A Major Milestone at Newberry, Oregon: Advancing Toward a Superhot Rock EGS Reservoir

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ABSTRACT

In 2025, Mazama Energy achieved a landmark advancement in geothermal technology by developing the world's hottest Enhanced Geothermal System (EGS) on the western flank of Newberry Volcano, Oregon. The project began with the workover of the existing 55-29 well (3,008 m deep and 331°C BHT) for use as an injector, followed by the drilling and completion of well 55A-29 to the same depth for use as a producer. After propped stimulation of both the wells, initial circulation and diagnostic testing confirmed strong hydraulic connectivity and stable fluid circulation within the newly engineered reservoir. During this first year of operations, Mazama collected extensive geological, geophysical, and geomechanical datasets. Integration of this data with prior site characterization efforts led to substantial refinement of the subsurface models, which are presented in this work. These achievements demonstrate the technical feasibility of EGS development in hot crystalline formations of various lithologies and represent a critical milestone toward establishing a Superhot Rock (SHR) EGS reservoir at Newberry site. This effort is part of the Newberry SHR EGS Demonstration Project, a multi-institutional collaboration funded in partnership with the U.S. Department of Energy, paving the way for next-generation geothermal power at unprecedented temperatures.

1. INTRODUCTION

The core motivation for Superhot Rock Enhanced Geothermal Systems (SHR-EGS) is to harvest heat from rocks at temperatures ~400°C and above to dramatically increase the energy per kilogram of produced fluid (enthalpy) and improve power-cycle efficiency. As a result, a single well pair could deliver substantially higher electrical output than conventional hydrothermal geothermal systems and require a small surface footprint. EGS can provide 24/7, clean, and firm power from resources that are geographically far more scalable than naturally permeable reservoirs targeted by conventional geothermal.
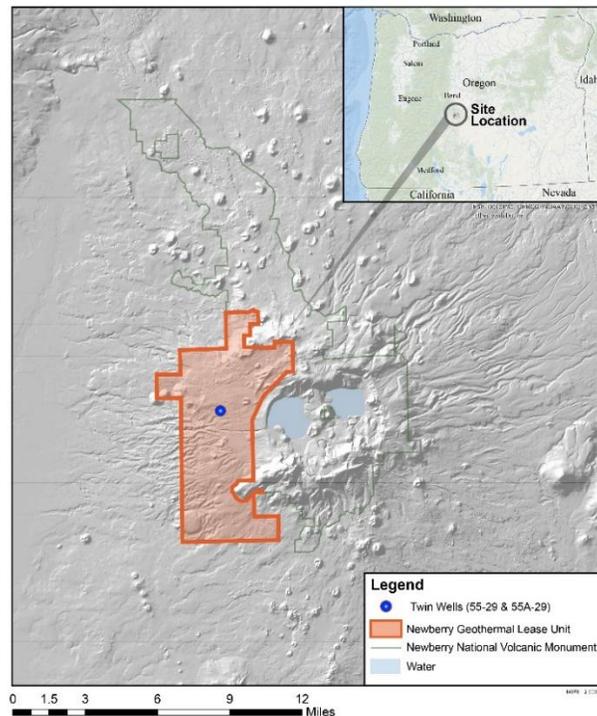

Figure 1: Geothermal lease and the twin wells 55-29 and 55A-29 location at the Newberry site, Oregon, USA

EGS in high-temperature crystalline environments faces coupled, system-wide engineering challenges. First is drilling and well construction at extreme temperature and pressure: maintaining rate of penetration in hard rock, managing lost circulation, and preventing failures in casing, cement, packers, seals, and zonal isolation under severe thermal cycling. Second, downhole tools and instrumentation (electronics, logging, directional systems, telemetry) must survive long-duration exposure to SHR temperatures and corrosive fluids. Third, reservoir creation and sustainment in crystalline rock remains uncertain under SHR conditions: stimulation must generate a connected fracture network with sufficient heat-transfer area while avoiding short-circuiting, excessive water loss, and rapid thermal drawdown.

A DOE-funded Newberry SHR EGS Demonstration project, led by Mazama Energy, plans to address many of the above-mentioned challenges by being part of creating an EGS reservoir in >4000 m deep volcanic rock with temperatures ≥374°C at the Newberry site in Oregon. The project was launched in October 2024 in collaboration with three DOE national laboratories (Lawrence Berkeley National Laboratory, Pacific Northwest National Laboratory, and National Laboratory of the Rockies) and two leading universities (University of Oklahoma and Oregon State University).

As a first step toward the superhot goal, the first results of the creation of an EGS reservoir between two deep wells in rocks at 330°C, one existing well 55-29 and one new one 55A-29, are presented here. The geothermal project is located on the northwestern flank of the Newberry site in Central Oregon, approximately 37 km south of Bend and 16 km north of La Pine, within Deschutes County. The site lies on federally managed land administered by the Bureau of Land Management, with surface oversight by the U.S. Forest Service, immediately adjacent to the Newberry National Volcanic Monument. The geothermal leasehold covers roughly 50 km² and is organized as a unitized block to support coordinated exploration and development (Figure 1). The area benefits from existing geothermal infrastructure, including well pads, deep exploration wells, temperature gradient boreholes, seismic monitoring stations, and established forest roads, allowing development while minimizing new surface disturbance.

2. NEWBERRY SITE GEOLOGIC SETTINGS

Newberry Volcano is a large, long-lived composite volcanic system that has been active for approximately 600,000 years (MacLeod et al., 1995). Its elliptical edifice spans roughly 50 km by 30 km and reaches elevations near 2,400 m above sea level. Geologically, the volcano occupies a unique tectonic setting at the intersection of the Cascade volcanic arc, the Columbia River Basalt Plateau, and the Basin and Range Province. The regional stress regime reflects the combined influence of north–south compression related to subduction along the Cascadia margin and east–west extension associated with Basin and Range tectonics (Flesch et al., 2000; Priest, 1990). This stress configuration has promoted faulting, dike emplacement, and fracture development within the volcanic edifice, all of which are critical factors controlling permeability enhancement and EGS reservoir stimulation potential.

The northwestern flank of the site is characterized by gently sloping terrain composed primarily of overlapping basaltic and andesitic lava flows, volcaniclastic deposits, and localized silicic intrusions. Surface drainage is limited due to the high primary permeability of young volcanic rocks. Data from four deep geothermal exploration wells indicate a dominantly conductive thermal regime, with little evidence of natural convective hydrothermal circulation (Waibel et al., 2014). Injection and flow testing demonstrate extremely low natural permeability, with bulk permeability values on the order of 10^{-16} m², confirming that the system behaves as a hot-dry-rock resource and requires engineered stimulation to achieve economic fluid flow (Cladouhos et al., 2016).

Lithologic data reveal a bimodal volcanic composition dominated by basaltic andesite and rhyodacite, with frequent intrusive bodies such as granodiorite and felsic dikes and sills. These intrusive units are mechanically brittle, fracture-prone, and thermally conductive, making them favorable targets for EGS development. Decades of exploration have established Newberry Volcano as one of the largest and hottest conductive geothermal anomalies in the western United States, with measured temperatures exceeding 315–320 °C at depths of approximately 2.7–3.0 km and projected temperatures above 400 °C below 4 km, placing the site among the most promising superhot EGS targets in North America (Bonneville et al., 2018).

3. INTEGRATED SUBSURFACE MODEL REFINEMENT

The geological framework presented in this paper is based on a previously developed 3D geologic model of the Newberry volcanic system by Mark-Moser et al. (2015). It builds on this well-established interpretation and migrates it into the Leapfrog Geothermal environment (Figure 2), enabling model manipulation, dynamic updating, and the generation of supporting meshes suitable for TOUGHREACT reactive transport modeling (Figure 3). This migration preserves the original geological interpretation while significantly enhancing its utility for coupled thermo-hydro-chemical simulations.

At the surface, the model incorporates volcanic and sedimentary units, including volcaniclastic deposits of the John Day Formation, overlain by younger units of the Mascal Formation in the west and the Newberry–Deschutes Formation (Sonnenthal et al., 2012). These surface units are consistent with regional geological interpretations (Mark-Moser et al., 2015).

Inferred intrusive subsurface bodies are a key component of the model and are based on high-gravity anomalies identified in the western portion of the Newberry system. These gravity highs are interpreted as dense intrusive complexes (Bonneville et al., 2017) that may play a critical role in controlling reservoir behavior. Seismic tomography interpretations further support this model. According to Heath et al. (2015), high-seismic-velocity bodies are inferred in the western part of the system, spatially correlated with and underlying the gravity highs, supporting the interpretation of intrusive bodies at depth. A similar high-velocity signature is observed in the eastern portion of the system, whereas a pronounced low-velocity anomaly beneath the caldera likely indicates the presence of partial melt.
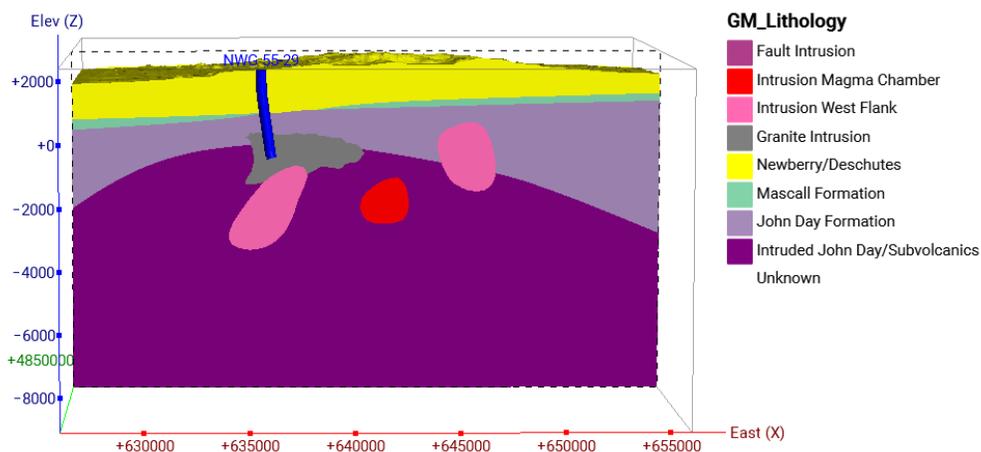
Figure 2 East–west cross section (left to right) showing the inferred subsurface structure beneath Newberry extracted from the Leapfrog Geothermal model (see text for details). The original well 55-29 is shown as a blue trace.
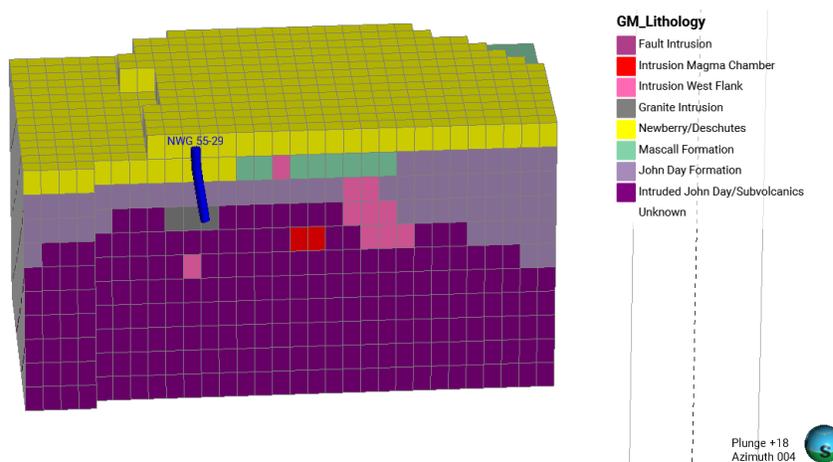

Figure 3 Leapfrog Geothermal mesh block model of the inferred subsurface structure beneath the Newberry volcanic system used as an input for THMC numerical modeling. The gray volume represents an interpreted granitic intrusive body constrained by gravity.
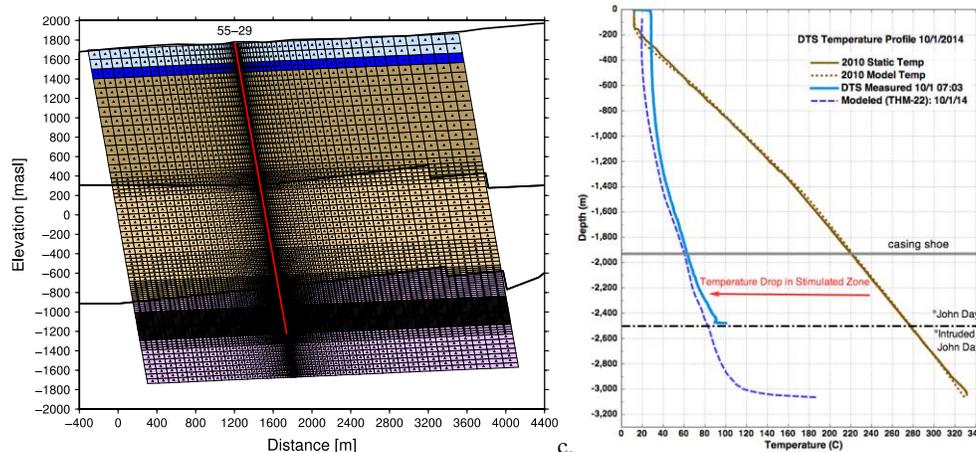

Figure 4 Newberry Demonstration Project THMC developed by Sonnenthal et al. (2015) Left: Model grid and 55-29 well discretization. Right: Measured and simulated static and stimulated temperature profiles in the NWG 55-29 well.

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The 3D THMC Model (Figure 4) developed for the Newberry Volcano Demonstration project (Sonnenthal et al., 2015; Smith et al. 2015) was extended to encompass the west flank and about 1,600 m deeper into the supercritical region. Native state and stimulated borehole temperatures were captured closely in the 2015 THMC model.

An updated geological and alteration model was adopted for the new "West Flank THMC Model" (Figure 5). Thermal and hydrological properties as well as the conceptual model for the thermal structure were adapted from the preexisting Newberry demonstration project THMC properties. Modifications were made to account for deeper units and alteration types (e.g., smectite, chlorite, chlorite-epidote). A supercritical water Equation-of-State module (EOS1Sc) has been added to the LBNL THMC code TReactMech (TOUGHREACT + geomechanics). The following steps were followed in building the native-state THMC model for the west flank:

- Export of rock types, alteration, and faults from LeapFrog PFA model to regular grid
- Creation of TReactMech (Sonnenthal et al., 2023) numerical grid
- Import of PFA grid and assignment of rock types to TReactMech numerical grid
- Use of LIDAR data to delineate surface topography
- Execution of a steady state thermal-hydrological model using the EOS1Sc supercritical water Equation-of-State (Magnusdottir and Finsterle, 2015) in TReactMech
- Assessment of boundary conditions (e.g., water table, outflow boundaries, infiltration, heat flux boundary)
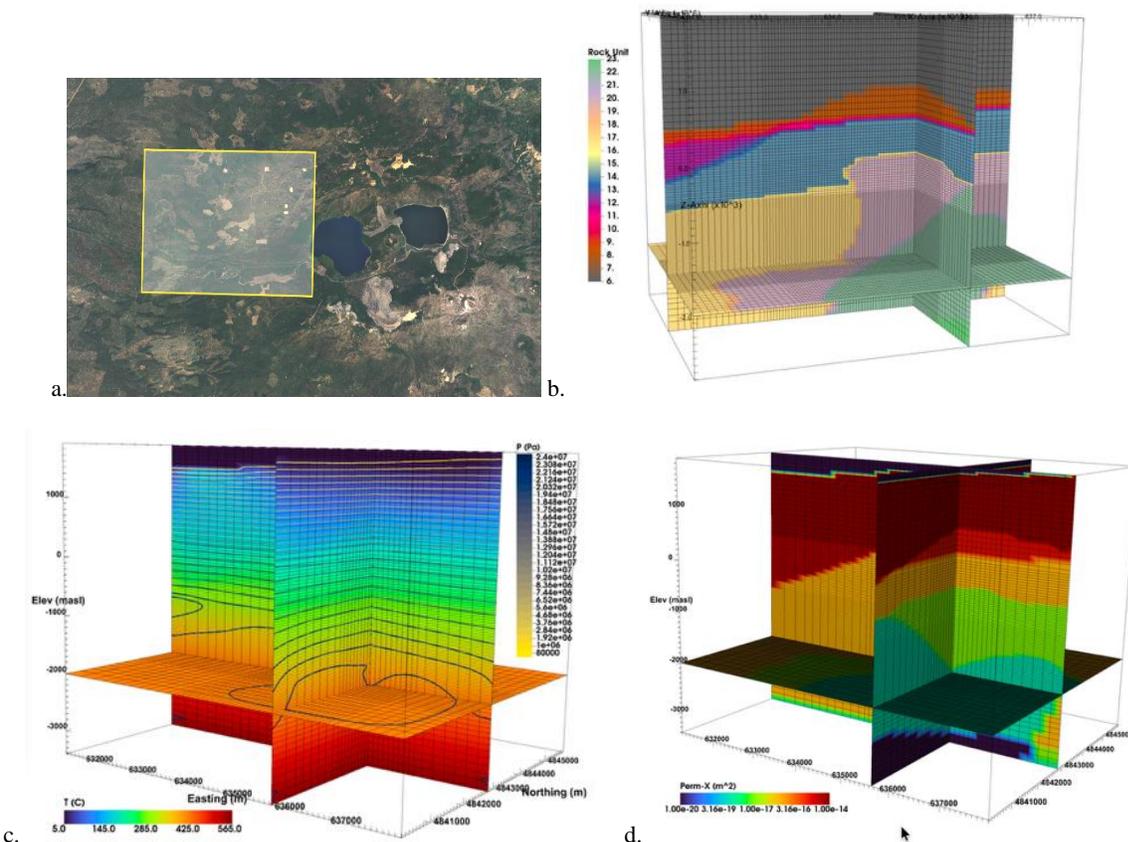

Figure 5 a) Areal view of Newberry site with area of West Flank THMC Model overlain. b) Cross-sections of rock units centered at 55-29. c) Simulated native-state temperatures and pressures (contour lines). d) Initial permeability (x-component).

Simulations were performed assuming a bottom temperature calculated using a uniform temperature gradient of 105°C/km from the ground surface to -3500 mbsl, and a fixed surface temperature of ~5°C. The maximum temperature at the model bottom boundary is 565°C, compared to 490°C in the previous model.

Simulated temperatures at wells in the West Flank THMC Model are shown in Figure 6 compared to measured temperatures and simulated temperatures from Frone et al. (2014). Whereas there are limited measured data available, the new West Flank Model simulated temperatures are generally close to measured values.
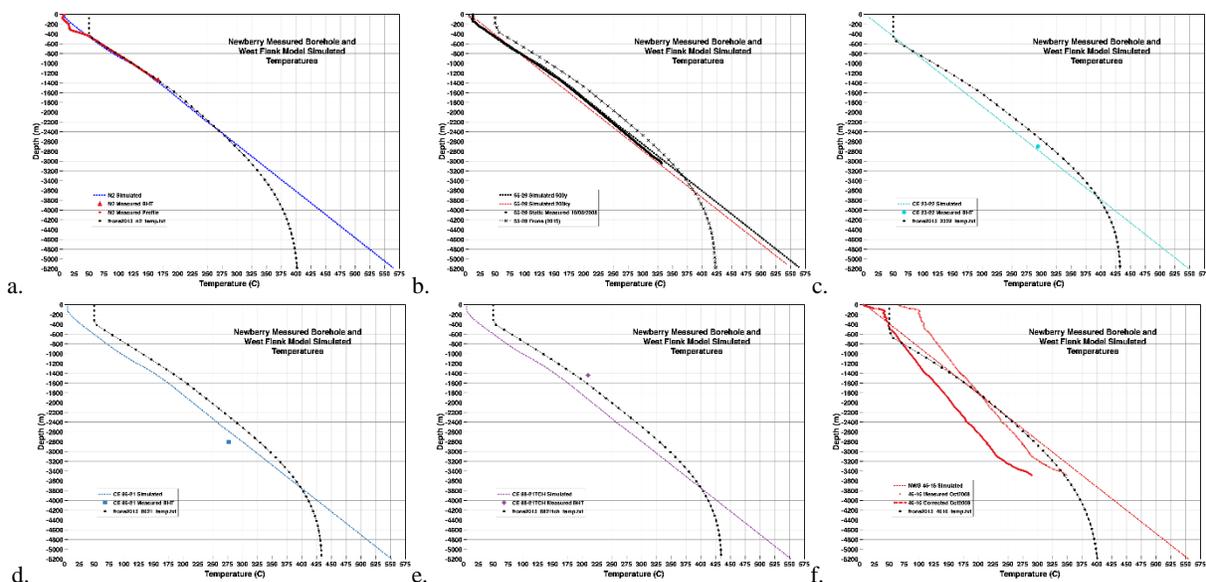
Figure 6 Simulated wellbore temperatures in West Flank THMC Model (solid lines), Frone (2015), and measured. a) N2. b) NWG 55-29. c) CE 23-22. d) CE 86-21. e) CE 88-21TCH f) NWG 46-16.

4. WELL DEVELOPMENT AND COMPLETION

Well development and completion activities were undertaken to enable high-temperature EGS operations at the Newberry site, including the workover of a legacy well and the drilling and completion of a new producer to support reservoir stimulation and testing.

4.1 Workover of Well 55-29 (Injector)

Well 55-29 (Figure 1 and Figure 7) was originally drilled in 2008 on the western flank to a total depth of 3,066 m (10,060 ft) MD through basaltic and granodioritic formations. The well was completed with a combination of surface, intermediate, and liner strings, including a 9⅝-in. liner set from 1,280 m (4,199 ft) to 1,970 m (6,462 ft) and a perforated 7-in. liner extending to near total depth. High downhole temperatures limited the quality of original wireline logging, and early injection testing indicated minimal injectivity. As a result, the well was temporarily abandoned as an open hole and later modified through multiple interventions to restore mechanical integrity and preserve future development potential. A major integrity issue was identified during a 2014 workover when the 13⅜-in. casing was found to be leaking. This was remediated by tying back the 9⅝-in. casing to surface, cementing the annulus via reverse circulation, and installing a refurbished 10-in. wellhead. A bridge plug was set within the 9⅝-in. casing and later drilled out during cleanout operations. Subsequent attempts to install and recover perforated liners resulted in two 7-in. liners being left in the wellbore, partially restricting internal diameter and limiting access to the deeper reservoir interval. Despite these challenges, the well-retained structural integrity that was preserved for future recompletion.

The 2024–2025 workover program was undertaken to convert Well 55-29 into a dedicated injector capable of supporting multi-stage stimulation of a >300°C EGS. Primary objectives included recovering or milling existing liners, restoring full wellbore access, recompleting the well with a casing configuration suitable for high-temperature, high-pressure stimulation, and validating a proprietary well design capable of accommodating extreme thermal loads and repeated thermal cycling. The workover also aimed to enable dual-injection stimulation and improve wellbore-to-reservoir connectivity without mechanical isolation devices.

Workover operations included extensive casing cleanout, partial liner retrieval and milling, pressure testing, and recompletion with a combined 4½-in. × 7-in. inner string. Milling and cleanout operations successfully restored access to near-total depth of 3,045 m (~9,990 ft) MD, confirming mechanical continuity and pressure integrity through formation integrity and leak-off testing. The final completion configuration provided a continuous pressure-rated flow path capable of supporting high-rate stimulation despite the presence of multiple casing strings and cemented intervals.

Upon completion of the workover, well 55-29 was successfully transitioned into stimulation operations, supporting stimulation in basaltic and granodioritic formations at temperatures exceeding 300 °C. Stimulation was executed with controlled fracture initiation and without screen-outs. Microseismic monitoring confirmed reservoir activation without significant induced seismicity. The workover demonstrated that legacy geothermal wells with complex mechanical histories can be successfully rehabilitated and repurposed for Superhot EGS injection through disciplined wellbore remediation, conservative pressure management, and thermally robust completion design.
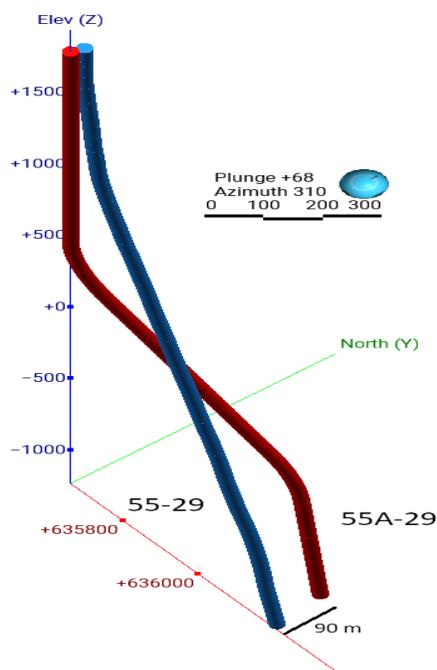
Figure 7 Newberry 55-29 and 55A-29 trajectories (UTM Zone 10N coordinates and elevation in meters)

4.2 Drilling and Completion of Well 55A-29 (Producer)

Well 55A-29 (Figure 1 and Figure 7) was drilled to a total MD of 3,109 m (10,200 ft) through the same hard, abrasive volcanic and granodioritic formations and extreme thermal conditions. The well was designed to parallel the existing injector 55-29 and enable engineered reservoir creation through stimulation as part of a high temperature EGS demonstration in a >300°C reservoir. Primary objectives included validating drilling and measurement technologies for deep volcanic environments, achieving precise inter-well placement to support fracture connectivity, and enabling sustained heat extraction during a planned 30–60-day production test. These objectives governed well design, trajectory planning, and operational execution.

A staged drilling strategy comprising four primary hole sections was employed to manage thermal exposure, drilling dynamics, and operational risk. A central technical challenge was executing directional drilling and reliable downhole measurement in an environment where static formation temperatures exceeded 300 °C, placing conventional drilling tools, electronics, and elastomers near or beyond their nominal operating limits.

The 26-in. surface section was drilled to approximately ~335 m (1,100 ft) through highly fractured and vesicular volcanic formations with severe lost circulation. Although bottomhole temperatures were moderate, extensive circulation losses and formation breakdown required adaptive fluid-loss mitigation strategies and extended drilling time. The section was successfully completed and provided a stable foundation for deeper drilling.

Thermal and mechanical challenges increased in the 17½-in. intermediate section drilled to 1,280 m (4,200 ft) MD. While temperatures remained below the superhot threshold, competent volcanic rock necessitated stiff, high-inertia bottom-hole assemblies (BHAs) to mitigate stick-slip and torsional vibration. Optimized Polycrystalline Diamond Compact (PDC) drill bits enabled sustained drilling performance, with cumulative drilling time of ~138 hours and penetration rates substantially exceeding offset benchmarks, confirming the viability of PDC technology in hard geothermal lithologies.

The 12¼-in. build and tangent section, drilled from ~1280 m (4,200 ft) to approximately 2743 m (9,000 ft) MD, marked the transition into high-temperature operations. Elevated drilling times, requiring ~196 hours to reach casing depth, reflecting both elevated thermal conditions and conservative operating practices. Bottomhole temperatures approached the survivability limits of conventional Measurement While Drilling (MWD) systems, necessitating disciplined thermal management through staged circulation, minimized static dwell time, insulated drill pipe, and controlled survey acquisition windows. Directional control was achieved using positive displacement motors (PDMs) with low dogleg severity (~2.5°/30 m) to limit vibration, torque, and elastomer degradation while preserving survey quality.
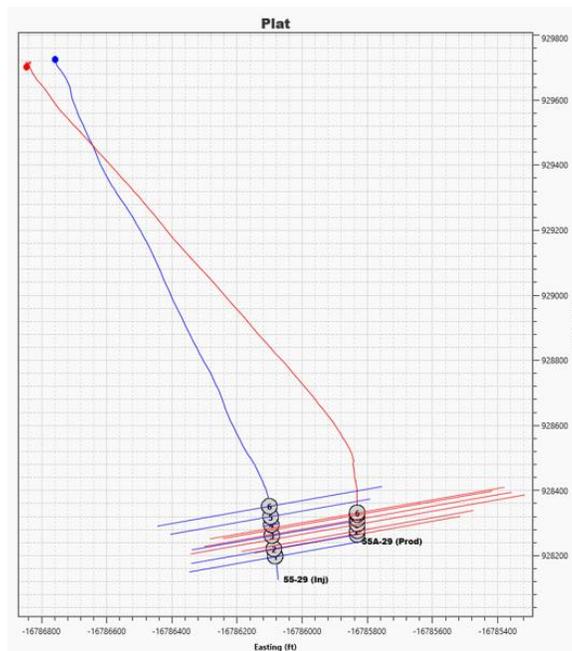
5. RESERVOIR STIMULATION AND CREATION

5.1 Stimulation Design

Creating an engineered reservoir volume requires an efficient network of flowing capabilities to sustain long term ability to harvest heat. Crystalline lithologies possess very low native permeabilities that do not enable flow capability for longer periods, hence do not pose an opportunity for efficient heat harvesting. To address this, a synthetically engineered reservoir volume is required.

Past stimulation in EGS have seen an application of variable stimulation techniques relying on the permeability enhancement from thermal, chemical, hydro shearing approaches. This approach has not proved to be an efficient stimulation method that can yield longevity in connection and flow for higher enthalpy requirements. The main approach of stimulation in the Mazama EGS pilot included a design process that would see the usage of propping agents and a proprietary stimulation approach to create an engineered reservoir volume. The design mindset approaching a >300°C environment included but was not limited to:

- Ability to create an efficient connection from the wellbore to the reservoir to enable the initiation of fractures and placement of pre-defined volumes of proppant at variable concentration

- Ability to initiate, propagate and place proppant in variable lithologies including basalt, andesite and granodiorite that possess variable mechanical properties affecting created reservoir geometry

- Ability to implement staged stimulation that would allow for isolation of flow in the wellbore adapting existing oil and gas technologies by implementing the learning of cooling and heating profiles from the installed DTS fiber

- Ability to utilize diagnostic technologies to infer created reservoir volume and plan for producer well placement to connect fractures for circulation and heat harvesting

The injector 55-29 and producer 55A-29 stimulation included the completion of multiple treatments utilizing a combination of high viscosity friction reducer and crosslinked fluid systems to enable fracture geometry generation and proppant transport (Grubac et al. 2025). Figure 8 shows the modelled main fractures created by the stimulation of both wells in January and August 2025. The stimulation operation included implementation of multiple types of propping agents varying in size distribution and physical properties. Isolation between stages during stimulation was achieved utilizing sand plugs while wellbore to reservoir connection was established by application of abrasive jetting in initial stages in the injector 55-29 stimulation. Subsequently, learnings from the cooling/heating profiles from the installed fiber allowed the application of composite plugs and wireline conveyed perforating. Through the stimulation process, real time monitoring of pressure interference, nano tracers pumped in treatment fluid, retrieval of core with proppants from the producer well drilling and circulation test tracer detection proved a connection between the wells that culminated in the ability to circulate between the wells and de-risk stimulation approach for future SHR application.
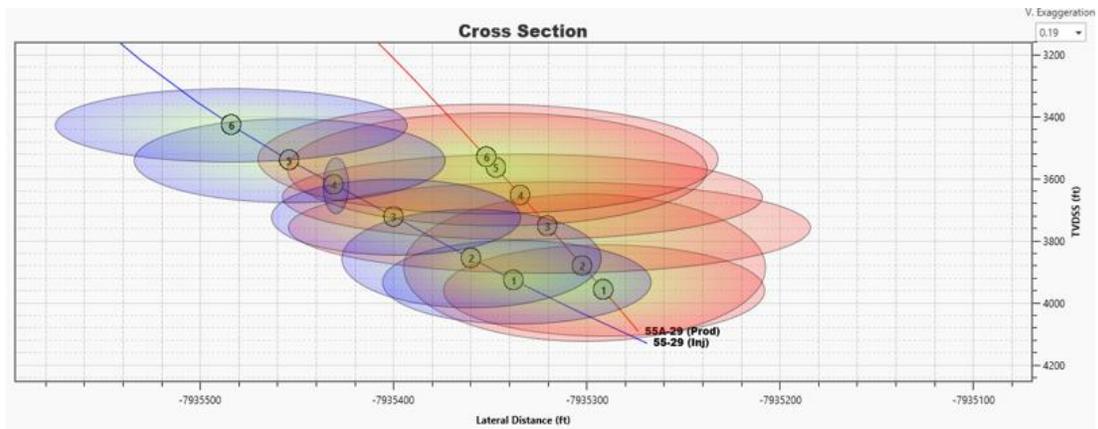
Figure 8 Simulation and alignment of modelled fractures between injector and producer assuming symmetry. The stimulation stages by well are numbered.

5.2 Initial Reservoir Response

The flow test demo objective with respect to the reservoir was to show evidence of fracture creation and connectivity that would apply to a full-scale pilot. The demo injector-producer doublet were slightly deviated wells which could accommodate a limited count of 6 fractures in the well sections above 300°C. The demo was to show thermal recovery through connected flow from injector to producer with flow rates per fracture that would apply to a future commercial-scale pilot.

Stimulation of 55-29 and 55A-29 used unique tracers for all six stages in each well, and production water from 55A-29 contained all the unique tracers from each stimulation treatment. While tracers tell the story of connected fractures, tracers cannot discern the level of mass flow through each fracture. Therefore, flowing production logging tests (PLT) were run on 55-29 and 55A-29.

The flow test was a step-rate test for the first four weeks. Figure 9 shows the thermal power produced during the test. The thermal power was calculated using DOE's NIST steam enthalpies from measured rates, temperatures, and pressures. The measurement system was deemed valid a couple of days after the testing began. The steps delivered up to 4.5 MWt for an equivalent power of approximately 0.7 MWe.
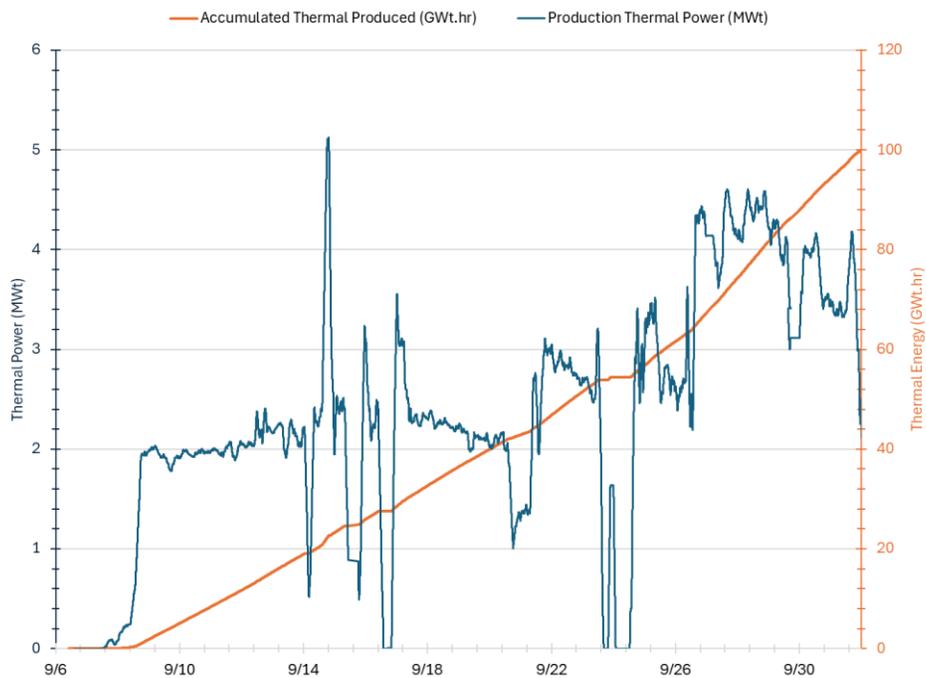

Figure 9 Thermal power produced during the flow test

A significant benefit to producing at hotter rock temperatures is that the enthalpy of the water is greater, and therefore, much less water is required to produce the same electricity as a lower temperature resource. Figure 10 shows the power density per unit of water potential for the pilot compared to several other EGS projects.
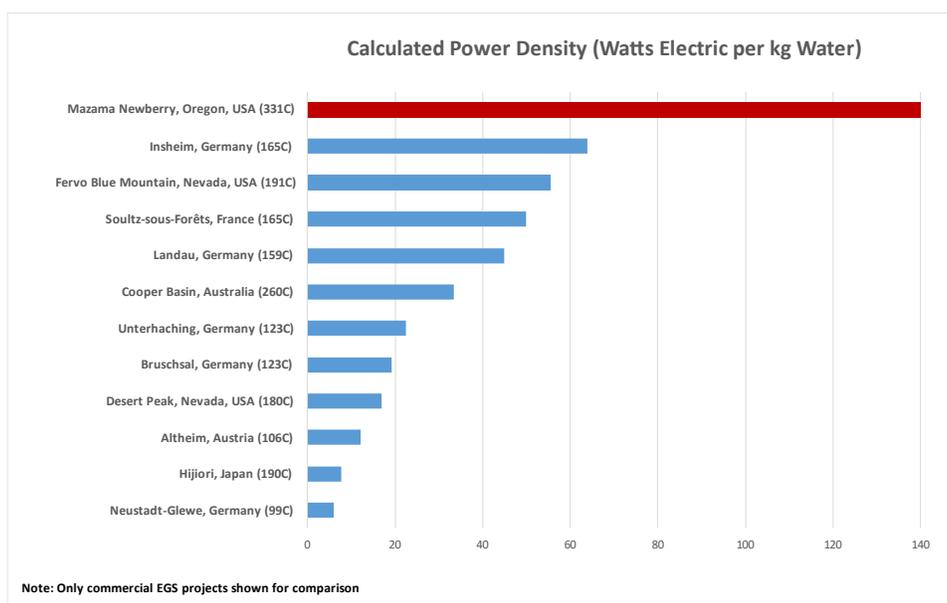

Calculated Power Density (Watts Electric per kg Water)

Note: Only commercial EGS projects shown for comparison

Figure 10 Power density per unit of water for several EGS projects

6 DATA ACQUISITION AND MONITORING

6.1 Core Description and Petrography

Approximately 3.5 meters of 100 mm wide drill core were obtained from hole 55A-29 at 2,929 m MD (9,610 ft) / 2,873 m TVD (9,426.8 ft)**.** This material is currently archived at the Oregon State University Marine Geological Repository (OSU-MGR) in Corvallis, Oregon. Preliminary characterization via logging and thin section petrography shows that drilled material consists of two primary rock types: (i) a mafic volcanic rock interpreted as a thick lava flow or shallow intrusive sill, and (ii) lesser amounts (< 5%) of a cross cutting intrusive mafic dyke lithology. The latter has finer grain size than the flow and shows chilled cross cutting contacts with the surrounding rock. Both lithologies are plagioclase-phyric, with phenocrysts upwards of several mm, and ground mass plagioclase microlites, which sometime appear to define a flow direction. Mafic phenocrysts such as olivine or clinopyroxene may also be present but are difficult to identify because of hydrothermal alteration.

Figure 11 Section of the core collected in 55-29 at 2,873 m TVD.

Both of the rock types exhibit moderate to strongly altered to a secondary propylitic chlorite-epidote-albite-pyrite-calcite assemblage (Figure 11). Alteration occurs as disseminated chlorite and albitization of existing igneous plagioclase, together with minor epidote and carbonate, and occasional quartz throughout all drilled lithologies. Some larger plagioclase phenocrysts are also partly to fully replaced by epidote-albite-carbonate. In addition, numerous altered fractures, involving several fracture sets, occur within the drilled material. Altered fractures and veins are up to 1 cm in width and contain coarser epidote-carbonate-chlorite-pyrite assemblages, with many showing

evidence of having crystallized as open space fillings with earlier euhedral epidote surrounded by later carbonate and chlorite. Some residual voids are also evident. Fractures are associated with macroscopically bleached selvages up to several cm wide. Alteration appears most intensely where fracture densities are highest and or where different fracture sets intersect.

6.2 Seismic Data

The seismic network (micro-seismic array; MSA) consists of eight three-component geophones installed in boreholes up to 300 m deep and one strong-motion accelerometer for monitoring surface shaking (purple triangles, Figure 12). These stations are supplemented with up to ten sensors operated by Pacific Northwest Seismic Network (PNSN) and USGS Cascade Volcano Observatory (CVO; blue and red triangles, respectively; Figure 12). All stations are sent in real time to LBNL where they are processed to estimate the location, magnitude, and other characteristics of local seismic events. To monitor geothermal activity, we distinguish natural earthquakes associated with the Newberry volcano itself from events induced by geothermal operations, currently using seismic wave propagation directions for identification. While hundreds of seismic events were detected and located during stimulation operations from 2012-2015, stimulations of well 55-29 in January 2025 resulted in a few detected events by the MSA.

In addition, a distributed acoustic sensing (DAS) fiber was installed in well 55-29 to monitor the reservoir stimulation via fracture characterization and imaging. DAS recordings were acquired in the 55-29 well during two stimulations in January and August 2025. Despite being much closer to the stimulation than the MSA sensors and being more sensitive, only 38 events were detected and located by the downhole DAS array during stimulation of 55-29 in January 2025. Figure 13 shows relocated origins for these events relative to those supplied by the onsite contractor during stimulation.

Future efforts will be to complete the template matching search for additional events, investigate the initial dearth of detected induced seismicity, and explore source mechanisms using the downhole DAS array, to better characterize fracture extent and state of stress. We also develop a convolutional-neural-network-based event detector using ConvNeXt (Liu et al., 2022) to automatically detect seismic events by performing pixel-level classification that distinguishes seismic signals from background noise. Applied to continuous DAS data, the model identifies nearly three times more candidate event patches with high sensitivity by capturing both local waveform features and larger-scale spatiotemporal coherence.
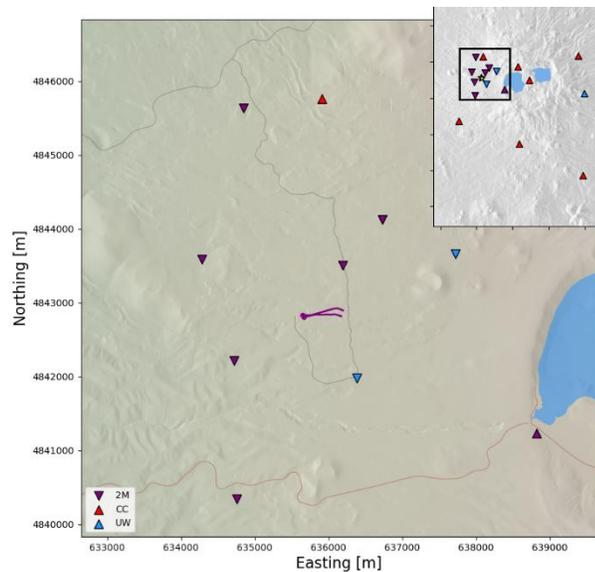

Figure 12 Mazama MSA at Newberry. Purple stations are owned and operated by Mazama and LBNL, blue by PNSN, and red by CVO. Downward triangles indicate sensors installed in boreholes. Upward pointing triangles are sensors installed at the surface. The purple lines indicate the well trajectories of 55-29 and 55A.29.
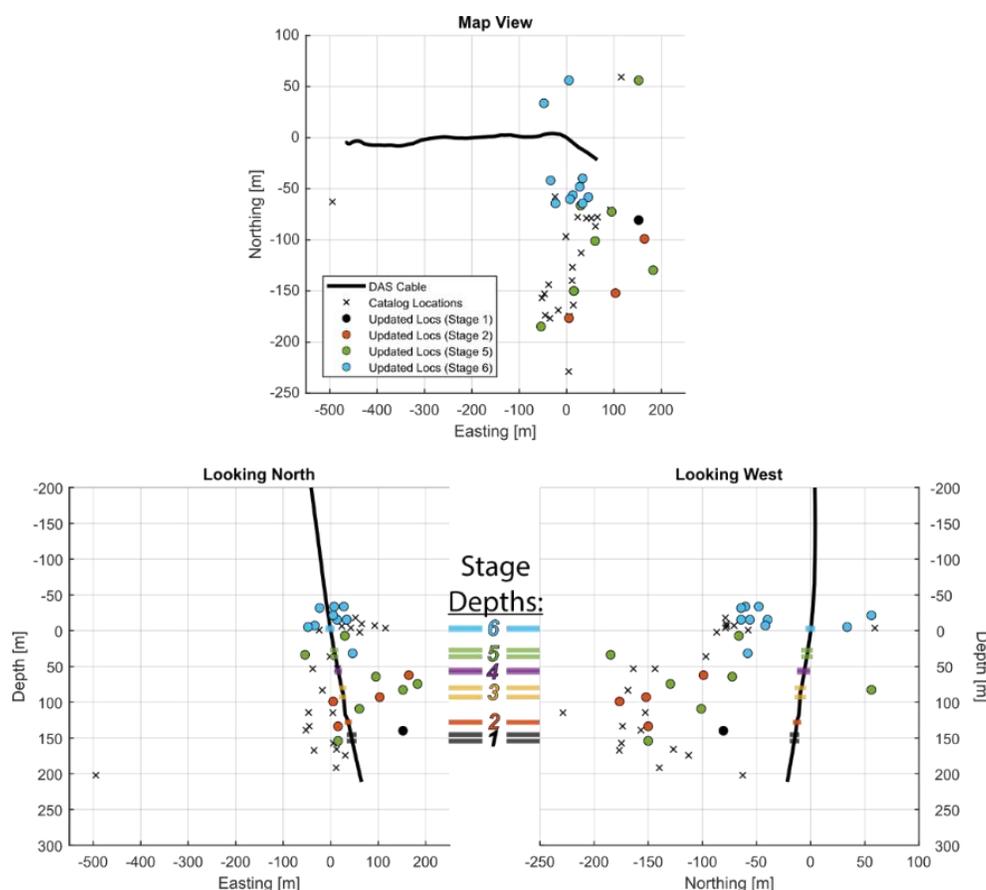
Figure 13 Revised hypocenters of the seismicity detected by DAS during stimulation of 55-29. X's indicate the locations from the onsite contractor. Filled circles show the revised locations, colored to match the stage of injection during which they occurred.

During the stimulation of 55A-29, more events were detected by the DAS, and a surface array was deployed covering approximately 28.5 km² (11 mi²) with 1,357 stations.

All three monitoring methods have shown that the stimulation of wells 55-29 and 55A-29 induced a few, very small seismic events. In total, only 150 microseismic events with magnitude comprised between -2.0 and -0.6 were recorded, most of them only detected by the DAS fiber deployed to a depth of 2705 m (8,875 ft) in well 55-59, very close to the stimulation stages. It should be also noted that no seismic activity linked to the EGS reservoir was detected during the months between the two stimulations and since August 2025.

7. CONCLUSION

The results presented in this paper mark a significant step forward in the practical realization of Super-Hot Rock Enhanced Geothermal Systems (SHR EGS). The successful workover of a legacy deep well, drilling and completion of a new high-temperature producer, and the creation of a hydraulically connected reservoir at >300 °C collectively demonstrate that many of the long-standing technical barriers to SHR development (well construction, stimulation, diagnostics, and circulation) can be overcome with existing and emerging technologies. Importantly, these achievements were realized in hard, heterogeneous volcanic and intrusive lithologies under extreme thermal conditions, underscoring the robustness and transferability of the approaches described here.

Integration of new drilling, stimulation, and monitoring datasets with refined geological and THMC models has substantially improved understanding of the Newberry west flank system. Early circulation results confirm that stimulation can generate sustained connectivity and meaningful heat extraction, while tracer, PLT, seismic monitoring and modeling results collectively indicate a stimulated volume that extends beyond simple planar fracture geometries. The observed power density per unit of injected water highlights the strategic advantage of operating at elevated temperatures in water-constrained environments.

Looking forward, the Newberry project now provides a calibrated field-scale platform for advancing toward deeper, hotter (>374–400 °C) reservoirs. Near-term priorities include extending stimulation concepts to longer laterals with higher stage counts, refining circulation strategies to balance heat extraction against thermal drawdown and further integrating cooling-induced geomechanical effects into predictive models. Continued development of high-temperature drilling systems, downhole instrumentation, and long-duration monitoring will be essential to enable sustained operations at supercritical conditions.

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Beyond Newberry, the outcomes of this work have broader implications for geothermal energy deployment. The demonstration that engineered reservoirs can be created and operated in low-permeability, high-temperature volcanic settings expands the geographic and geologic envelope of viable geothermal resources. With continued iteration, scale-up, and cost reduction, SHR EGS has the potential to transition from demonstration to commercial wellfields capable of delivering utility-scale, carbon-free baseload power. The Newberry SHR EGS Demonstration Project thus represents not only a milestone for this site, but a foundational step toward unlocking a globally scalable class of next-generation geothermal resources.

ACKNOWLEDGEMENTS

REFERENCES

Bonneville, A., T. T. Cladouhos, K. Rose, A. Schultz, C. Strickland, and S. Urquhart (2017), Improved image of intrusive bodies at Newberry Volcano, Oregon, based on 3D gravity modelling, paper presented at 42nd Workshop on Geothermal Reservoir Engineering, Stanford University, Stanford, California, February 13–15, 2017.

Bonneville, A., T. T. Cladouhos, S. Petty, A. Schultz, C. Sørlie, H. Asanuma, G. Ó. Friðleifsson, C. Jaupart, and G. de Natale (2018), The Newberry Deep Drilling Project (NDDP) workshop, Sci. Dril., 24, 79–86, doi:10.5194/sd-24-79-2018.

Cladouhos, T. T., S. Petty, M. W. Swyer, M. E. Uddenberg, K. Grasso, and Y. Nordin (2016), Results from Newberry Volcano EGS Demonstration, 2010–2014, Geothermics, 63, 44–61, doi:https://doi.org/10.1016/j.geothermics.2015.08.009.

Flesch, L. M., W. E. Holt, A. J. Haines, and B. Shen-Tu (2000), Dynamics of the Pacific-North American Plate Boundary in the Western United States, Science, 287(5454), 834–836, doi:doi:10.1126/science.287.5454.834.

Frone, Z., A. Waibel, and D. Blackwell (2014), Thermal Modeling and EGS Potential of Newberry Volcano, Central Oregon., paper presented at Thirty-Ninth Workshop on Geothermal Reservoir Engineering, Stanford University, February 24–26.

Grubac, G., Gullickson, G., Bonneville, A., Brand, P., Goloshchapova, D., Dunham, E. M., Khan, M., Cuthill, D., Shokanov, T. A., Gibson, C., Palisch, T., Hopp, C., and Nakata, N., 2025. *Enhanced geothermal system propped stimulation >300 °C: From design to implementation—Phase I*. Proceedings, SPE Annual Technical Conference and Exhibition, Houston, Texas, USA

Heath, B. A., Hooft, E. E., Toomey, D. R., & Bezada, M. J. (2015). Imaging the magmatic system of N ewberry V olcano using joint active source and teleseismic tomography. *Geochemistry, Geophysics, Geosystems, 16*(12), 4433-4448.

Liu, Z., H. Mao, C.-Y. Wu, C. Feichtenhofer, T. Darrell, S. Xie (2022) A ConvNet for the 2020s, arXiv, 2201.03545.

MacLeod, N. S., D. R. Sherrod, L. A. Chitwood, and R. A. Jensen (1995), Geologic map of Newberry Volcano, Deschutes, Klamath, and Lake Counties, Oregon. USGS Miscellaneous Geologic Investigations Map I-2455, US Geological Survey.

Magnusdottir, L., and Finsterle, S.: An iTOUGH2 equation-of-state module for modeling supercritical conditions in geothermal reservoirs, Geothermics 57, (2015), 8–17.

Mark-Moser, M. K., Rose, K. K., Schultz, J. D., Schultz, A., Heath, B., Urquhart, S., & Vincent, P. (2015). *A Conceptual Geologic Model for the Newberry Volcano EGS Site in Central Oregon: Constraining Heat Capacity and Permeability Through Joint Interpretation of Multifaceted Geophysical and Geological Data Sets*.

Priest, G. R. (1990), Volcanic and tectonic evolution of the Cascade volcanic arc, central Oregon, Journal of Geophysical Research: Solid Earth, 95(B12), 19583–19599.

Smith, J.T., E.L. Sonnenthal, and T. Cladouhos, 2015. Thermal-Hydrological-Mechanical Modelling of Shear Stimulation at Newberry Volcano, Oregon. Proceedings of 49th US Rock Mechanics/Geomechanics Symposium, American Rock Mechanics Association, ARMA 15-0680.

Sonnenthal E.L., J.T. Smith, T. Cladouhos, J. Kim, L. Yang, 2015. Thermal-Hydrological-Mechanical-Chemical Modeling of the 2014 EGS Stimulation Experiment at Newberry Volcano, Oregon. Proceedings, Fortieth Workshop on Geothermal Reservoir Engineering Stanford University, Stanford, California, January 26-28, 2015. SGP-TR-204.

Sonnenthal, E., Spycher, N., Callahan, O., Cladouhos, T., & Petty, S. (2012). *A thermal–hydrological–chemical model for the enhanced geothermal system demonstration project at Newberry Volcano, Oregon*. Paper presented at the Proceedings of the 37th Workshop on Geothermal Reservoir Engineering, Stanford, CA.

Sonnenthal, E.L., J.T. Smith, N. Spycher, 2023. TReactMech V4.217. LBNL IPO Software 2023-112. Software for simulating geomechanics and reactive transport, including supercritical geothermal systems.

Waibel, A. F., Z. S. Frone, and D. D. Blackwell (2014), Geothermal Exploration of Newberry Volcano, OregonRep., Medium: ED; Size: 147 p. pp, United States.