

Deep Fracture Mapping at DUSEL Using Acoustic Techniques

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Project Goal:

The goal of this proposal is to investigate methodologies to quantify fracture parameters (length and width) using acoustic signals. Successful completion of this goal will allow estimations of rock properties, water flow paths, and fluid discharges to be quantified.

Scientific and Engineering Justification:

Fractures are fundamentally important to the design engineering of new research spaces at DUSEL, particularly in the construction of the large areas proposed for the physics Neutrino experiments. Fractures also are the conduits through which large volumes of water flow through the mine. The effect that lateral extent of any single fracture and its interactions with intersecting fractures has on the overall strength characteristics of the bulk rock mass is largely unknown. Bulk rock mass properties at DUSEL are generally characterized as inhomogeneous and anisotropic. Intense shear is present at all levels in the mine and fracture width seemingly does not always close at depth, despite the increased stress regime, and high discharges are observed in particular fracture systems at great depth. The extent of these fractures are unknown. These experiments would define techniques to utilize acoustic signals for acquisition of rock and fracture properties. The effect of conjugant fracture sets from simple (1 intersecting fracture) to complex (more than 1 intersecting fractures) would also be explored. Results of these experiments would be beneficial for planning future development of DUSEL and for defining portions of the underground workings to be retained for future research.

Proposed Experiments:

The work proposed here is phase 1 of a multi-phase project that is intended to extend into future years as access to deeper portions of the mine is re-established. Phase 1 involves 2 parts, A) the proof-of-concept for using diagnostic ultrasound to map fracture lengths (both simple and complex systems) over short distances at shallow depths, and B) comparative measurements acquired at the 4850 level. Results will define the procedure and tools to acquire the most definitive rock and fracture properties.

Ideally, part A of the experiment will occur at shallow depths (a few hundred feet maximum,

such as the tramway or 300 level) where a low vertical stress regime will promote wider fracture spacing and the best opportunity for straight fracture paths. The first experiment will utilize a corner of two intersecting drifts that are near the Ross shaft and geologic mapping will be used to locate a dry fracture set that is present in both exposed drifts, theoretically having a lateral distance through the corner of no more than 1 m. Instrumentation will be set up on both exposed fracture faces, one side used as the acoustic source and the other side containing receivers. The experiment will involve trials where the frequency of the source pulse will be changed to define the correct frequency required to ‘map’ the known distance between source and receiver. Based upon initial results of frequency effects through a fracture, the experiment may require transformation into propagation of sound through a solid where the fracture would be ‘mapped’ indirectly as indicated by a change in received energy at the sensor due to reflection off the fracture.

Another set of shallow experiments, as described above, will be conducted on multiple intersecting dry fractures to determine effects due to anisotropy and inhomogeneity of the rock mass. A third set of shallow experiments, as described above, will be conducted at a location where there is active seepage through a fracture. These tests will document water effects on the mapping techniques being developed. In every set of trials under varying rock and hydrologic conditions, the techniques used to define rock and fluid flow properties will be defined.

Utilizing the knowledge gained from the shallow experiments, a second set of data would be collected at the 4850 level across similar distances and hydrologic regimes, most likely not to exceed 1 m on an intersecting corner. Again, a single dry fracture, intersecting dry fractures, and water-filled fractures would be measured. From both of these data sets, a fracture model would be constructed which could be used to determine depth-controlled fracture properties (length and width).

Based on these initial experiments we would propose a similar experimental program that would move laterally away from the primary access shaft on any drift (the 4850 level, for example) and proceed deeper into the mine as deep access is restored. Results of these experiments may shed new knowledge on the hydrologic properties of fractures in the mine and aid engineers as new drifts and rooms are constructed in the underground spaces.

Infrastructure Requirements and Impact on Other Users:

There are no surface infrastructural requirements for this proposal. There are no underground infrastructural requirements for this proposal other than underground access (plus light and power—see attached underground space worksheet). We do not envision an impact to any other researchers during phase 1. The number of intersecting drifts are numerous and we will be able to locate these experiments away from any other group that may be present on the same level. The only potential for a space conflict would be the 4850 level, however, moving away from the access shaft a few hundred feet should be sufficient to lessen any potential impact to others. The footprint of these experiments will be small as we require only the space of a corner intersection having a small (~1 m) distance through the intersection.

Readiness for Deployment – technology:

Existing equipment housed at Montana Tech and the University of North Florida will be used in

phase 1. These experiments will be ready for immediate deployment as soon as underground access is restored.

Readiness for Deployment – effort and funding:

No external funding has been secured for this project. Our intent is to seek such funds from NSF and any other identifiable source if this LOI receives favorable review by the SDSTA. The overall costs will be low given that there are no equipment purchases required.

Environment, Safety, and Health:

All members of the research team will wear the required OSHA mine safety gear while in the mine. Experimental procedures will be developed to fit into the schedule for ingress-egress established by the SDSTA during operation of the lab.

UNDERGROUND LABS and SPACE

Experiment or Program Name: Deep fracture mapping at DUSEL using sonic techniques

Principal Investigator or Contact Person: Dr. Larry D. Stetler, SDSM&T

Brief Summary: Develop a technique using ultrasound to map fracture geometric and hydrologic properties as a function of overburden stress

1. Modules or Functional Uses: _____

___ other: _____

2. General Information:
Probable Start (year) 2007
Duration 1 year for phase 1
Space (Volume) L x W x H (m³) drift intersections having an approximate 1 m separation
Depth/Shielding (mwe) N/A
Occupancy (Peak/Avg) 3/2

4. Electrical
Approx. total power (kW) (Peak/Avg.) 2500/1500
Other electrical needs (describe): _____

3. Mechanical
Temperature X Uncontrolled 20 +/- 5 deg. C (Air Cond.)
___ other: _____
Humidity 50% +/- 20%
X Uncontrolled
___ other: _____
Air Filtration/Recirculation (describe): N/A

5. Chemicals:
___ Bases
___ Acids
___ Solvents
___ Radioisotopes
___ Chemical inventory storage
___ Chemical waste storage
___ Biological storage
___ Radioisotope storage
___ Cryogenics
___ Hazardous/Special Handling: _____

9. Other Needs or Requests:

___ Low-Radon Background (mBq/m³) N/A
Special Fume Exhaust requirements: N/A
Plumbing

Other chemicals (describe): _____

6. Architectural: Special needs:
Floors _____
Walls _____
Partitions _____
Clean room _____
Storage _____

___ Industrial Hot/Cold Water
___ Potable Hot/Cold Water
___ High Purity/DI Water
___ Steam/Condensate return
___ Safety Shower/Eyewash
___ Compressed Air
Cylinder Gases:
___ Inert
___ Flammable
___ Toxic
___ Carbon Dioxide
___ Nitrogen Gas
___ Liquid Nitrogen

7. Special Facilities:
Material Access _____
Access Schedule _____
Cleanliness _____
Security _____
Data Communication: _____

8. Laboratory, Machine Tools, and Other Equipment:

SURFACE LABS and SPACE

Experiment or Program Name: Deep fracture mapping at DUSEL using sonic techniques

Principal Investigator or Contact Person: Dr. Larry D. Stetler, SDSM&T

Brief Summary: Develop a technique using ultrasound to map fracture geometric and hydrologic properties as a function of overburden stress

1. Rooms or Functional Uses:
No surface structures required

Radioisotopes _____
 Chemical inventory storage _____

2. General Information:
Probable Start (year) 2007
Duration _____
Occupancy (Peak/Avg) _____

Chemical waste storage _____
 Biological storage _____
 Radioisotope storage _____
 Cryogenics _____
 Hazardous/Special Handling: _____

3. Mechanical
Temperature
 Uncontrolled
 20 +/- 5 deg. C (Air Cond.)
 other: fireplace
Humidity
 50% +/- 20%
 Uncontrolled
 other: _____
Air Filtration/Recirculation (describe): _____

Other chemicals (describe): _____

Special Fume Exhaust requirements: _____
Plumbing
 Industrial Hot/Cold Water
 Potable Hot/Cold Water
 High Purity/DI Water
 Steam/Condensate return
 Safety Shower/Eyewash
 Compressed Air
Cylinder Gases: _____

6. Architectural: Special needs:
Floors _____
Walls _____
Partitions _____
Clean room _____
Storage _____
Other: _____

4. Electrical
Approx. total power (kW) (Peak/Avg.) unknown
Other electrical needs (describe): _____

7. Special Facilities:
Material Access _____
Access Schedule _____
Cleanliness _____
Security _____
Crane Access: _____
Data Communication: _____

5. Chemicals:
 Bases
 Acids
 Solvents

8. Laboratory, Machine Tools, and Other Equipment:

9. Other Needs or Requests:

