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Developing EGS Collab Site Geologic Framework Models at the Sanford Underground Research Facility, Lead, South Dakota

Ghanashyam Neupane, Robert Podgorney, Patrick Dobson, Henry Johnson, William Roggenthen, Paul Schwering, Craig Ulrich, Jeff Wagoner, Mark White, EGS Collab Team

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Ghanashyam Neupane and EGS Collab Team

Abstract

The DOE/GTO EGS Collab project aims to stimulate fractures and conduct inter-well flow tests at an intermediate scale (~10-20 m) in an underground mine in Lead, South Dakota. To provide spatially accurate and consistent parameter data for geomechanical and geophysical process modeling tasks, we are preparing geologic framework models at three model domains: 1) EGS Collab (200 m on each side), 2) Intermediate (about 1000 m, 1000 m, 600 m), and 3) Large (5000 m, 5000 m, 2000 m) – using RockWorks 17 software. The first version of the models incorporate local geology, drifts/shafts, 4850 L boreholes, and weep positions into these models. As data is collected at the Collab site, we envision to develop a series of baseline 3-D block models (ASCII files for scattered data/point clouds in the form of X, Y, Z, g) for various physical/mechanical properties of rock. At this point, we have assembled a preliminary suite of physical/mechanical properties of rocks. Some of the earth modeling results (3-D block models) have been tested by some modeling/simulation team members to test their applicability and for developing additional modeling capability or modifications in RockWorks exported 3-D block models. As new bore holes' data, experimental and simulation results become available, updated versions of earth models will be created distributed among EGS Collab modeling groups.

Three Model Domains

1. EGS Collab model (X = Y = 200 m, Z = 200 m)
2. Intermediate model (X = Y = 1000 m, Z = 600 m)
3. Large area model (X = Y = 5000 m, Z = 2000 m)

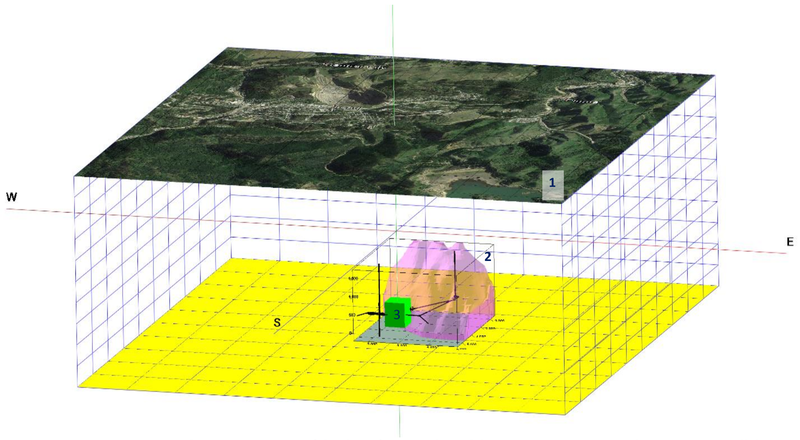

Figure 1. Comparative domain extensions of the three framework models; (1) Large, (2) Intermediate, (3) EGS Collab

Intermediate Model Geology Examples

Stratigraphy and Lithology

- ***Yates Unit*** - amphibolite schist with strong textural (grain-size) as well as compositional layering (hornblende and plagioclase), calcite veins and some local oxidized sulfide layers define the zones of weakness.
- ***Poorman Formation*** - graphitic sericite-biotite phyllite/schist with local interlayers of quartz, intense folded with minute crenulations to mesoscale folds, calcite veins.
- ***Tertiary dikes*** - cross-cut both Yates and Poorman Formation (not shown in Figure 2), aphanitic rhyolite with scattered sanidine phenocrysts.

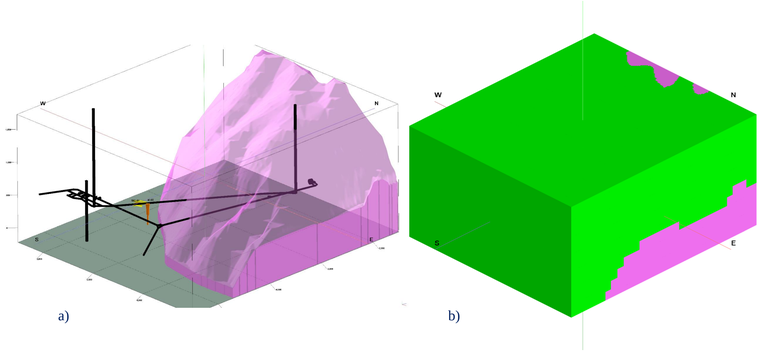

Figure 2. Intermediate model depicting stratigraphic contact (magenta) surface that separates the underlying Yates unit from the overlying Poorman Formation (a) and 3-D lithologic block model with Yates unit (magenta) and Poorman Formation (green) (b).

Mine Features in Intermediate & EGS Collab Models

Shafts, drifts, existing and to-be-drilled Collab holes are incorporated in the Rockworks models.

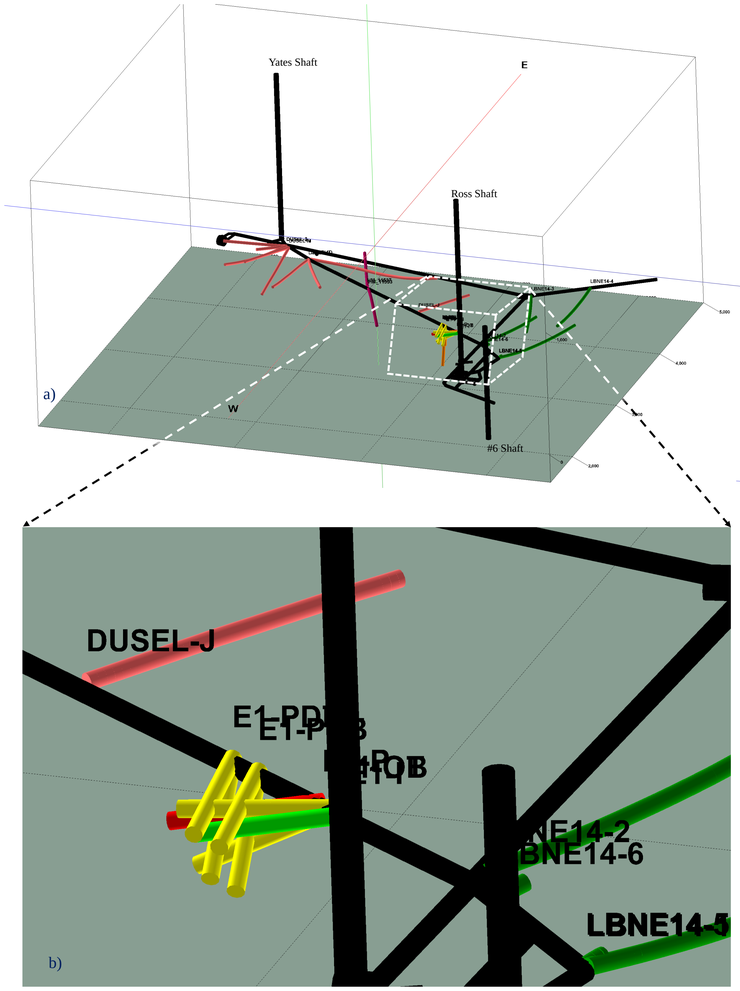

Figure 3. a) Shafts, drifts, and bore holes (existing as well as planned) at 4850 L. b) Enlarged part of (Fig 3a) showing planned EGS Collab holes. Green (E1-I) and red (E1-P) are future injection/stimulation and production bore holes, respectively. Yellows (E1-OT, E1-OB, E1-PST, E1-PSB, E1-PDT, and E1-PDB) are future monitoring holes.

Version Control and Revisions

Three versions of EGS Collab geologic framework models are being prepared and shared with EGS Collab Team as baseline 3-D block (point clouds) models:

Version 1: Pre-test. It includes mine geometry and Formation level geologic details. Efforts to this version also helped assemble geomechanical/gepphysical rock parameters and their available values.

Version 2: After drilling and characterization.

Version 3: After first set of experiments.

Workflow to Numerical Modeling Example

Besides the visualization purpose, the geologic framework modeling effort will create consistent 3-D block (cloud points) models for several rock properties (e.g., Table 1). The point clouds of rock properties will be used by EGS Collab simulation groups to generate mesh for process modeling tasks (Figure 4).

Table 1. A representation of physical/mechanical properties of rock types at/nearby EGS Collab site.

Parameters	Values	Method	Formation/holes/level	Notes	Ref.
Compressive strength (MPa)	107.4	Triaxial UCS	Poorman, kISMET	Average, foliation parallel	1
	88.1	Triaxial UCS	Poorman, kISMET	Average, foliation parallel	1
	71.02	UCS	Poorman, 4850L	Average	2
	81.7	UCS	Yates/Poorman, 4850L	Average	2
	182.71	UCS	Yates, 4850L	Average	2
	115	Uniaxial CS	Yates, DUSEL	Average	2
	165.47	UCS	Rhyolite, 4850L	Average	2
	111	Uniaxial CS	Rhyolite, DUSEL	Average	2
Tensile strength (MPa)	4.1	Axial loading	Poorman, kISMET	Average, foliation parallel	1
	8.4	Axial loading	Poorman, kISMET	Average, foliation perpendicular	1

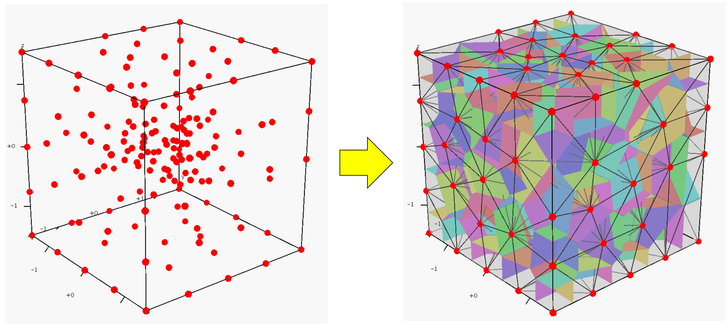

Figure 4. An example of INL's EGS Collab modeling group's approach to create tetrahedral mesh from RockWorks exported X,Y,Z,g point clouds for FALCON simulation.

Summary

The Collab project is conducting well controlled and highly monitored fracture stimulation testing and flow tests to validate numerical fracture creation, fracture flow, and heat transport modelling to support GTO's FORGE efforts.

Geologic framework models for EGS Collab site are being prepared to transmit a consistent information such as geology, geometry of shafts, drifts, weeps/fracture locations/orientations, bore holes to the EGS Collab modeling groups.

A series of 3-D block models (point clouds) for various rock properties are being created as baseline values to all EGS Collab modeling/simulation groups.

It is expected that the earth modeling effort and results will provide an interface between researchers producing characterization/validation data for the EGS Collab project and modeling team.

References

Vigilante, P.J., Sone, H., Wang, H.F., Haimson, B., Doe, T.W., 2017. Anisotropic Strength of Poorman Formation Rocks, kISMET Project. ARMA 17-766, 6 p.

Vigilante, P.J., 2016. Critical review of laboratory rock properties and state of stress in the Sanford Underground Research Laboratory (SURF). 51 p.

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