac Stimulation Concept in Utah FORGE**
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   - Project Start and End Date: 04/01/2024-09/31/2026

2. **Project Objectives and Purpose**
   - Design and implement a reservoir stimulation concept in Utah FORGE EGS. Of particular emphasis is improving near-wellbore and well-to-well conductivity while enhancing the SRV and promoting self-propping, and heat exchange.
   - We propose to create multiple (1-3 depending on the cost/budget and operational constraints) narrow SRV zones with three to five closely spaced hydraulic fractures, placed sequentially.
   - Take advantage of pressure cycling of these fractures to impose strong pressure and stress changes on the rock lying within and adjacent to the fractured zone, thus promote shearing (with possible wing cracks) and opening of adjacent hydraulic fractures (HF) and existing natural fractures (NF) inside and outside the zone.
   - The fracture zone will also be subject to strong thermo-poroelastic stress during stimulation and production, leading to deformation on existing natural fractures, promoting cross-flow between the main hydraulic fractures.
   - The work intends to improve effective heat production from EGS via concepts relying on multi-stage fracturing.
3. **Technical Barriers and Targets**
   - The overarching concept is to use the imposed pressure and stress in the rock contained within the fracture zone and vicinity to generate shear and opening deformation to create an extended self-propped conductive fracture zone
   - Produce lower flow impedance between the injector/producer and enhance heat sweep
   - Year 1 targets are the selection of suitable zones and operational viability (M1-M9), and forward modeling of stimulation designs to assess the wellbore/reservoir response (M3-12).
4. **Technical Approach**
   - Compile/synthesize data for design modeling based on previous FORGE experience, existing geology, geomechanics, reservoir, geophysical, and well and completion data. Model different scenarios of injection and depressurization cycles, injected fluid viscosities and rates.
   - Assess stimulation growth direction, shape and size in relation to the production well, and estimate the impact of cyclic injection on shear stimulation of each zone, and analyze the impact on fracture growth from stress shadow and stress rotation due to coupled processes.
   - The overarching concept is to use the imposed pressure and stress in the rock contained within the fracture zone and vicinity to generate shear and opening deformation to create an extended self-propped conductive fracture zone. We will use advanced numerical modeling of the hydraulic fractures and of the rock mass (boundary and finite element methods) to enable treatment of a range of physics.
5. **Project Timeline (list milestones achieved and/or decision points)**
   - We have multiple milestones in Year 1 and there is a Go/NoGo at the end of Year 1.

	Actual Qtr.	Q2 24	Q3 24	Q4 24	Q1 25
	Project Qtr.	Q1	Q2	Q3	Q4
Project Milestones	Deliverable				
Task 0 – Project Management and Planning			●		
Task 1 – Selection of suitable zones and operational viability					
Sub Task 1.1 – Selection of the intervals for stimulation using all available relevant data from FORGE, including geological earth model, petrophysical and rock mechanical characterization, microseismic data, well logs and images, and in-situ stress estimates			X		
Milestone 1.1 -Stimulation interval candidates selected.			X		
Sub Task 1.2 – Design injection rate and volume to obtain desired frac extension. Check for coalescence and divergence of subsequent fractures placed into a zone and then numerical modeling. Compare to design to previous fracturing treatments.				X	
Milestone 1.2 -Rate and volume requirements, and the impact of different injection schemes determined by integrating field data and simulation modeling and analysis				X	
Task 2 – Forward modeling of stimulation designs to assess the wellbore/reservoir response, develop alternative injection scenarios					
Sub Task 2.1 –Formulate a preliminary multi-cycle injection program based on available laboratory and intermediate-scale in-situ tests reported in the literature. Model the multi-cycle injections using the specific characteristics of the selected stimulation zones in FORGE well					X
Milestone 2.1-Multi-cycle design proposed for each zone. Stimulation design reported to FORGE team and other stakeholders. Careful planning and evaluation will have been done to assure that stimulation activities will not interfere with the potential for future research					X
Sub Task 2.2 – Simulation of multiple fracturing and modeling of temperature in the fracture system for several assumed fracture spacings for 3, 4, and 5 fractures per zone. Modeling of temperature with time between fracture zones					X
Milestone 2.2- Three suitable zones, preferably having low natural fracture intensity are identified, preliminary stimulation plan prepared and the required number of fractures and zonal spacing finalized, rate and volume needs identified					X
Go/No-Go Decision Point #1: Successful completion of the requirements for zonal spacing and the number of fractures per zone, necessary rates and volumes, and implementation steps; Delineation of permeability and hear transfer potential that can be achieved.					X

6. Technical Accomplishments

- Identified some candidate zones for the proposed stimulation based on logs from well 16B and the observed fracture driven interactions (FDI) from well 16A. Carried out simulations for stimulation design and identified field requirements for the stimulation job and some issues to address for site preparations. We have conducted forward modeling of stimulations to assess hydraulic fracture and natural fracture interactions as well as the heat extraction for various possible hydraulic fracture spacings considered in design. Rate and volume requirements have been studied, and the impact of different injection rates determined. Forward modeling of hydraulic fracture and natural fracture interactions for the Utah FORGE reservoir conditions and 3D analysis of heat extraction for various possible hydraulic fracture spacings have been considered for the design. Rate and volume requirements have been studied, and the impact of different injection rates determined. We also have checked for coalescence and divergence of subsequent fractures placed into a zone using field data and simulation modeling and analysis.

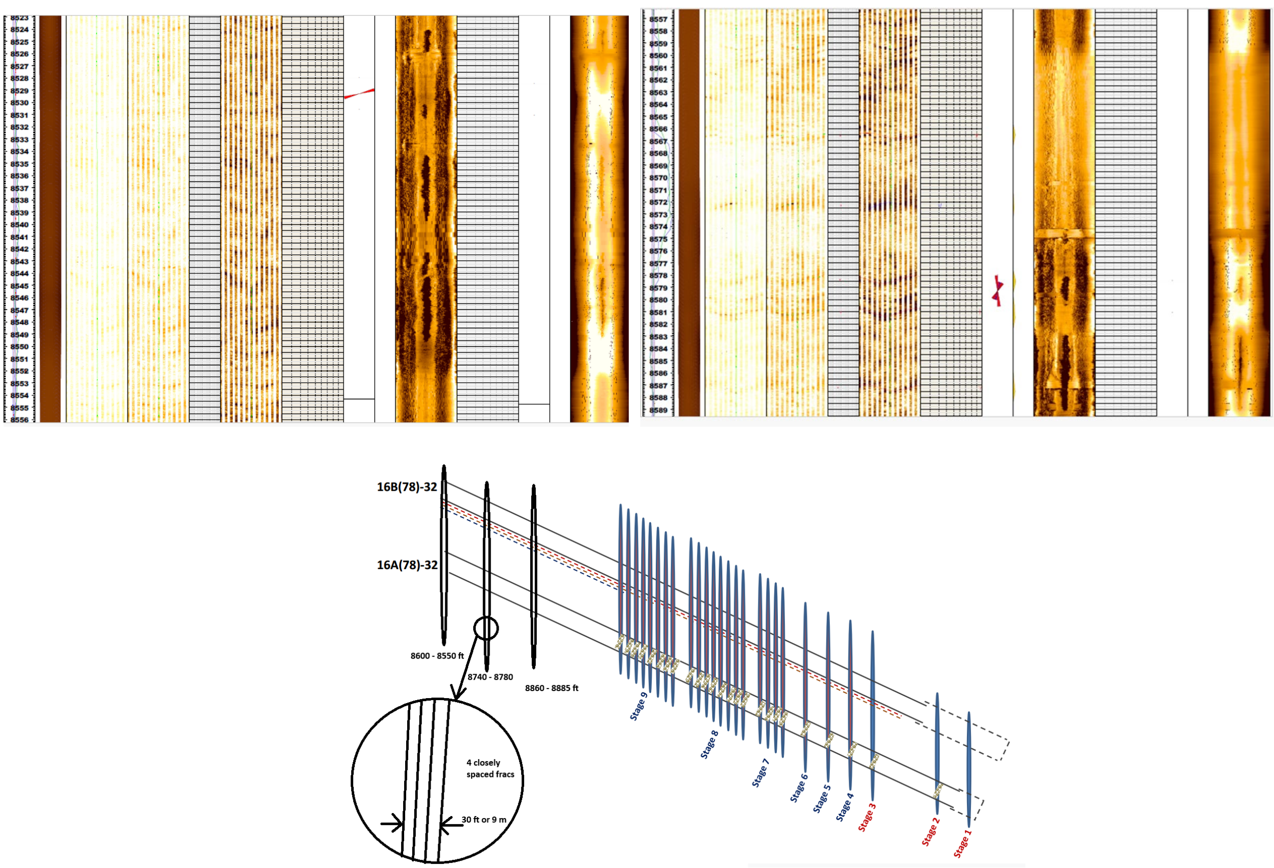

Figure 1. FMI log of 8600-8525 ft (MD), 8885-8860 ft and 8778-8740 ft do not show many natural fractures (not all images are shown). Potential stage locations. We also consider the interval between Stages 2-3 for a test of abrasive jetting instead of conventional perf guns.

1. Perforation: Assuming abrasive jetting is possible, use two perfs per frac located to be on the sides of the wellbore (horizontal orientation). 180 degree phasing and 1 to 2 inches in diameter. A penetration of more than 6 inches is desired. These perf tunnels should point approximately in the direction of the maximum horizontal stress.
2. Fracturing fluid: For fractures that do not contain proppant stages, use slick water (water plus friction reducer). We will get rheology as a function of temperature of this slick water from the service company.
3. Fracture volume and rate: Refer to previous fractures placed in these wells. For slick water fracs, a reduced rate can be used. Target rate is 15 bpm (2.38 m^3/minute). Injected volume will likely be at least 1,000 barrels (160 m^3). Rate and volume to be established based on modeling.

The plan is to fracture the deepest perf zone 1st and then move up the well to the next zone and fracture it. If a straddle packer system is available, the jetted perforating can be done for all zones first, followed by the fracturing. Otherwise, using bridge plugs will require a jet and frac approach for each zone before moving to the next. The fractures will be spaced at 9.8 ft (3m) along the well with 4 fracs for each target depth.

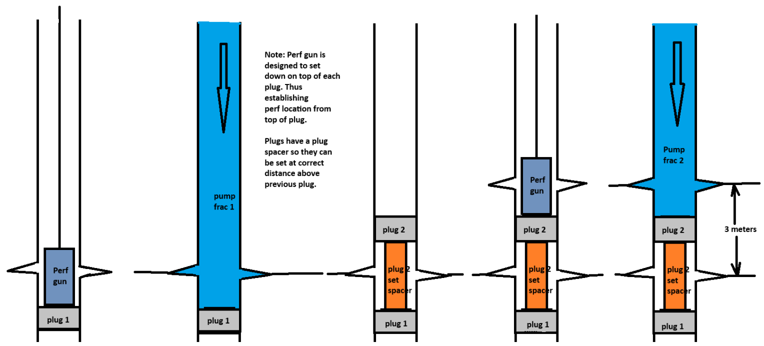

Figure 2: An illustration of the sequence of steps to place bridge plugs, perforate, and frac to generate the closely spaced fractures.

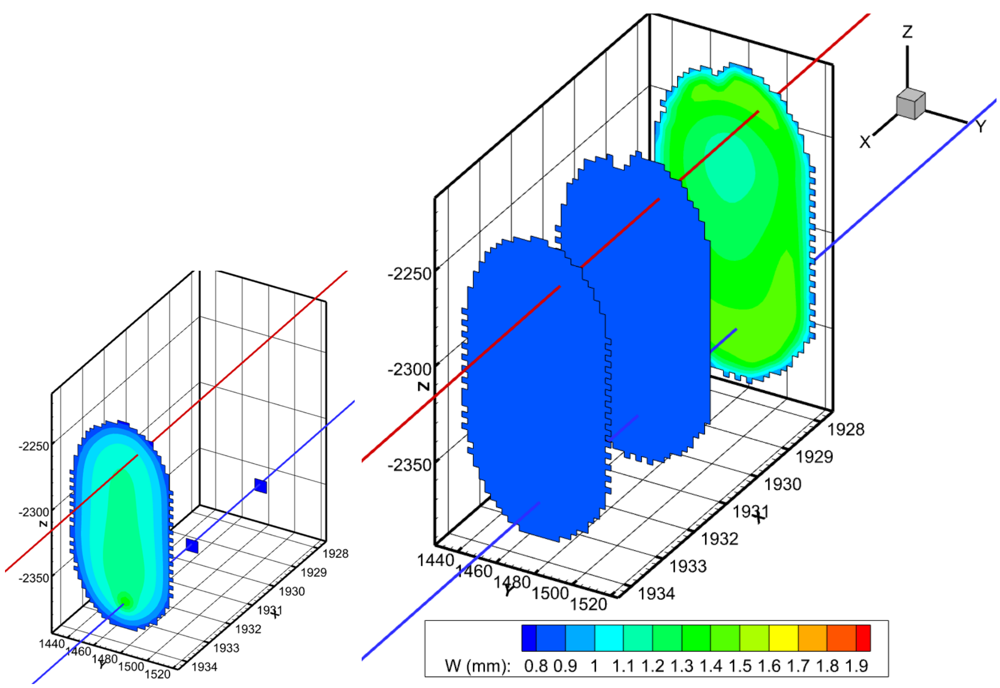

Figure 3. Simulation of a new stage above Stage 10 in Utah FORGE at a measured depth (well 16A) of 2745m. The cluster spacing is 3.5m. Pumping for 70 minutes, 80 minutes, and 90 minutes for each cluster using a constant injection rate of 11.7 bbl/min.

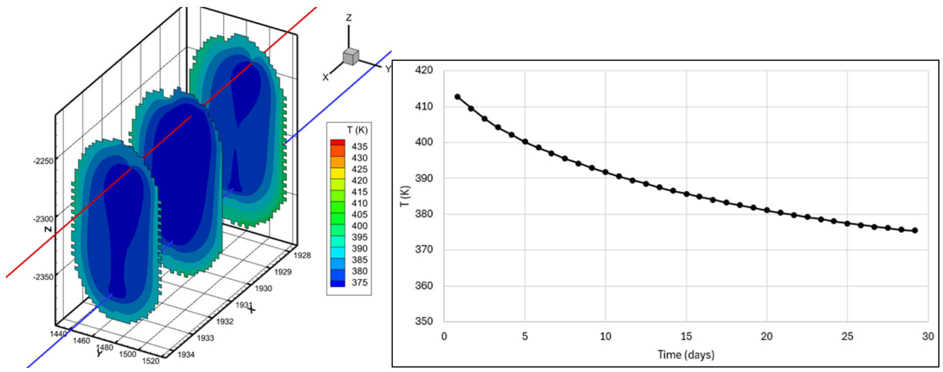

Figure 4. The temperature distribution inside the fracture and the produced fluid temperature after 30 days of circulation using 10 bpm. The pressure BC at the production well (BHP) is set to 24 MPa throughout the circulation.

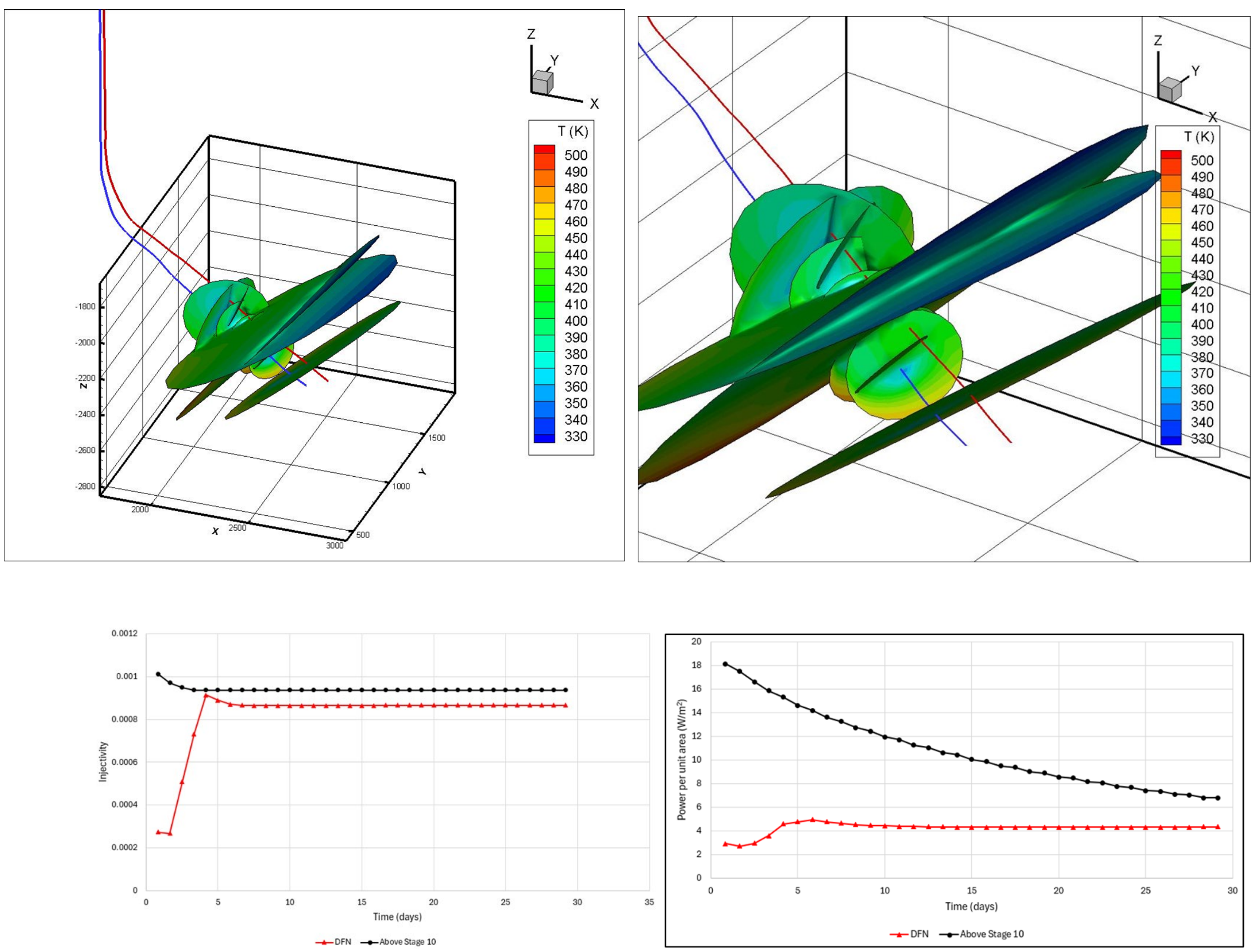

Figure 5. Top: Circulation in the UF network of HF and DFN. Comparison of injectivity and power production from the current DFN and the proposed stimulation. The total energy generated per unit area is 2.89 kWh for the DFN for 7.32 kWh for the closely spaced fracs. More explanation on what DFN is required.

7. Challenges to Date

- Perforation method & zonal isolation tools.

8. **Conclusion and Plans for the Future**
   - Proceed to carry out the tasks outlined in the SOPO to finalize the stimulation plan.

9. **Geothermal Data Repository**
   - NA

10. **Publications and Presentations, Intellectual Property (IP), Licenses, etc.**
    - Ratnayake, R., & Ghassemi, A. (2025). Fracture geometry and permeability evolution in response to thermo-poro-chemo-mechanical processes during circulation in EGS. US Rock Mech./Geomech. Symp. Paper D032S039R002.
    - Ratnayake, R., & Ghassemi, A. (2025). Impact of fluid thermophysical properties on long-term fluid circulation and heat production in enhanced geothermal systems. 50th Workshop on Geothermal Reservoir Engineering.
    - Ghassemi, A., & Ratnayake, R. (2025). Hydraulic fracturing in geothermal reservoirs: The Utah FORGE EGS and Newberry superhot projects. SPE HFTC. Paper D031S008R005.
    - Ratnayake, R., & Ghassemi, A. (2025). Where is the heart-shape fiber response? Impact of poroelasticity on strain and frac height estimation. SPE HFTC. Paper D031S009R007.
    - Ratnayake, R., & Ghassemi, A. (2024). Forward modeling of Utah FORGE 2024 hydraulic stimulation: Fiber signatures & seismicity. Unconventional Resources Technology Conference, 2373–2388.

11. **Publicity and outreach (Optional)**
    - NA