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NEWBERRY VOLCANO EGS DEMONSTRATION – PHASE I RESULTS

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ABSTRACT

Phase I of the Newberry Volcano Enhanced Geothermal System (EGS) Demonstration has recently concluded. This twenty month effort included permitting, community outreach, seismic hazards analysis, initial microseismic array (MSA) deployment and calibration, final MSA design, site characterization, and stimulation planning. The multi-disciplinary Phase I report, recently approved by a team of independent reviewers selected by the Department of Energy (DOE), summarizes the Phase I activities and supports stimulation planning and regulatory permitting, as well as addressing public concerns including water usage and induced seismicity. The final step of Phase I, an Environmental Assessment (EA) prepared by the Bureau of Land Management (BLM), has been released for a 30 day public comment period with a regulatory decision expected soon after.

In Phase II of the demonstration, an existing deep hot well, NWG 55-29, will be stimulated using hydroshearing and multi-zone isolation techniques to create an EGS reservoir. The Newberry Volcano EGS Demonstration will allow geothermal industry and academic experts to develop, validate and enhance geoscience and engineering techniques, and other procedures essential to the expansion of EGS. Successful development will demonstrate to the American public that EGS can play a significant role in reducing foreign energy dependence, and provide clean, renewable, and safe baseload geothermal power generation.

INTRODUCTION

Newberry Volcano is a shield volcano located in central Oregon, about 20 mi (35 km) south of the city of Bend and approximately 40 mi (65 km) east of the crest of the Cascade Range. The Newberry EGS Demonstration is being conducted on federal geothermal leases and National Forest system lands located in the Deschutes National Forest, adjacent to Newberry National Volcanic Monument (NNVM). Extensive exploration activities have been conducted in the Newberry area by public and private entities, including various geoscience surveys, and the drilling of thermal gradient, slimhole, and deep, large-bore wells since the 1970s. AltaRock Energy, Inc. (AltaRock), in partnership with Davenport Newberry (Davenport), has been awarded a DOE grant to demonstrate EGS technology at Newberry. The goals of the project include (Osborn et al., 2010):

- Stimulate multiple zones in existing well NWG 55-29 using AltaRock's proprietary diverter technologies,
- Create an EGS reservoir,
- Test single well tracers,
- Confirm EGS reservoir viability through a flow-back test of the injected water,
- Drill two production wells to intersect the EGS reservoir (scheduled for 2013), and
- Using well NWG 55-29 as the injector, demonstrate EGS viability through a three month circulation test.

SUMMARY OF PHASE I ACTIVITIES

Phase I of the Demonstration began in May 2010 and was concluded in December 2011. The team's activities, as well as those of the grant sub-recipients, included various field, laboratory and administrative studies. Field studies included installing a temporary MSA, a seismic calibration study to develop a local velocity model, monitoring background seismic data, upgrading water well equipment and testing the two existing water wells, conducting a baseline injection rate test, pressure-temperature surveys, and borehole televiewer imaging. Laboratory and office studies included development of a native state numerical reservoir model, a fracture stimulation model, developing new reservoir tracers and tracer models, and laboratory analyses of core and cuttings.

Permitting and administrative efforts included development of comprehensive plans for conducting Phase II activities, compiling a hydrological study of the local area, independent hydrology and seismic hazard and risk assessments, and working with the BLM, the US Forest Service (FS) and the DOE to conduct an EA of project plans, establishing an Induced Seismicity Mitigation Plan, and assembling a comprehensive report of Phase I activities and Phase II plans for a DOE 'stage-gate' review. The stage-gate report was completed in August 2011, and submitted to the DOE. The DOE convened a technical committee to perform a stage-gate review process, a prerequisite to Phase II activities. After minor revisions, the report and plans were approved by the DOE in November 2011.

AltaRock has established and maintained a comprehensive public outreach campaign to inform the public about project-related activities by conducting outreach and informational meetings in local communities, publishing project plans and independent consultant reports, and providing relevant educational materials about geothermal and EGS on multiple web sites and social media outlets.

Phase I activities and results are also discussed in Osborn et al. (2010, 2011), Cladouhos et al. (2011a, 2011b), the EA (BLM, 2011) and the Phase I stage-gate report (AltaRock, 2011a). Below, we update technical highlights and accomplishments, with an emphasis on the past 6 months.

INDUCED SEISMICITY MITIGATION PLAN

To quantify and mitigate the risks associated with induced seismicity at the Newberry EGS demonstration, AltaRock developed a project-specific induced seismicity mitigation plan (ISMP). The final report (AltaRock, 2011b) was completed on August 3, 2011 and, after expert review, deemed adequate by the DOE. After approval the ISMP was made publically available on AltaRock's website and included in the EA (BLM, 2011).

The ISMP was initially based on the *International Energy Agency Protocol for Induced Seismicity Associated with Enhanced Geothermal Systems* (Majer et al. 2008). While the Newberry ISMP was in its final revision, a new protocol was published online (Majer et al., 2011). The revised protocol is more detailed than the first and includes knowledge of induced seismicity obtained in the intervening three years. The new protocol's steps are:

- Step 1: Perform Preliminary Screening Evaluation
- Step 2: Implement an outreach and communication program
- Step 3: Identify criteria for ground vibration and noise
- Step 4: Establish seismic monitoring
- Step 5: Quantify the hazard from natural and induced seismic events
- Step 6: Characterize the risk from induced seismic events
- Step 7: Develop risk-based mitigation plans

The general steps of both the 2008 and 2011 versions of the protocol are satisfied by AltaRock's ISMP. The compliance is summarized below and provided in detail in AltaRock (2011b).

Step 1: Perform Preliminary Screening Evaluation

AltaRock selected the Newberry area and NWG 55-29 as a highly favorable EGS demonstration site through a screening process and evaluation of previously permitted geothermal activities. An EIS prepared in 1994 for a geothermal power plant (the plant was never built) and a 2007 EA prepared for more recent geothermal activities and exploration suggested that there were no major obstacles to the contemplated demonstration project. Preliminary screening indicated that the induced seismicity hazard would be low because there are no large, stressed faults in the vicinity of the potential site. The nearest town, La Pine, is about 10 miles (16 km) from the well and no recorded historic (since 1891) large (M >5.0) earthquakes have occurred within 100 miles (160 km) of the site. These conclusions provide strong evidence that the Newberry site is an appropriate location for an EGS demonstration.

Step 2: Implement an outreach and communication program

As noted in the summary above and also described in more detail below, AltaRock has made public outreach a high priority. Comments received at public meetings and online during Phase I of this Demonstration have indicated a favorable social and political climate. Water use and groundwater quality seem to be of greater concern to the public living in the area surrounding the demonstration project than induced seismicity. This is likely a consequence of the distance between the demonstration well and permanent residences and the lack of natural historic seismicity.

Step 3: Identify criteria for ground vibration and noise

AltaRock has conducted a review of relevant federal, state and local laws and regulations, and has determined that laws and regulations are not so restrictive that any effects of induced seismicity would not be allowed. No laws or regulations in Oregon specifically prohibit or regulate induced seismicity. In the absence of laws and regulations relating directly to induced seismicity from EGS activities, AltaRock reviewed laws and regulations relating to activities that could potentially cause vibration or induced seismicity, such as the impounding of reservoirs, and mining and quarrying (Cypser, 1996), both activities that are not uncommon in Oregon.

Step 4: Establish seismic monitoring

A primary component of induced seismicity mitigation is the installation and operation of a seismic monitoring system. Previously there was only one regional seismic station within 16 miles (25 km) of the Demonstration site operated by the Pacific Northwest Seismic Network (PNSN). To improve the coverage of this network, AltaRock added two stations to the PNSN. AltaRock has also installed a local MSA of seven seismic stations surrounding the target EGS well, NWG 55-29, that is currently collecting background natural seismicity data. The results of the background seismicity monitoring are described in a section below.

The plan for the Phase II MSA (Figure 1) has been reviewed and accepted as part of the ISMP for the Demonstration (AltaRock, 2011b). It consists of 6 surface seismometers and 8 borehole seismometers. Deployment in boreholes at least 210 m (700 ft) deep is desirable to reduce noise from surface sources and reduce waveform distortion caused by propagation through weathered rocks near the surface. Permissions for the proposed seismic station locations will be granted after the pending decision on the EA. Surface occupancy and disturbance are limited within the NNVM and in a buffer to the monument; therefore, the station coverage to the east of NWG 55-29 is primarily surface MSA stations rather than borehole installations. In addition to the stations, a strong motion sensor (SMS) will be installed at or near the Paulina Lake Visitor Center (PLVC). Any shaking recorded on this sensor is expected to be about 10 times greater than shaking that might occur in La Pine, making PLVC the optimal SMS monitoring site.

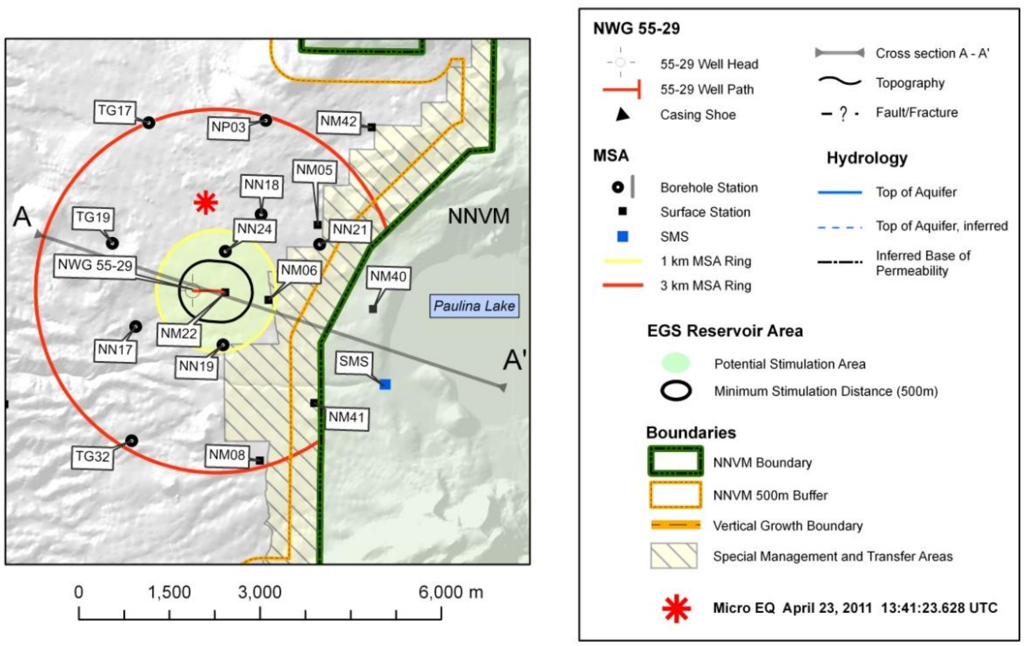

Figure 1: AltaRock final MSA design, including borehole installations, as currently planned. Minimum and potential stimulation areas are shown (light green shaded circle) based on a preliminary stress model of the microseismicity cloud that will be induced and the approximate extent of the EGS reservoir. Hatched area is a limited use buffer to the Monument, which is in green. Line of cross-section A-A' on Figure 3 is also shown. The red star shows the locations of the one seismic event detected below the network between Nov. 2010 and Nov. 2011. The legend is also applicable to Figure 3.

Step 5: Quantify the hazard from natural and induced seismic events

In addition to the seismic monitoring described above, AltaRock has conducted detailed geologic and geophysical investigations of the Demonstration area. Based on analysis of BHTV images (Davatzes and Hickman, 2011) and LiDAR data (Cladouhos et al., 2011a), AltaRock concluded that there is no evidence of recent faulting or other brittle deformation near NWG 55-29. These results suggest that hydroshearing of the small fractures intersected by the well will not trigger slip on any nearby fault.

URS Corporation (URS), an independent engineering consultant, prepared an Induced Seismicity and Seismic Hazards Risk Analysis for the Newberry EGS Demonstration (URS Corp., 2010). Based on case histories of other EGS projects, URS assumed a range of 3.5 to 4.0 for the largest magnitude of a seismic event that could be induced by the EGS Demonstration. URS then conducted a cumulative probabilistic seismic hazard analysis to determine the risk due to both natural and induced seismicity. The URS report concludes "the results of the probabilistic seismic hazard analysis indicate that there is no difference in hazard at La Pine, Sun River, and the Project site (NWG 55-29) between the baseline conditions (which incorporates the hazard from both natural tectonic and volcanic seismicity) and the EGS induced seismicity."

URS also modeled the potential shaking at Newberry assuming an induced seismic event with a moment magnitude (M_w) of 3.5 at the target injection well, NWG 55-29. The resulting shakemap predicts 0.01 gravity (g) peak ground acceleration (PGA) in La Pine and 0.1 g PGA at Paulina Lake.

To develop site-specific, theoretical models of M_{max} for the Newberry EGS Demonstration, AltaRock commissioned the William Lettis & Associates division of Fugro Consultants. Their assessment (Fugro, 2011) included additional analysis of LiDAR data, updated physical and injection plan parameters, a model incorporating high heat flow at Newberry, and estimates of the probability of the different M_{max} levels. The report concludes "[b]ased on this analysis, the probability of the Newberry injection activity inducing an event with M > 3.0 is less than 1% over a 50-day period that would include injection and pressure dissipation. At a 95% probability, the maximum induced event has M less than 2.2."

To conclude, the combined conclusions of two different independent engineering analyses indicate that:

1. The probable upper-bound maximum magnitude of an induced seismic event at Newberry is M_w 3.5 to 4.0.
2. The probability of a seismic event with a magnitude greater than M_w 3.0 is less than 1%
3. There is no difference in seismic hazard between the natural seismicity and the hazard introduced by EGS induced seismicity
4. If an M 3.5 seismic event did occur, the potential for damage at the nearest structures would be light, corresponding to a Modified Mercali Intensity of VI .

Step 6: Characterize the risk from induced seismic events

In order to assess the risk of damage of built structures, the FS provided AltaRock with a list of 52 key assets within the NNVM, which includes various buildings, two bridges, a road, a dam, and three slope faces. In June 2011, a structural engineer and a geotechnical engineer conducted a visual inspection of the bridges, the dam, and 15 representative buildings and cabins. The purpose of the visit was to become familiar with the construction types of the buildings and the bridges. They determined that the buildings are all of wood-frame construction. The older vintage buildings are log cabin style, while the newer buildings are more traditional modern wood frame construction, all with either a stone or concrete foundation. The three structures at the outlet of Paulina Lake were also inspected: the small (3 to 4 feet high) dam, the older (1954) and integral concrete bridge which is no longer in use, and the new (2008) steel bridge installed over the concrete bridge. The talus slopes could not be observed in the field due to snow cover; however they were observed on a follow-up visit. On June 22, 2011, AltaRock presented the preliminary results of the field visit to the BLM, FS and DOE, and proposed the methodologies for evaluating the assets on a second visit.

After agreement by the regulators, twelve representative structures were scored using the national standard document, "Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook" (FEMA, 2002). For the twelve NNVM structures scored, the PGA resulting in a 10% probability of collapse was determined to be between 0.25 and 1.1 g. Further analysis indicates that in a "worst case" 0.10 g PGA that an M 3.5 seismic event could produce the collapse probability would be 1.2% or less for all NNVM structures.

For the purpose of the EA (BLM, 2011), AltaRock and its consultants developed a simplified metric for seismic risk; the probability that seismic shaking will surpass the threshold for cosmetic damage to structures. This probability can be estimated for both natural seismicity and EGS related seismicity. For the Newberry-specific studies, the following was determined.

1. Peak ground acceleration (PGA) above 0.028g has the potential to cause cosmetic damage to the structures in the NVNM nearest the demonstration site. The shaking threshold for structural damage (at a 10% probability) was estimated to be ~10 times higher (0.25 g).
2. The probability that natural seismic or volcanic events would produce shaking that exceeded 0.028 g is 5% per year (URS, 2010).
3. While seismicity induced by the EGS demonstration project will create many small seismic events that will be detectable by a network of sensitive seismometers, the probability that an induced seismic event will be large enough to cause shaking that exceeds 0.028 g in the NNVM is 0.2%.

In other words, cosmetic damage to structures in the NNVM is 25 times more likely to occur due to natural seismic and volcanic events than EGS demonstration project induced seismic events. Further, AltaRock has agreed to cease injection into the EGS Demonstration well if shaking above 0.028 g is detected at the Paulina Lake SMS (see next step).

Step 7: Develop risk-based mitigation plans

For control and mitigation of induced seismicity, the ISMP defines limits (or 'triggers') that, if activated, will initiate mitigation actions up to and including stopping injection and immediately flowing the well to reduce reservoir pressure. The triggers will be monitored during hydroshearing and EGS reservoir creation, and throughout the remainder of the Demonstration. These triggers are based on real-time measurement of seismic activity on the PNSN regional network, the AltaRock MSA and the Paulina Lake SMS. There are three levels of mitigation based on event magnitude or shaking: (1) hold flow rate and pressure constant if a locatable seismic event with $2.0 \leq M \leq 2.7$ occurs; (2) reduce flow rate and pressure if a seismic event with $2.7 \leq M \leq 3.5$, or $0.014 \text{ g} \leq PGA \leq 0.028$ g on the PLVC SMS occurs; and (3) stop injection and flow well to reduce reservoir pressure if a seismic event with $M \geq 3.5$ or $PGA \geq 0.028$ g on the SMS occurs. Diverter materials will be added to the injected water to shift fluid flow to a different well depth if events are located at a depth of less than 6000 feet (1830 m) or within 1640 feet (500 meters) of the NNVM. Each trigger level also includes more frequent and detailed reporting and communication activities. See Figure 2 for a graphical summary of the mitigation plans.

HYDROLOGY AND GROUND WATER MONITORING

The primary source for the water to be injected during stimulation is a groundwater well on the same drill pad (S-29) as the geothermal well, NWG 55-29. Pad S-16, about 2 miles (3 km) north of pad S-29, also has a groundwater well which will serve as the backup.

Groundwater on the flanks of Newberry Volcano around the project area is hosted in young volcanic flows and interspersed sedimentary deposits, with occasional and discontinuous impermeable lithologies. Cross section A-A' (Figure 3) shows the shallow partially confined to unconfined aquifer on the flanks of Newberry Volcano. Based on review of shallow loss zones during drilling, isothermal temperature profiles, and increasing clay alteration with depth described in mud logs, the mostly unconfined aquifer intersected by the water wells on pads S-16 and S-29 (well numbers DESC 58649 and DESC 58395, respectively) only extends to depths of about 1,000 ft (~300 m) across the project area, with some spatial variability (Dames and Moore, 1994). Below this depth, decreasing permeability caused by increasing clay content forms a basal aquiclude.

As part of the permitting process, a water usage plan was developed for all Phase II activities (AltaRock, 2011c). Many variables will affect actual water usage, including reservoir size (cumulative fracture volume), system leak-off rate, production enthalpy and resulting steam fraction, and the duration of circulation testing. The water usage plan predicts that Phase II will utilize between 223 and 435 acre-ft of water over 2 seasons. The stimulation of NWG 55-29 is expected to use less than 74 acre-ft (24.1 million gallons), while the long-term circulation test will use between 52 and 242 acre-ft, depending on test duration (30 versus 60 days) and steam fraction (estimated to be between 16.3% and 37.6%). For comparison, in 2008, the nearby city of Bend had a maximum demand of 29.2 mgd (million gallons per day), and an average demand of 12.8 mgd (HDR, 2010). That is, the three week stimulation in 2012, will use about the same amount of water as Bend does on a peak day.

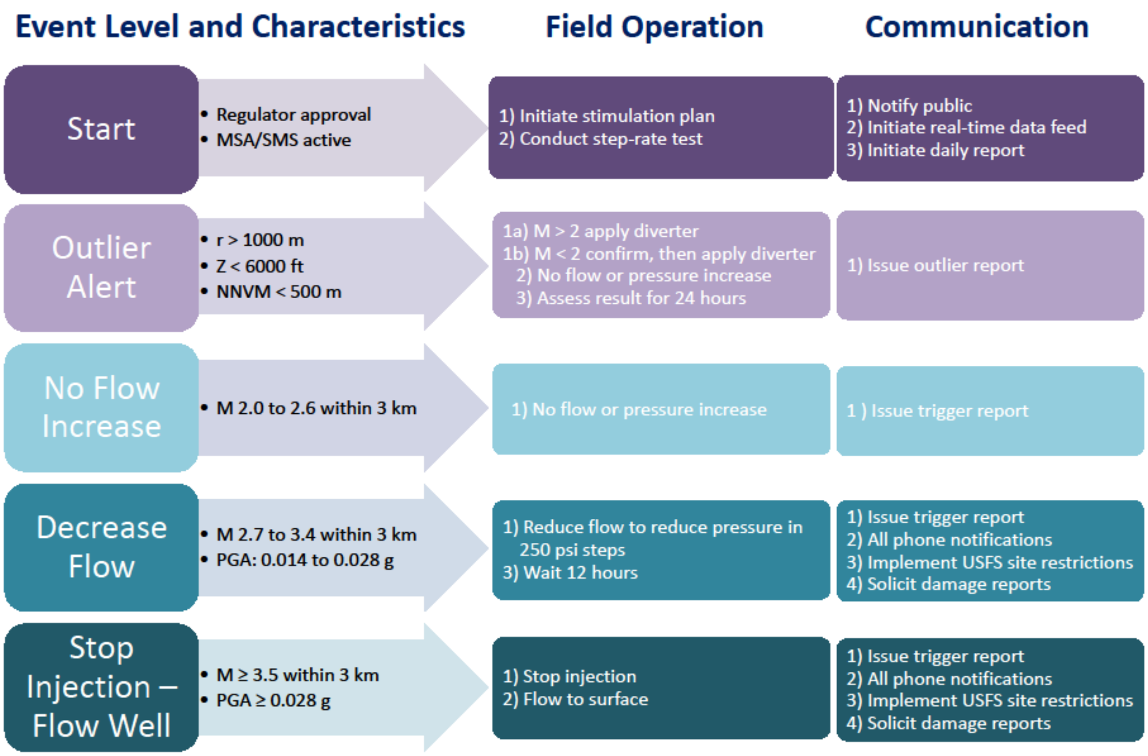

Figure 2: Decision tree for induced seismicity triggers and mitigation actions. See AltaRock (2011b) for details.

In January 2011, Kleinfelder was selected to provide an independent assessment of the water usage plan, They assessed the source of water that will be used, the effects of water use on local and regional aquifers, and how monitoring should be conducted to quantify effects during planned operations. The study also evaluated the evolution of the water that will be injected into the EGS reservoir, including the potential for water migration outside the planned EGS fracture network and unlikely impacts to the overlying shallow groundwater aquifer, the caldera lakes, and adjacent stakeholders. Their report, which reviewed the drawdown testing data from 2010, the proposed sampling plan and addressed several public scoping questions, was submitted to the BLM and posted to public sites in February 2011. Their report (Kleinfelder, 2011) concluded that there will be no detrimental impacts to the hydrologic environment from planned Demonstration activities. The report also suggested further drawdown testing of the water supply wells on Pads 16 and 29.

A drawdown and constant rate test was conducted on the Pad 29 water well the week of August 8, 2011. The well demonstrated a flow capacity of at least 700 gpm with minimal drawdown when projected for a constant flow test of over one month, easily sufficient for the NWG 55-29 stimulation. Pad 16, ~2 miles from Pad 29 has a groundwater well which will be used as a backup water source; therefore this well was tested in 2011 as well. A three-step drawdown test was conducted on Pad 16 water well from November 1 to November 2. The total volume pumped during the drawdown test was 3.27 ac-ft (~1 million gallons). A final drawdown test report concluded that the Pad 16 water well is also fully capable of meeting the sustained groundwater pumping needs for the 55-29 stimulation.

To monitor the regional hydrological system and detect the impacts, if any, of the EGS stimulation upon local groundwater and hydrothermal features, AltaRock has developed a geochemical and hydrological sampling campaign for ten sites: three drinking water wells at residences and campgrounds, two monitoring wells, the two injection supply wells, two hot springs, and Paulina Lake. The monitoring plan, which was approved by Kleinfelder and the DOE, includes water level monitoring, geochemical analysis for water quality and injected tracers, and turbidity measurement. By the close of 2011, some background monitoring had been initiated at 7 of 10 monitoring sites. Baseline levels at all sites will be established prior to stimulation.

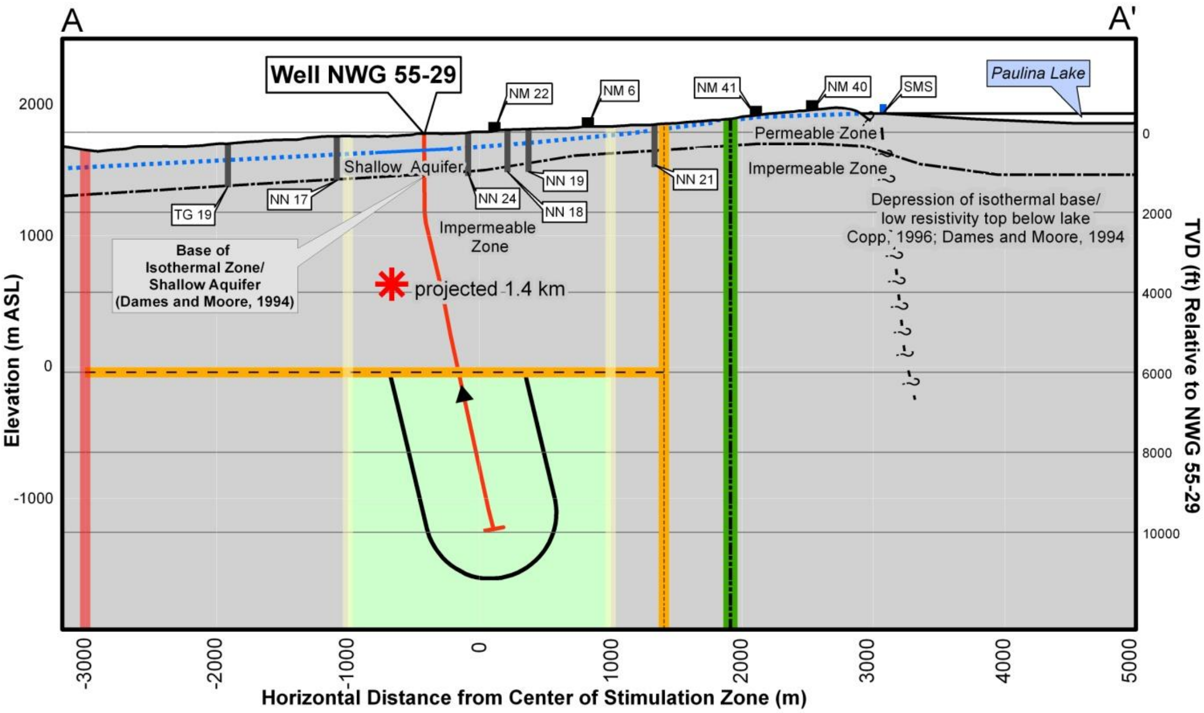

Figure 3. Cross section A-A' (Figure 1 shows line of section) showing groundwater aquifer, geothermal well bore profile (red), monitoring wells (black), and planned seismometer locations (labeled boxes) and target stimulation zone (green area). The full legend is shown in Figure 1.

BACKGROUND SEISMIC MONITORING RESULTS

In one year of data (11/2010-11/2011) two small seismic events and one aftershock were detected on at least 5 stations of the operating MSA. An event at 13:41:23 UTC, April 23, 2011 occurred at a depth of 472 m above sea level about 2 km north of NWG 55-29 (red star in Figures 1 and 3). This event had a small aftershock 88 seconds after the main event. The similarity of its waveforms, suggest that the two occurred in essentially the same location. Moment magnitudes of 0.8 and 0.1 were calculated for these two events.

An event at 08:56:56 UTC, July 30, 2011 was also detected. Both P and S phases are clearly recorded at most stations for this event. The times between the two phases constrain the hypocentral distance to be approximately 10 km NW of the center of the Newberry microseismic network, in the direction of the town of Three Rivers. Because the event lies well outside the network (not on Figure 1), its hypocentral location could only be determined approximately.

In November 2011, the 4.5 Hz geophones were replaced with more sensitive seismometers (1 Hz Geotech GS-13) in a joint effort with Lawrence Livermore National Lab (LLNL) to collect ambient background seismicity data (“noise”). LLNL’s noise processing algorithms should yield an improved seismic velocity model for the study area. This new velocity model will help improve accuracy of earthquake locations during the stimulation of NWG 55-29. The surface MSA will continue to operate and the data processed until replaced by a more sensitive array in Phase II.

INJECTIVITY TESTING

A static pressure-temperature (PT) survey was conducted with memory tools in NWG 55-29 to record the temperature profile, identify fluid level, and ensure that the well was open to total depth. A conductive gradient and maximum temperatures in excess of 600 °F (>316 °C) at total depth were observed, identical to that measured after well completion in 2008. An injection test was conducted to measure baseline injectivity prior to stimulation. Cool (50 °F, 10 °C), groundwater produced from the onsite water well was injected at approximately 10 gpm (0.63 L/s) at a surface pressure of 750 psi (51.7 bar) for three days, after which time an injecting pressure-temperature survey was conducted to determine if injection was indeed cooling the well bore. The PT survey showed water exiting the well from 9,280 to 9,560 ft (2,829 to 2,914 m). In this depth range, the mud log identifies many small felsic dikes and the contacts between three large granodiorite dikes and subvolcanic basalt, including one contact with a highly altered zone containing abundant epidote. The intrusive contacts are prime stimulation targets because of the likely presence of thermal cracking, alteration and weakening.

After conducting the injecting PTS survey, and demonstrating that low-rate injection would successfully cool the well, injection was discontinued. It was then re-started three weeks later under the same conditions to cool the well bore in preparation for BHTV logging. For three days, a higher injection rate of 21 gpm (1.3 L/s) at a surface pressure of 1,153 psi (8.0 MPa) was achieved. Natural injectivity was calculated to be 0.02 gpm/psi, which is comparable to injectivities measured in surrounding Newberry wells and to pre-stimulation injectivities at other EGS sites (Table 2; Spielman and Finger, 1998). A third PT survey was conducted just prior to BHTV logging to ensure that the well was cool enough for tool deployment. Fluid was found to be exiting from 8,640 to 8,800 ft (2,633 to 2,682 m) and from 9,280 to 9,560 ft (2,829 to 2,914 m). The zone from 8,640 to 8,800 ft (2,633 to 2,682 m) did not appear to accept injection when water was injected at 750 psi (5.2 MPa) and 10 gpm (0.63 L/s), but did when water was injected at 1,153 psi (79.5 bar) and 21 gpm (1.3 L/s). Since the zone from 8,640 to 8,800 ft (2,633 to 2,682 m) did not show any cooling during initial injection, it appears that 750 psi (5.2 MPa) was not enough to shear and dilate existing fractures at that depth, but at 1,153 psi (8.0 MPa) may be approaching the shear failure pressure.

Table 1: NWG 55-29 Injectivity into Open Hole from 6,462 to 10,060 feet (1,970 to 3,066 m)

Average WHP (psig)	**Injection Rate (gpm)**
751	14
821	17
1,153	21

HYDROSHEAR MODEL

AltaStim, a stochastic fracture and flow software package developed by AltaRock, was used to model a plausible stimulation scenario (Cladouhos et al., 2011b) based on analysis of injecting temperature logs, BHTV image logs and a stress model (Davatzes and Hickman, 2011), and geomechanical properties. In the model, a simulated wellhead pressure of 1950-2350 psi (13.4-16.2 MPa) results in a robust EGS reservoir comprised of three stacked stimulated zones, each with a total injected volume of 4-10 million gallons (15,000-40,000 m^3) and a map view half length of 1600 ft (500 m). In each zone, the injected volume was accommodated by 400-700 fractures with average radius of 60 m and stimulated aperture of 1-1.5 mm. In the model, the predicted microseismic cloud (Figure 4 shows one example of many) is generally controlled by the average stress and fracture orientations; some finer details are due to the stochastic fracture parameters.

PERMITTING

On December 23, 2011, the BLM published an EA for the Newberry EGS Demonstration (BLM, 2011) and initiated a 30 day public comment period. The EA is a direct response to the Notice of Intent to Conduct Geothermal Resource Exploration Operations (NOI) that was submitted to the BLM in May 2010, and is standard practice in this type of project as federal agencies have responsibilities under the National Environmental Policy Act (NEPA) to conduct environmental analysis and make a determination and decision based on the findings of that analysis. The EA contains documents discussing water usage, induced seismicity mitigation protocols, test equipment, alternative evaluation, and chemical information about the tracer and diverter materials to be used during the stimulation of NWG 55-29. The EA was prepared by the BLM in conjunction with the DOE and FS. A 30-day comment period ending 1/25/2012 provides the public the opportunity to direct questions and comments to the BLM. At the end of the 30-day comment period, the BLM will review and consider comments that are submitted and determine whether to issue a Finding of No Significant Impact (FONSI) or whether it is necessary to prepare an Environmental Impact Statement (EIS).

The EA includes the ISMP (AltaRock, 2011b; URS, 2010, 2011; Fugro 2011) and the independent assessment of the water usage plan (Kleinfelder, 2011) as these studies cover the primary environmental concerns expressed by the regulators and public. In addition, the EA includes a scenic resource assessment that concluded that impacts to scenic resources would be minimal and project activities are not expected to draw attention or adversely affect the viewing experience. The FS performed a Biological Evaluation and wildlife report of the project area. There are no known active raptor nests within or adjacent to the project sites; nor does the project area contain any habitat for any threatened, endangered, or candidate species.

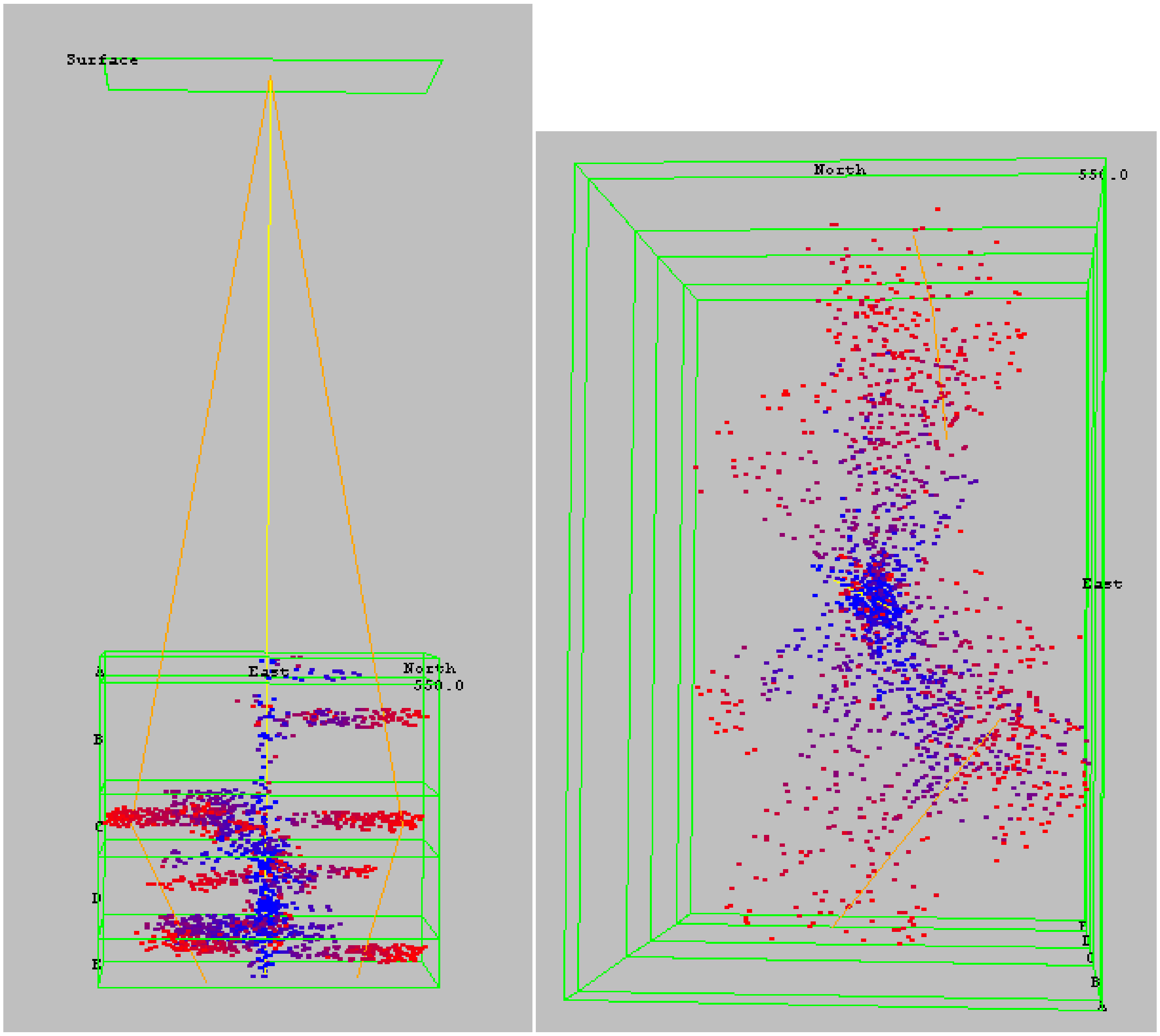

Figure 4: Example of AltaStim model of microseismicity for all five geologic zones in the open hole (depth of 6,500-10,000 ft); (left) scaled view looking west includes surface and well courses of injector (yellow) and proposed producers (orange), (right) map view of combined microseismicity, green bounding box is 2300 ft (700 m) east-to-west and 3610 ft (1100 m) north to south. See Cladouhos et al. (2011b) for more details.

In addition to initiating the NEPA process with the federal agencies, the project team worked with state agencies to secure the necessary environmental permits on the state level. The Oregon Water Resources Department issued a limited water use license to supply the necessary groundwater required by the Demonstration project. Oregon Department of Environmental Quality (DEQ) issued a temporary underground injection control permit for the baseline injection test at NWG 55-29. AltaRock will continue to work with the federal and state agencies to secure the necessary environmental permits for the subsequent phases of the project.

PUBLIC OUTREACH

Four community outreach meetings have been held in La Pine, Sunriver, Bend, and at the Demonstration site to communicate plans with regulatory agencies and local stakeholders, and provide educational opportunities on the Demonstration plans and benefits. Public concerns have been primarily related to water consumption, evolution of water used for stimulation, induced seismicity, and potential visual and recreational impacts to the nearby national monument. We have addressed the primary concerns related to water and induced seismicity by commissioning independent assessments of our project plans by Kleinfelder and URS, respectively.

These studies, subsequently published on our web sites and announced through social media, investigated potential impacts to the environment and, where appropriate, recommended additional mitigation measures, which AltaRock has incorporated into project plans.

Two web sites[1] and several social media outlets[2] have been established to actively communicate Demonstration plans and activities. AltaRock has posted project plans and technical reports to the Demonstration websites and social media sites to keep the public informed of recent developments, and to relay related information about geothermal energy, enhanced geothermal systems, and related energy issues. Search engine optimization techniques are used to enable concerned stakeholders to readily access project information. Positive public support is evidenced by increasing numbers of the public actively following the posts and *liking* the Facebook page. These sites will be continuously updated through the lifetime of the Demonstration to keep the public and regulators informed, including frequent text and video updates during periods of major field activities such as stimulation, drilling and flow testing. Before well stimulation begins, notices will be published in the local newspapers and contact information (phone numbers, email addresses, websites, etc.) provided for interested citizens to receive more information and report concerns. Public meetings will be held monthly during active Phase II field operations.

To date, AltaRock and Davenport have also provided more than 20 presentations at public venues and professional meetings, including the outreach meetings mentioned above, the 2010 and 2011 Geothermal Resources Council Annual Meeting, Oregon Geothermal Working Group meetings, and the 2011 Stanford Geothermal Workshop. The project team meets regularly with county, state and federal elected leaders, and other stakeholders, including environmental groups, to inform them of our progress and plans.

AltaRock participated in the Bend Fall Festival October 1-2, 2011 attended by an estimated 40,000 people. The booth set up by AltaRock was well-attended. The display premiered an eight minute, professionally narrated video explaining hydrothermal energy and EGS in general and the Newberry demonstration in particular. We personally discussed the project with hundreds of visitors and handed out over 500 items branded with the project logo. The public response was overwhelmingly positive, with visitors expressing interest in renewable energy and economic development.

The video was also shown on a continuous loop at the annual GRC meeting and posted to the social media sites and YouTube. Oregon Public Broadcasting did a radio story on the project that aired on December 23, 2011 (OPB, 2011) and a TV story for the Oregon Field Guide which will air February 16, 2012.

PHASE II ACTIVITIES

The primary objective of Phase II is the creation an EGS reservoir, and demonstration of efficient extraction of heat from the underlying resource at economically viable flow rates using three hydraulically-connected wells. Tasks to be completed in Phase II represent the core of the EGS reservoir development effort, including four principal subtasks: 1) stimulation and testing of the target injection well (summer 2012); 2) drilling and testing of the first production well (2013); 3) drilling and testing of the second production well; and, 4) a 30-day circulation test involving the injection well and both production wells.

Phase II will begin after the EA review is complete and the NOI is approved. At that point, AltaRock plans to contract to begin drilling five holes for installation of borehole seismometers. Once the holes are completed, the microseismic array will be installed and tested. This will set the stage for stimulation of NWG 55-29 when testing of the diverter materials and tracer modeling methods will be accomplished.

SUMMARY

During Phase I, the Newberry project team studied existing data and gathered new regional and well bore data to develop a comprehensive geoscience and reservoir engineering model of the resource underlying the Demonstration site. AltaRock formulated a detailed plan to conduct Phase II operations, which includes seismic monitoring, stimulation, drilling and testing. Concurrently, the team assembled a large array of project information to conduct public outreach and inform regulatory agencies. The completed tasks include implementing a public relations campaign by distributing information and determining stakeholder concerns through the use of public meetings, web site and

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[1] www.newberrygeothermal.com and www.altarockenergy.com

[2] www.facebook.com/NewberryEGS, www.twitter.com/NewberryEGS and www.newberrygeothermal.wordpress.com

social media and providing detailed project plans and background information to aid the Environmental Assessment and the Phase I stage-gate review.

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Intellectual property statement

AltaRock holds a portfolio of patents, patent applications, licenses and related proprietary intellectual property regarding its diverter and stimulation technology, materials and methods.

REFERENCES

AltaRock (2011a), Newberry EGS Demonstration Phase 1 Report - Confidential, 290 pp. plus 27 appendices. Not yet publically available.

AltaRock (2011b), Newberry EGS Demonstration Induced Seismicity Mitigation Plan, 64 pp. plus 14 appendices. Available at: http://altarockenergy.com

AltaRock (2011c), Evaluation of Water Usage for the Newberry EGS Demonstration. 35 pp. Available at: http://altarockenergy.com

BLM (2011), "Newberry Volcano Enhanced Geothermal System (EGS) Demonstration Project, Environmental Assessment," 148 pp. plus 2 appendices, Available at http://www.blm.gov/or/districts/prineville/plans/newberryegs/index.php

Cladouhos, T., Petty, S., Callahan, O., Osborn, W, Hickman, S. and Davatzes, N. (2011a), "The Role of Stress Modeling in Stimulation Planning at the Newberry Volcano EGS Demonstration Project," *Proceedings: Thirty-Sixth Workshop on Geothermal Reservoir Engineering, Stanford University, Stanford, California, January 31 - February 2, 2011*, **SGP-TR-1191**, 630-637.

Cladouhos, T.T., Clyne, M., Nichols, M., Petty, S., Osborn, W.L. and Nofziger, L. (2011b), "Newberry Volcano EGS Demonstration Stimulation Modeling," *Geothermal Resources Council Transactions*, **35**, 317-322.

Cypser, D.A. and Davis, S.D. (1998); "Induced Seismicity and the Potential for Liability under U.S. Law," *Tectonophysics*, **289**, 239

Dames and Moore (1994), Revised report Newberry Geothermal Project Hydrology Baseline Study Newberry Volcano, Oregon for CE Exploration Company. Portland, OR, 268 pages.

Davatzes, N.C. and Hickman, S. H. (2011), "Preliminary Analysis of Stress in the Newberry EGS Well NWG 55-29," *GRC Transactions*, **35**, 323-332.

FEMA (2002), "Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook." 165 pp. Available at: http://www.fema.gov/library/viewRecord.do?id=3556

Fugro Consultants Inc. William Lettis & Associates Divsion (2011), "M_{max} Assessment for the Newberry EGS Demonstration at the Davenport 55-29 Site," 40 pp., Appendix E. of AltaRock (2011b).

HDR (2010), "Surface Water Improvement Project: Surface Water / Groundwater Cost Comparison," Technical memo,. http://www.bend.or.us/modules/showdocument.aspx?documentid=3962

Kleinfelder (2011), "Report: Independent Hydrologist Review, AltaRock Energy, EGS Demonstration Project, Newberry, Oregon." Available on http://altarockenergy.com

Majer, E., Baria, R., and Stark, M. (2008). "Protocol for induced seismicity associated with enhanced geothermal systems." Report produced in Task D Annex I (9 April 2008), International Energy Agency-Geothermal Implementing Agreement (incorporating comments by: C. Bromley, W. Cumming, A. Jelacic and L. Rybach). Available at: http://www.iea-gia.org/publications.asp.

Majer, E., Nelson, J. Robertson-Tait, A. Savy, J. and Wong I. (2011). "(Final Draft) Protocol for Addressing Induced Seismicity Associated with Enhanced Geothermal Systems (EGS)." Available at: http://esd.lbl.gov/files/research/

projects/induced_seismicity/egs/EGS-IS-Protocol-Final-Draft-20110531.pdf

OPB, 2011, http://news.opb.org/article/geothermal-experiment-may-cause-small-quakes-central-oregon/

Osborn, W., Petty, S., Nofziger, L. and Perry, D. (2010), "Newberry Volcano EGS Demonstration," *Geothermal Resources Council Transactions*, **34**, 413-418.

Osborn, W.L., Petty, S., Cladouhos, T.T., Iovenitti, J., Nofziger, L., Callahan, O., Perry, D.S. and Stern P.L. (2011), "Newberry Volcano EGS Demonstration – Phase I Results," *GRC Transactions*, **35**, 499-505.

Spielman, P. and Finger, J. (1998), "Well Test Results of Exploration Drilling at Newberry Crater, Oregon in 1995," *Proceedings: Twenty-Third Workshop on Geothermal Reservoir Engineering, Stanford University, Stanford, California, Jan 26-28, 1998*, **SGP-TR-158**,21-26.

URS Corp. (2010), "Evaluations of Induced Seismicity / Seismic Hazards and Risk for the Newberry Volcano EGS Demonstration." Appendix F of AltaRock 2011b. 106 pp.

URS Corp. (2011), "Development of Scenario Ground Shaking Maps and Evaluations of the Impacts of Ground Shaking on Local Buildings, Avalanches, and the Lava River Cave." Appendix G of AltaRock 2011b, 14 pp.