NREL is a national laboratory of the U. S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

Sandia National Laboratories is a multi-program laboratory operated and managed by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000

SURGE: Technology Transfer at Edgar Mine Fracture Flow and Heat Exchange Efficiencies

Chad Augustine, National Renewable Energy Laboratory
Stephen Bauer, Sandia National Laboratory
Masami Nakagawa, Colorado School of Mines

INTRODUCTION

Fluid flow through fractured rock networks is not well understood and there is a paucity of data to validate models used to predict the performance of systems in fractured rock masses. The goal of this project is to create a small fracture network that can be accessed relatively easily in order to characterize the fractures. The study will create a fracture network by drilling into the wall of the mine and fracturing the rock, characterizing the size and nature of the fracture network, circulating fluid through the network, and measuring the efficiency of heat extraction from the reservoir by monitoring the temperature of the "produced" fluid with time. An ideal site would be a mine, where a fracture network could be created at a reasonable distance below the surface, but the fractures would still be relatively accessible for study and characterization. For this study, we are using the Edgar Experimental Mine in Idaho Springs, Colorado – an underground laboratory operated by the Colorado School of Mines (CSM) Mining department. This will be a multi-year project. A key objective of the first year will be to estimate the stress state and orientation of existing fractures in the mine, as these will determine the direction of fracture growth and dictate viable locations within the mine for further activities. This project will be done as a collaboration between the National Renewable Energy Laboratory and the Colorado School of Mines as part of the Colorado Subsurface Research in Geothermal Energy (SURGE) collaboration, and Sandia National Laboratories.

METHODS

Primary tasks for Year 1 of the project are:

1. Select candidate locations in mine for experiment.
2. Map mine walls in candidate locations to determine locations of existing fractures, faults, and discontinuities. Use this information to create 3D geologic and structural models of candidate locations. Use 3D model to finalize experiment location.
3. Drill core holes in in experiment location to estimate in-situ stresses and fracture set descriptions.
4. Created detailed experimental plan for FY16.

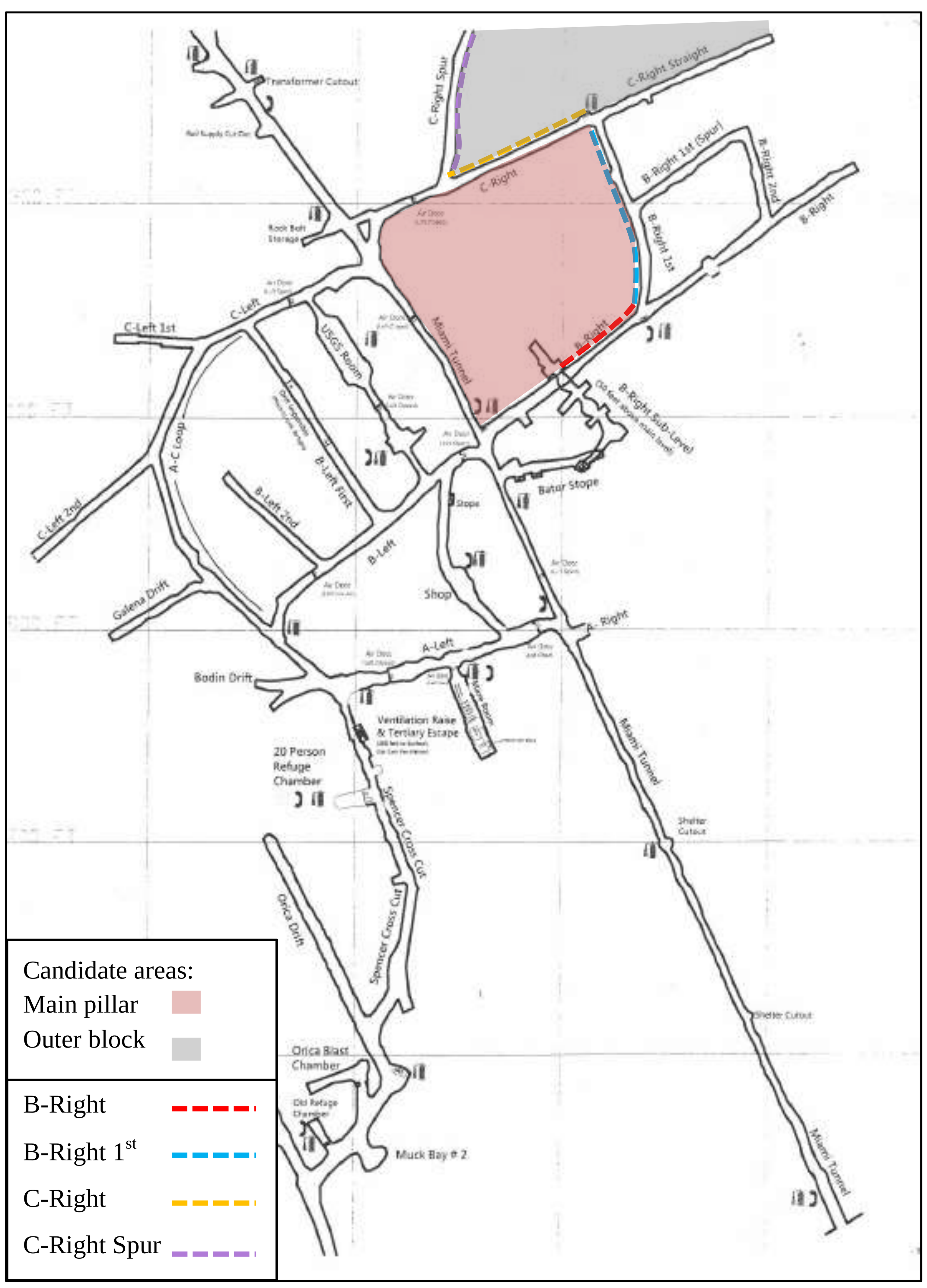

Figure 1. Map of Edgar Experimental Mine, showing primary and secondary candidate areas for experiment. Dashed lines indicate areas of mine that have been mapped for discontinuities to date.

RESULTS

Based on multiple tours of the mine, two candidate locations for the experiment were selected (Figure 1.). Scan lines* have been completed in the drifts (Figure 1) surrounding candidate locations and pole plots of discontinuities have been constructed. Pole plots for mapped discontinuities in B-Right 1st and C-Right are shown below in Figures 2 and 3. The lines show discontinuity sets as interpreted by the software program DIPS, using fuzzy c-means clustering analysis (see Table 1 for summary of results).

Figure 3 and Table 1 show that the fracture-dominated discontinuity sets tend to line up parallel to B-Right and C-Right. This implies that we should drill into the main pillar horizontally (likely from C-Right) so that core holes intersect fractures indicated in the discontinuity sets at nearly a right angle.

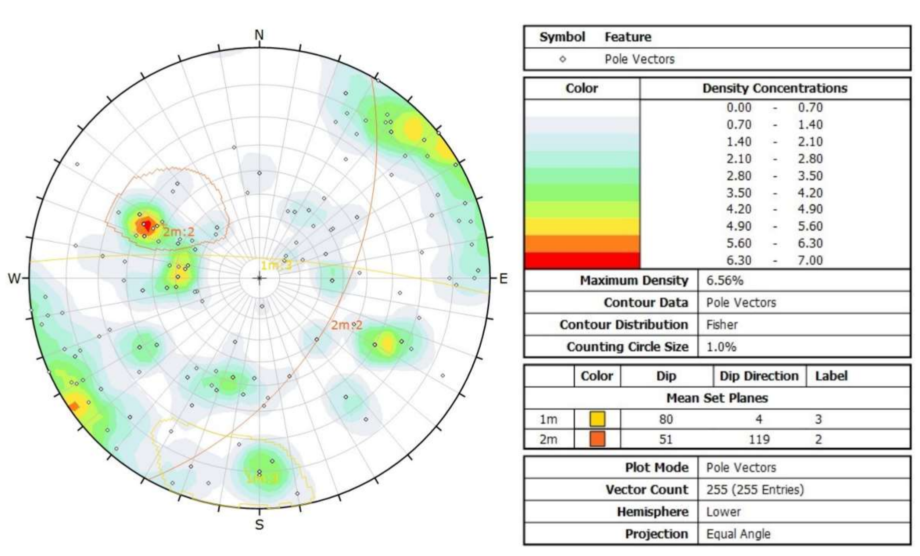

Figure 2. Stereonet of B-Right 1st (from DIPS software)

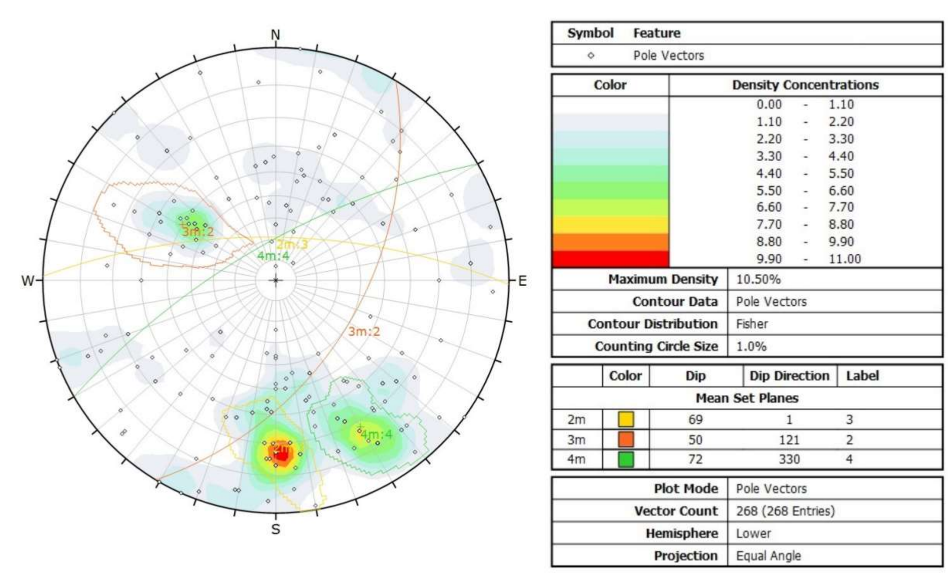

Figure 3. Stereonet of C-Right (from DIPS software)

Table 1. Main discontinuity sets from Edgar Mine mapping.

Discontinuity Set	Type of Discontinuity	Average Dip (Degrees)	Average Dip Direction (Degrees)	Average Spacing (ft)
Scanline B-Right, Trend: 060				
1	Fracture	78	148	1.3
3	Fracture and Foliation	68	345	1.3
Scanline B-Right-1st, Trend: 350				
2	Fracture	50	121	2.9
3	Fracture and Foliation	69	1	3.1
4	Fracture	72	330	3.8
Scanline C-Right, Trend: 240				
2	Fracture	51	119	2.5
3	Fracture and Foliation	80	4	6.1
Scanline C-Right-Spur, Trend: 005				
2	Fracture	48	136	3.4
3	Fracture and Foliation	63	354	8.8
4	Fracture	69	334	4.8

CONCLUSIONS

Underground inspections of the mine lead us to conclude that we will likely use the main pillar for the experimental activities due to access for characterization of the fractures from all 4 sides of the pillar. Development and safety approval of an experimental plan for this area is underway.

Fracture mapping indicates that the major discontinuity sets are sub vertical (nearly vertical) and nearly parallel to drifts B-Right and C-Right. Based on this information, we believe that horizontal "wells" drilled from C-right will intersect the vertical fractures and allow for circulation experiments consisting of flow from horizontal wells through nearly vertical fractures to be carried out.

FUTURE WORK

Future work for this fiscal year consists of the following:

- Additional mine mapping along the Miami tunnel. This information will be used to determine if any of the fractures in B-Right 1st extend through the entirety of the pillar.
- Drill up to 3 coreholes in the chosen experimental area. These coreholes will be used to further identify fracture sets, provide access for borehole logging tools, and to estimate in-situ stresses, if possible. However, we believe that existing fractures will dominate fracture creation.
- Finalize 3D geologic and structural model using information from mine mapping and cores.

A detailed experimental plan will be developed based on information gathered this year for carrying out circulation experiments in FY16.

This work was supported by the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy (EERE), Geothermal Technologies Office (GTO) under Contract No. DE-AC36-08-GO28308 with the National Renewable Energy Laboratory (NREL).

***Special thanks to Dr. Wendy Zhou and Robert Duran of Colorado School of Mines for their work mapping Edgar Mine and interpreting results.**

GTO Peer Review
May 2015