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Technology Transfer at Edgar Mine: Phase 1

October 2016

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National Renewable Energy Laboratory

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Matt Schreiner
Clinton Dattel
Robert Duran
Mahmood Arshad
Lucila Dunnington
Robert Duran
Kamran Jahanbakhsh

Executive Summary

The objective of this project is to study the flow of fluid through the fractures and to characterize the efficiency of heat extraction (heat transfer) from the test rock mass in the Edgar Mine, managed by Colorado School of Mines in Idaho Springs, CO. The experiment consists of 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. This is a multi-year project performed as a collaboration between the National Renewable Energy Laboratory, Colorado School of Mines and Sandia National Laboratories and carried out in phases. This report summarizes Phase 1: Selection and characterization of the location for the experiment, and outlines the steps for Phase 2: Circulation Experiments.

After several tours of the mine, a pillar roughly 200 feet by 200 feet in size was chosen as the experimental location. The walls of the pillar were mapped to identify the locations of fractures, and these maps were used to create a 3D model of the pillar. Mapping showed that the dominant fractures in the pillar are sub-vertical and are oriented roughly parallel to the North and South drifts and perpendicular to the East and West drifts that define the pillar. A core hole was drilled from the northern drift horizontally and roughly perpendicular to the dominant fracture planes about half way (93 feet) into the pillar and the core was logged. An in-situ stress measurement was also taken from that drift. Drilling caused a 20°C increase in the rock in the area around the drill hole, resulting in additional thermal strains. A thermal correction was applied to the resulting in-situ stress measurements. However, the authors feel that applying a thermal correction is not ideal and leaves doubt regarding the validity of the in-situ stress measurements presented in this report and we recommend that they not be used.

After evaluating Phase 1 data, we recommend continuing with Phase 2 in the selected experiment location. The fracture networks are well-aligned with the core hole so that it can likely be used as an injection point for future circulation experiments. We believe that fluid circulation experiments in the pillar will be dominated by the existing fracture networks in the pillar. The fracture networks are high enough in intensity that lost circulation may be a concern. The report identifies two locations in the pillar with relatively low fracture intensity as targets for circulation experiments and presents an outline and recommendations for proceeding with circulation experiments in Phase 2.

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1 Introduction

The objective of this project is to study the flow of fluid through the fractures and to characterize the efficiency of heat extraction (heat transfer) from the test rock mass in the Edgar Mine, operated by Colorado School of Mines in Idaho Springs, CO. The experiment consists of 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. The fracture network can be characterized using remote imaging (ex., microseismic monitoring, ultrasonic imaging, etc.), tracer studies, overcoring affected regions, and potentially even mine back of the fracture network. Since the rock in the mine is at near-ambient temperatures, hot fluid will be circulated through the fracture network and heat transfer will be characterized by watching for temperature breakthrough of the produced fluid. The study aims to quantify the fracture network (reservoir) performance in terms of thermal breakthrough time, sweep efficiency (effective surface area used for heat transfer), channeling within fractures, and distribution of flow among fractures.

This project is being done as a collaboration between the National Renewable Energy Laboratory (NREL), Colorado School of Mines (CSM) and Sandia National Laboratories (Sandia or SNL), and is planned as a multi-year project. The first year (referred to throughout the report as Phase 1) focused on developing a detailed experimental plan for out years. A key objective of the first year was to estimate the stress state and orientation of existing fractures in the mine, as these determine the direction of fracture growth and dictate viable locations within the mine for further activities. The objectives of the first year of the project were:

1. Detailed site characterization and initial scoping and planning of the experimental test plan for the site,
2. Stress state estimates and characterization of orientation of existing fractures to determine the likely direction of fracture growth, and
3. Development of an experimental test plan (informed by results of stress state and fracture orientation estimates) for Phase 2 to create, image and characterize a fracture network, connect the fracture network via multiple holes, and characterize heat extraction from it via the circulation of fluids.

At the time of writing of this summary report, Phase 2 of the project was not funded to continue. Data from Phase 1 and the proposed plan for Phase 2 are presented in the case that the project is resumed at some point in the future and for the benefit of future research at Edgar Mine.

1.1 Edgar Mine Test Facility

The Edgar Experimental Mine, located in Idaho Springs, Colorado, is an underground laboratory operated by the Colorado School of Mines Mining Department that is used to provide students hands-on experience in mining practices, as well as conduct on-going research by numerous academic, government, and industry groups (http://inside.mines.edu/Mining-Edgar-Mine). The mine, situated in Precambrian rock, has been studied extensively and is well-characterized. Since the Edgar Mine is an active research and teaching mine with ongoing research in mining technologies, conversations with the mine manager and CSM Mining Department staff indicate that the creation and study of flow through a fracture network fall within the scope of normal mine operations.

1.2 Phase 1 Activities

A summary of Phase 1 activities is given below:

1. Data gathering, mine mapping and development of 3D model
2. In-situ stress measurements and core drilling
3. Development of Phase 2 experimental plan and recommendations

Each of these activities is described in its own section of this report. Most of the data and results from Phase 1 activities are included in the appendices and/or as attached reports.

2 Data Gathering and Mine Mapping

The first step in Phase 1 was to gather background information and existing data on the Edgar Mine. Next, a location for experimental study in the Mine was selected. The mine walls around the selected area were then mapped (via scanline surveys) to identify the locations, frequency, and dip/direction of fractures. This information was used to create stereonets and a 3D model of the experimental area. The information on fracture orientation was interpreted to determine the optimal location and direction for drilling.

2.1 Edgar Mine Background and Existing Data

The Edgar Mine has been extensively studied over the last two hundred years due to its initial allure as a gold, silver, lead and copper mine, and later on as an experimental mine for CSM as well as other institutions, including the U.S. Army, the National Institute for Occupational Safety and Health, the U.S. Bureau of Mines, the USGS and several private research companies. It is located in the old Idaho Springs Mining District, on the central Front Range of Colorado. The Front Range is characterized largely by gneissic rocks, with plutonic intrusions from the Precambrian. The corresponding Mineral Belt in this region was developed through Laramide age intrusive rocks and hydrothermal ore deposits. Massively to moderately foliated biotite gneiss is the most abundant rock type in the Edgar Mine site.

Three major tectonic events are responsible for the observable structural features in the Edgar Mine. First, the Precambrian Boulder Creek Orogeny caused high-grade metamorphism, and two episodes of plastic deformation, producing northeast trending folds in the Front Range. A few igneous intrusions followed during the Precambrian at which time the Boulder Creek, Silver Plume and Pikes Peak granites emerged with associated rock. Late Cretaceous uplift in the region formed younger faults, which are superimposed on the Precambrian structures, until the late Paleozoic, when the Ancestral Rocky Mountains formed from a taphrogenic event (Montazer, 1982). Additionally, porphyritic plutons and dikes from the early Tertiary appear as bostonite and monzonite around the mine site. The Edgar Mine sits northwest of the Idaho Springs Anticline (axis trending N55E), and northeast of the Idaho Springs Fault (trending N60W). Thorough reviews of the local geology of Idaho Springs exist(Hutchinson, 1967).

A summary of geomechanical data are available in Table 1 from a previous School of Mines informational report on the Edgar Mine. The relatively wide ranges for uniaxial compressive strength and elastic modulus are expectedly due to the heterogeneity of rocks found in the mine. Additional rock-type specific data are provided in Table 2 from a CDC report (Scott, Tesarik, & Knoll, 2004). The generally hard, impermeable rock mass in addition to the mine's general dryness has made it valuable in the past for hydrogeology experiments interested in tracking fluid in fractured media (Miller, 1993) and (Montazer, 1982).

Table 1. Typical geomechanical properties of rocks encountered in the Edgar Mine

Property	Value
Uniaxial Compressive Strength	40-150 MPa
Elastic Modulus	60-90 GPa
Poisson's Ratio	0.2
Joint Friction Angle	30^0-40^0
Rock Mass Rating (RMR)	40-80

Table 2. Breakdown of geomechanical properties by discrete rocks common in the Edgar Mine (Scott, Tesarik, & Knoll, 2004)

Rock type	Modulus of deformation, MPa (psi)	Poisson's ratio	Angle of internal friction, deg	Cohesion, MPa (psi)	Tensile strength, MPa (psi)	Density, g/cm³ (lb/ft³)
Biotite-hornblende schist	72,395 (10,500,000)	0.14	35	50 (7250)	35 (5,076)	2.803 (175)
Biotite microcline pegmatite	48,667 (7,058,600)	0.19	30	30 (4350)	20 (2900)	2.594 (162)
Migmatite gneiss	43,115 (6,253,300)	0.14	30	30 (4350)	20 (2900)	2.803 (175)
Quartz-feldspar biotite gneiss	35,365 (5,129,300)	0.25	30	7 (1015)	5 (725)	2.947 (1840)
Biotite schist	22,063 (3,200,000)	0.25	30	2.5 (363)	0.5 (973)	2.947 (184)
Vein	134 (19,500)	0.30	30	0	0	2.082 (1300)
Grout	11,721 (1,700,000)	0.25	35	11.5 (1670)	4.4 (640)	2.403 (150)

A bounty of historical information (pictures, maps, surveys, deeds, claims) is available at the School of Mines Mine Archive. An inventory is available in Appendix A.

2.2 Selection of Experimental Location in Edgar Mine

The Edgar Mine was scouted in search of a suitable location for circulation experiments. A location was sought that provided access via tunnels on several sides to allow for characterization and monitoring of the formation, as well as indications of existing fractures and foliation favorable for circulation experiments. Based on multiple field excursions of the mine, two candidate locations for the experiment were selected (Figure 1).

Underground inspections of the mine lead us to choose the main pillar for the experimental activities due to access for characterization of the fractures from all 4 sides of the pillar. This pillar is bounded on four sides by tunnels. The shape of the pillar is roughly square and is approximately 200 feet on each side.

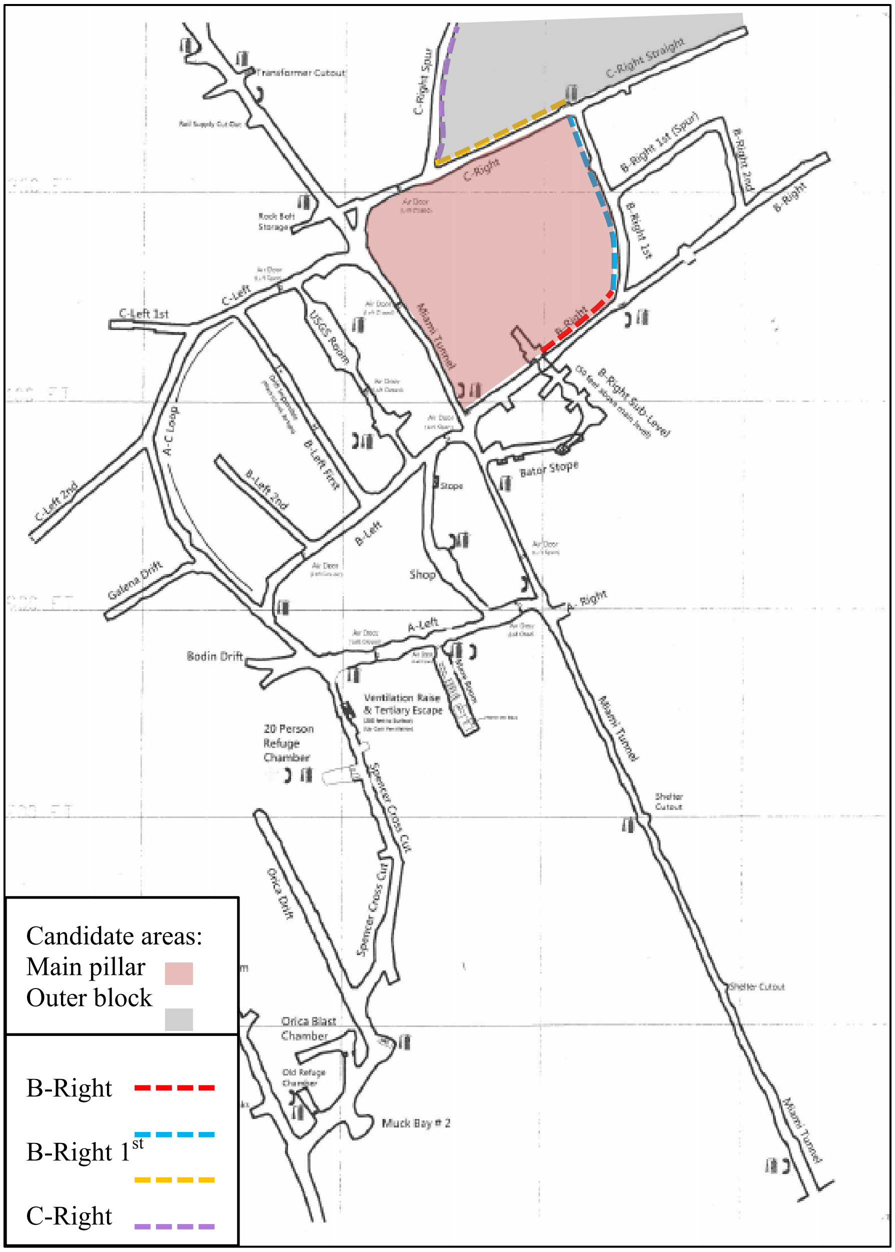


Figure 1. Map of Edgar Mine showing locations of candidate experimental areas and scan lines (colored lines). The main pillar (in pink) was chosen as the experimental area.

2.3 Mine Mapping

Four scanline surveys of the experimental area were conducted surrounding candidate locations in order to collect information regarding the existing discontinuities present in the Edgar Mine. The tunnel walls were power washed prior to the surveys and data was collected following International Society for Rock Mechanics (ISRM) standards (Brown, 1981). The scanline survey locations are indicated in Figure 1, and an enlargement of the area is shown in Figure 2. Raw scanline data are in Appendix B.

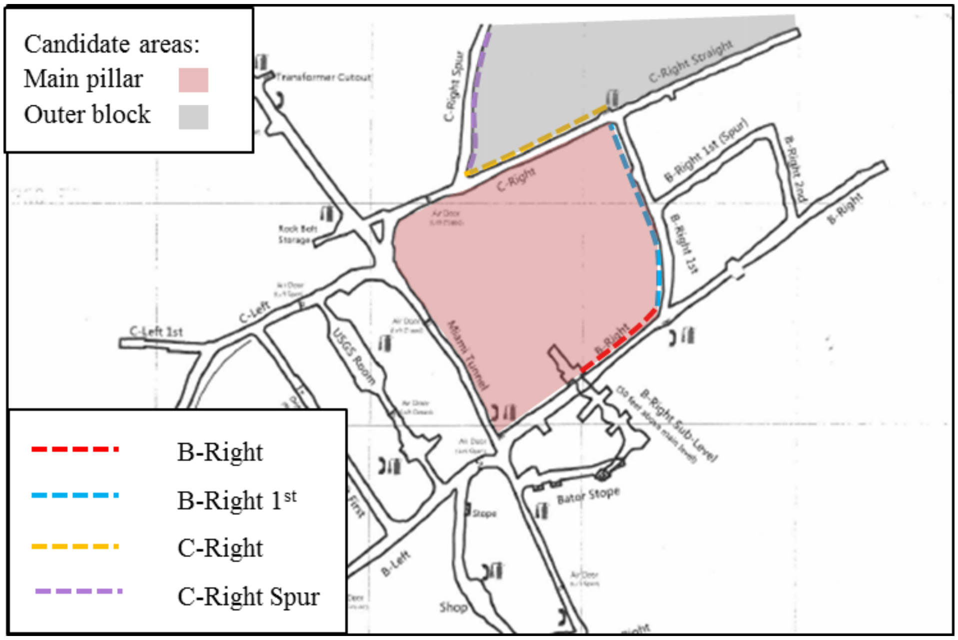


Figure 2: Location of scanline surveys for mine mapping

2.4 Stereonets and 3D Map

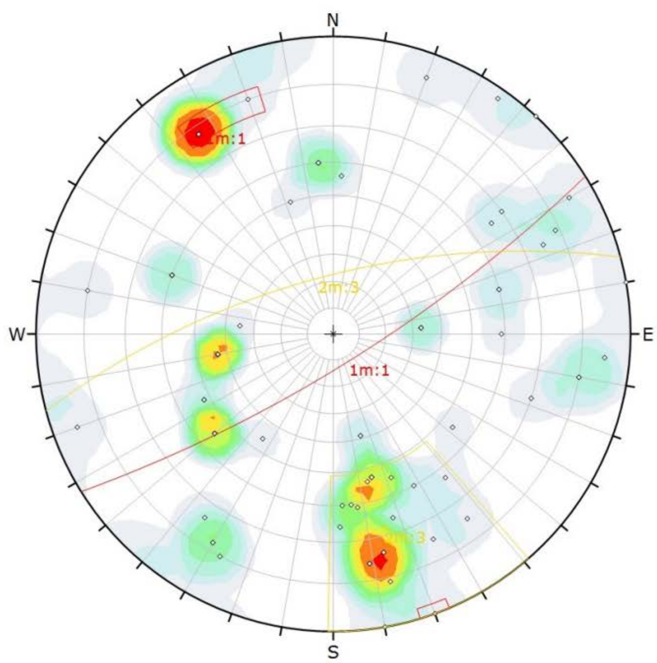
After the Scanline surveys were conducted, the dip and dip direction of each discontinuity was imported into the Rocscience software DIPS. DIPS is a clustering analysis tool that calculates the average dip and dip direction of the major discontinuity sets. Four major discontinuity sets were identified from DIPS (Table 3). The average dip and dip direction for each main discontinuity set was calculated. A multivariate clustering analysis algorithm, CYL, was used to validate the DIPS results and to calculate the apparent spacing of each of the 4 main discontinuity sets. CYL takes into account multiple discontinuity parameters including orientation, aperture, infilling, roughness, persistence, spacing, and lithology simultaneously (Zhou & Maerz, 2002).

Table 3. Major discontinuity sets from scanline surveys

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

Stereonets from DIPS for each of four Scanline surveys are shown in Figure 3 through Figure 6. A stereonet is a graph that is a lower hemisphere that geological data can be plotted on. Plotting 3D information on a 2D surface is called stereographic projection. 3D planes (discontinuities) are represented as lines when stereographically projected. The line that is the projection of the plane is the line of intersection of the plane and the lower hemisphere. A plane can also be represented on a stereonet as a pole. A pole is an imaginary line that is perpendicular to the plane. Lines are represented as points when stereographically projected. The pole to the discontinuity plane is a point that is 90 degrees away from the line that represents the plane. The discontinuities that were recorded during the scanline surveys are plotted on stereonets as poles.

The software program DIPS that is made by Rocscience takes these plots and uses fuzzy c-means clustering analysis to group the discontinuities into discontinuity sets. The lines on the figures below show discontinuity sets as interpreted by the software program DIPS. Figure 5 and Table 3 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 so that core holes intersect fractures indicated in the discontinuity sets at nearly a right angle.



Symbol	Feature
◇	Pole Vectors

Color	Density Concentrations
	0.00 - 0.90
	0.90 - 1.80
	1.80 - 2.70
	2.70 - 3.60
	3.60 - 4.50
	4.50 - 5.40
	5.40 - 6.30
	6.30 - 7.20
	7.20 - 8.10
	8.10 - 9.00
Maximum Density	8.51%
Contour Data	Pole Vectors
Contour Distribution	Fisher
Counting Circle Size	1.0%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		78	148	1
2m		68	345	3

Plot Mode	Pole Vectors
Vector Count	82 (82 Entries)
Hemisphere	Lower
Projection	Equal Angle

Figure 3: Stereonet from DIPS for B-Right.

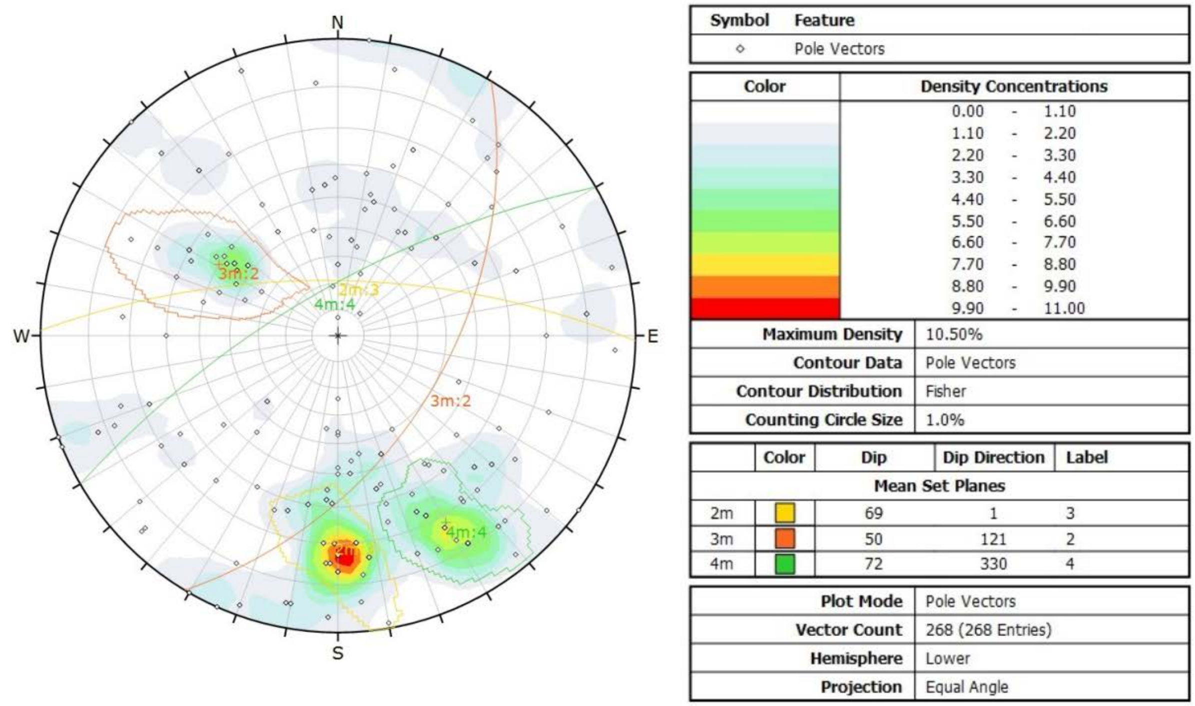


Figure 4: Stereonet from DIPS for B-Right 1st

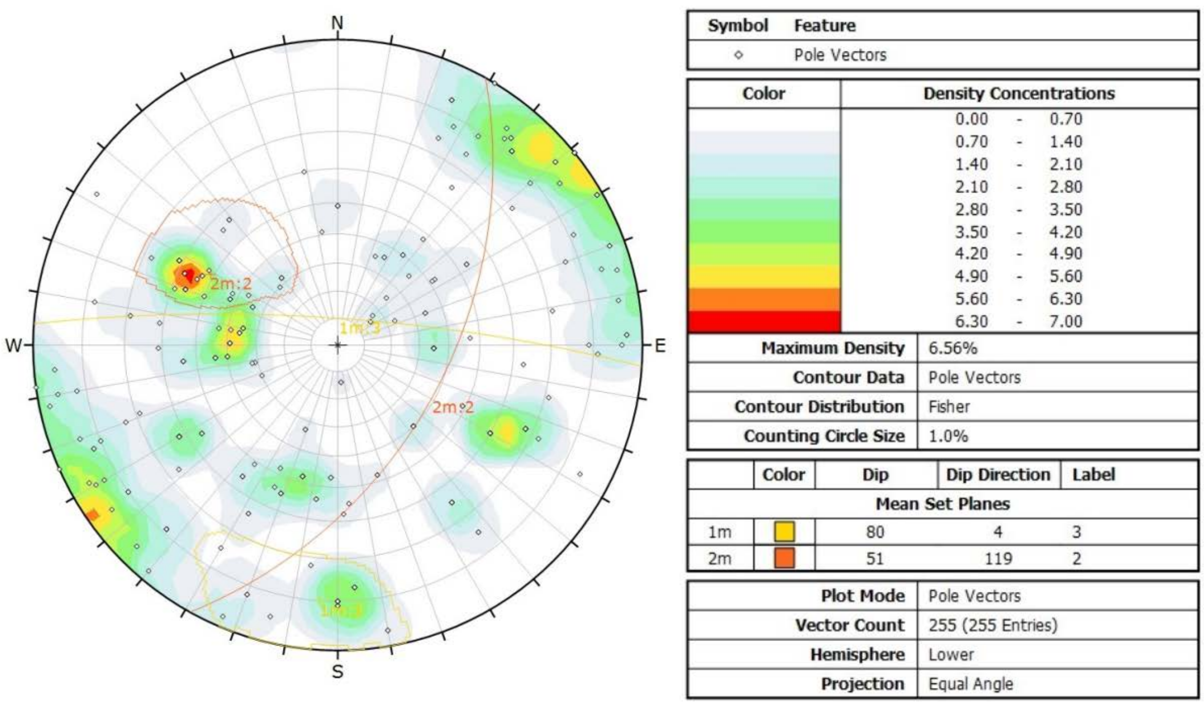
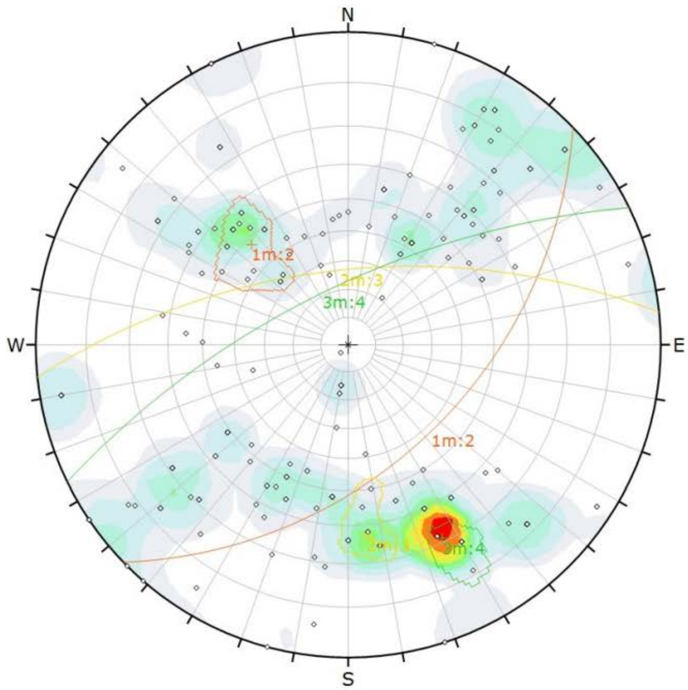


Figure 5: Stereonet from DIPS for C-Right



Symbol	Feature
◇	Pole Vectors

Color	Density Concentrations
	0.00 - 1.00
	1.00 - 2.00
	2.00 - 3.00
	3.00 - 4.00
	4.00 - 5.00
	5.00 - 6.00
	6.00 - 7.00
	7.00 - 8.00
	8.00 - 9.00
	9.00 - 10.00
Maximum Density	9.67%
Contour Data	Pole Vectors
Contour Distribution	Fisher
Counting Circle Size	1.0%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		48	136	2
2m		63	354	3
3m		69	334	4

Plot Mode	Pole Vectors
Vector Count	250 (250 Entries)
Hemisphere	Lower
Projection	Equal Angle

Figure 6: Stereonet from DIPS for C-Right Spur

A generalized 3D discontinuity density model (Figure 7) was constructed from scanlines for B-Right, B-Right 1st, and C-Right using C Tech MVS. MVS stands for "Mining Visualization System" and is a 3D modeling and visualization tool. This model was based on the linear fracture density[1] along the scanline as calculated per 10ft section (number of fractures/10 ft) as well as on the average dip angle, dip direction, and spacing of each discontinuity set. A model was built in MVS showing different zones based on fracture density. The fracture density values and locations are keyed to B-Right 1st (Miami Tunnel was not mapped, so fracture density data does not apply to Miami Tunnel). There are 4 zones of different fracture densities. The first zone is fracture density between 0.0 and 1.5, the second zone is between 1.5 and 2.5, the third zone is between 2.5 and 3.5, and the fourth zone is >3.5. The model also shows the major joint set in the pillar as a line. The view of the orientation of the joint set is enhanced by "cutting out" a portion of the 3D map. The joint set is dipping at 78 degrees towards 148 degrees.

[1] Fracture density calculated using a moving average. Fractures include discontinuities of Types 0, 1 and 2 (fault zones, fractures, and joints, respectively) as detailed in Appendix B.

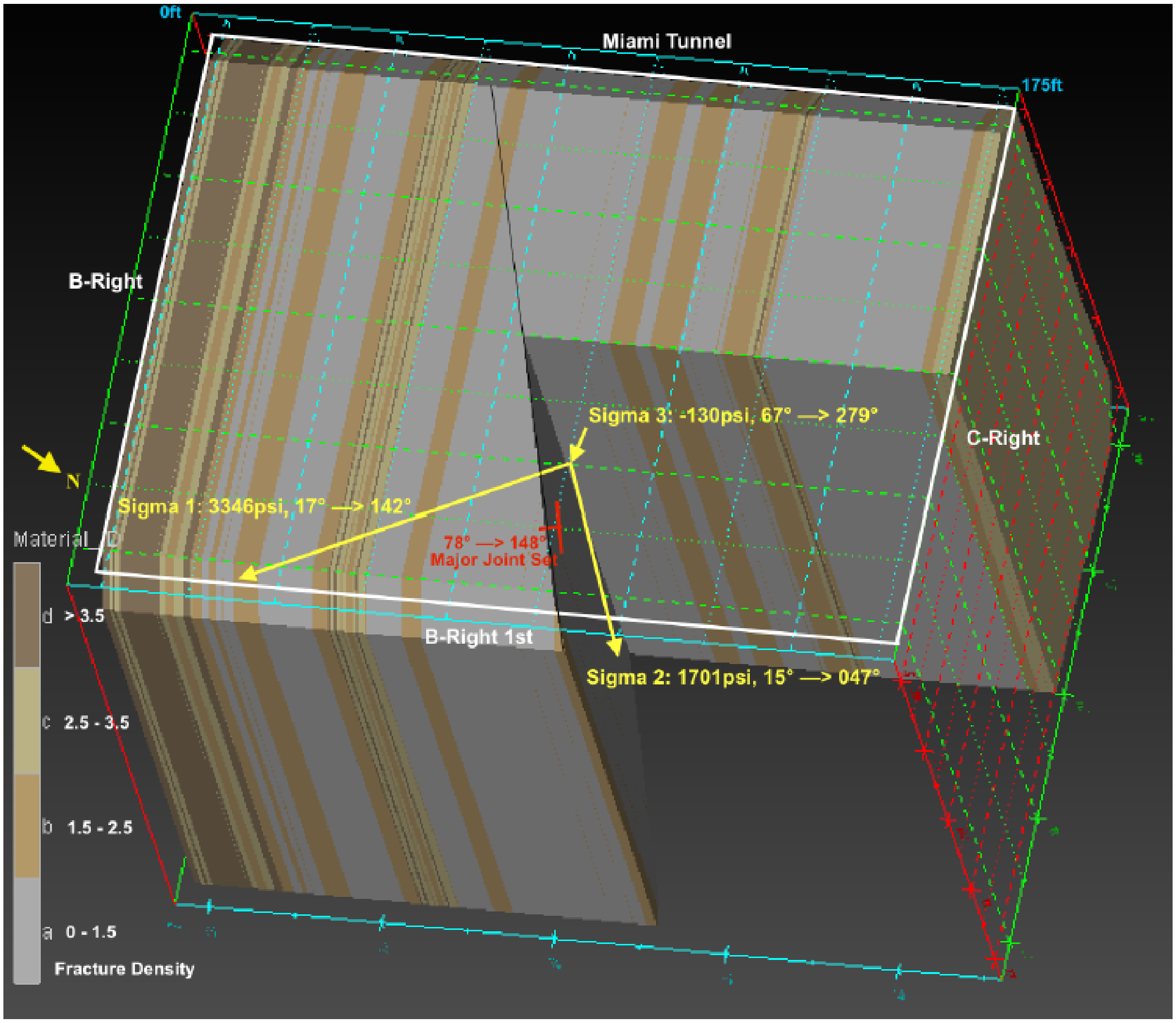


Figure 7. Generalized 3D discontinuity density model of experimental test area (main pillar) in Edgar Mine. Map shows fracture density and line/cut out indicate orientation of major joint sets. Yellow text indicates stress measurement results from Agapito (see Table 4).

2.5 Results

The mine mapping confirmed about fracture and foliation directions what was evident from looking at walls. Fracture mapping indicates that the major discontinuity sets are sub vertical (nearly vertical) and nearly parallel to drifts B-Right and C-Right. Two major discontinuity sets in main pillar (2m:3 and 3m:2 in the stereonets in Figure 3 through Figure 6) appear nearly perpendicular to B-Right 1st.

Based on this information, we believe that horizontal "wells" drilled from C-right will intersect the vertical fractures at nearly a right angle and allow for circulation experiments consisting of flow from horizontal wells through nearly vertical fractures to be carried out. Given that there are multiple discontinuity sets with different dip angles, we should also assume that these discontinuities could intersect each other at some point in the pillar. Conversations with Matt Schreiner, the Edgar Mine Manager, support this conclusion. He said such an intersection is noticeable in the mine where B-Right and B-Right 1st intersect. At this location where discontinuities interact, there is a large fallout section. The potential for discontinuities to intersect could impact circulation tests, allowing fluid to flow from one discontinuity to another. This could make it difficult to predict and track where fluids are flowing during a circulation test and lead to lost circulation.

3 Core Drilling and In-Situ Stress Measurements

The information on fracture orientation was interpreted to determine the optimal location and direction for drilling cores and performing in-situ stress measurements. Rock cores were collected to obtain information on fractures within the pillar. The subsequent hole could also serve as an injection or production "well" for future circulation experiments. In-situ measurements were taken to determine the direction and magnitude of stresses in the pillar so their potential influence on fracture creation and growth (if needed in future experiments) could be assessed. A summary of the drilling plan and results is given below.

3.1 Drilling Plan

A drilling plan was developed based on the budget available for Phase 1. The plan was to drill up to three H-size core holes (~3.5" holes yielding ~2.5" cores) and perform three in-situ stress measurements. The core holes were planned to be 150 feet in length. Based on information from scanline surveys, the plan was to drill the first core hole from C-Right horizontally into the pillar, with the core hole located approximately in the center of the pillar. Locations for the second and third core holes would be determined based on information gathered from the first core hole. The default plan was to drill these core holes flanking the first one as shown in Figure 8 with the hope that the holes could be used for injecting and producing fluids during future circulation tests in the pillar.

The locations of the three planned in-stress stress measurements would be proximal to the core holes. Multiple stress measurements are needed to characterize the stress in the pillar with confidence.

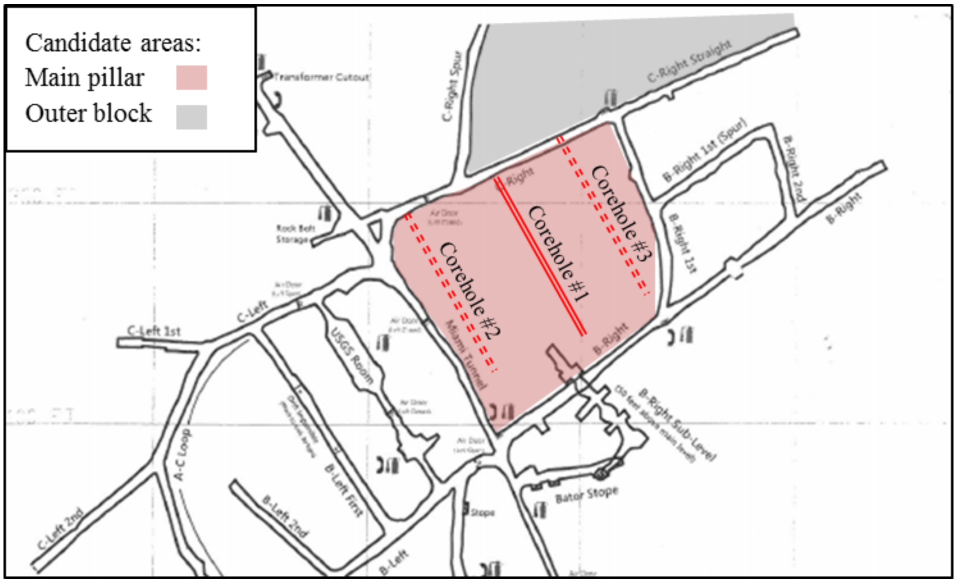


Figure 8. Proposed work location (main pillar, pink) for drilling core holes and conducting circulation tests. Approximate locations and directions of proposed core holes shown by red lines.

3.2 Drilling Summary

Agapito Associates, Inc. from Grand Junction, CO were contracted to drill the core holes and perform in-situ stress measurements on a time and materials basis. Full details of the drilling plan, operation and results are included in the drilling report from Agapito, included in this report as Appendix C. A short summary is given here.

Drilling commenced on July 13, 2015 and continued through July 28, 2015. Both coring and overcoring work at CSM was initially undertaken in the C-Right Drift near the C-Right Spur. HQ core hole (2.50-inch diameter core and 3.875-inch-diameter hole) C-R-Center was drilled at an angle of approximately 2.0 degrees (°) (up) from horizontal at an azimuth of 135°.

Drilling proved more difficult than anticipated. Some minor equipment issues were encountered at the beginning of drilling. Once these issues were resolved, drilling proceeded without further interruption. Unfortunately, the rate of penetration was much slower than anticipated, averaging around 1 foot/hour. Core was taken up to a total depth of 93 ft. At this point, the contract was running low on funds and it was clear that we would not achieve the planned schedule of 3 core holes and 3 in-situ stress measurements.

The decision was made to use remaining funds to take an in-situ stress measurement. A twelve-strain-gauge CSIRO HI cell was used for this project. The stress measurement procedure included first drilling a 6-inch-diameter access hole to the test location where an HI cell was installed and bonded in a cored 1.5-inch-diameter (EX) pilot hole. The HI cell was then overcored, and the strain response and temperature variation were monitored as the stresses on the core were relieved. Overcoring hole CR1-6 was drilled at an angle of approximately 1.0° (up) from horizontal at an azimuth of 140° in C-Right spur just east of the C-R-Center core hole.

The HQ core was boxed and left on site at the mine and the overcoring core was sectioned at AAI's Grand Junction, Colorado, laboratory, and was subsequently returned to CSM after inspection.

3.3 Core and Stress Measurement Data and Results

The 93 feet of HQ core was logged on site. The core log is included as Appendix D.

Table 4. HI Cell Overcoring Three-Dimensional Stress Measurement

Hole No.	Run No.	Depth (ft)		Principal Stresses[1] Magnitude (psi)	Dip[2] (°)	Bearing (°)	Resolved Stresses[1] N-S (psi)	E-W (psi)	Vertical (psi)	Shear Stresses[1] NS-EW (psi)	EW-Vert (psi)	Vert-NS (psi)
CR1-6	1	19.5	Major	3,346	17	142	2,625	1,989	304	-684	947	-470
			Intermediate	1,701	15	47						
			Minor	-130	67	279						

[1]Stress convention: "+" = compression, "–" = tension.

[2]A positive value indicates down, from horizontal .

HI Cell overcoring stress measurements are summarized in Table 4 above. The stress measurements and a comparison to stress measurements taken previously by USGS are described in detail in the report from Agapito in Appendix C. However, the stress measurements reported from Agapito in Appendix C are flawed and should not be used in any experimental planning that requires a precise measure of the *in situ* stress tensor.

During the measurement, a 20^{o} C temperature rise was experienced—presumably caused by excessive load on the drill bit. This temperature rise is well beyond the manufacturer's recommendations. The thermal strains caused by the HI Cell temperature rise are significant relative to the strains associated with the *in situ* stress relief during overcoring. The *in situ* stress relief strains are on the order of tens to several hundred με. Thermal-induced strains resulting from the 20^{o} C temperature rise are estimated to be on the order of 100 με, assuming a thermal expansion coefficient for Gneiss of about 6-8 ($10^{-6}/^{o}$ C). Clearly the superposition of thermal strains of this magnitude on the *in situ* stress relief strains is expected to be a source of major error.

There are a number of complexities that may render the thermal strains uncorrectable. First, during the actual run the drill bit and drill water did not heat the overcore rock/cell uniformly as we did during our laboratory correction. The actual heating from the over coring process involved a complex three-dimensional and transient heat source. Secondly, the 6-inch core itself was attached to the rock mass during the heating event, thus complicating conduction and thermal expansion in a way not simulated in the laboratory. Finally, anisotropy and heterogeneity in the thermal properties of the 6-inch core, if present, can be expected to further complicate the thermal response.

Applying a thermal correction is not ideal and leaves doubt regarding the validity of the results presented in this report.

If further studies requiring an understanding of the in situ stress state are to be pursued at the Edgar Mine, we recommend re-analyzing the set of in situ stress measurements completed by the

USGS. The five historical overcore runs show variability in both the orientations and magnitudes of the stresses measured by the USGS. Stress measurements in this mine are location dependent (proximity to the opening, pillar conditions, overburden, topography, weathering, etc.) with a strong influence from the natural rock fabric, faulting, and other factors.

3.3.1 Location of Edgar Mine Core

At the time of the writing of this report, the core from the Edgar Mine C-R-Center core hole was in the possession of Dr. Masami Nakagawa and was being stored on the CSM campus in the Brown building. The current plan is for the core to remain there for 2-3 years and then to be donated to the USGS repository in Lakewood, CO.

4 Phase 2 Experimental Plan and Recommendations

Phase 1 activities and data found that the pillar (Figure 1) chosen for evaluation looks like a promising location for Phase 2 circulation experiments:

1. The pillar that can be accessed from four sides, facilitating experiments and fracture network characterization;
2. Fractures in this section are pre-dominantly vertical or sub-vertical;
3. Fracture planes are aligned nearly orthogonally to tunnels and drifts that define the pillar;
4. Given points 2 and 3, the core hole drilled in Phase 1 favorably intersects the fracture network (hole is approximately perpendicular to major fracture planes) and can be used as an injection well for circulation experiments;
5. Mine wall mapping and 3D model (see Figure 7) characterized fracture density in the pillar. Fractures appear to exist throughout the pillar, so that fracture networks are likely to dominate flow behavior within the pillar. There is likely no need to create new fractures. Some stimulation or extension of an existing fracture may be needed for circulation experiments.
6. Mapping identified large stretches with low fracture density (0-1.5 fractures per foot) that may be good targets for circulation tests. We believe that these are the best targets for circulation experiments since they provide fracture pathways but at a low density so that fluid leak off is less of a concern.
    - The largest low-density section is located 70-130 feet N/NE of the B-Right drift. Since the core hole is only 93 feet deep, it may not access this section well.
    - The second largest low-density section is located 125-145 feet N/NE of the B-Right drift.

Our recommendation is that the experiment move forward and continue in the pillar identified. We further recommend that existing fracture networks be used for circulation experiments if possible (and extended if necessary), with the low-density fracture network sections identified above as potential targets for circulation tests. However, additional characterization steps are recommended, and we recommend that the project proceed in a step-wise manner with additional Go/No-Go decisions. The experiment steps are outlined in the sections below.

4.1 Phase 2.1: Additional 3D Mapping and Fracture Network Characterization

The first step in Phase 2.1 should consist of additional 3D mapping of the pillar. These steps could be performed as part of mining class studies at CSM, if possible.

1. Map the Miami Tunnel (side of pillar opposite B-Right 1st, which has been mapped) and incorporate results into 3D model. Confirm joint directions and analyze whether fracture density identified in Phase 1 persists through the pillar.
2. Incorporate core log data into 3D model to further confirm persistence of fracture density pattern. Identify any fractures that appear to persist through the pillar.
3. Visually log fractures in existing core hole (Hole C-R-Center) with borehole televiewer/optical. Confirm locations and directions of fractures in core log and update 3D map.

The 3D model should be further improved using geophysical and remote sensing technologies (ex., sonic imaging). The goal of this phase is to characterize the 3D nature of the fracture networks – their location, extent (height and length), and any other properties possible (ex., width). The characterization could also be performed as part of mining class studies at CSM, if possible. By the end of this phase, at least one fracture/fracture network should be identified for circulation experiments.

A go/no-go decision on the suitability of the identified fracture network should be made before proceeding.

4.2 Phase 2.2: Preliminary Circulation Experiments

Preliminary circulation experiments will validate the suitability of potential fractures/fracture networks for full tests. These experiments will establish and verify fracture connectivity and conductivity. Steps include:

1. Drill second core hole to establish fluid flow path. The core hole should run parallel to the existing core hole and intersect identified promising fractures. Locations for additional core holes are indicated in Figure 8. The core should be logged and the core hold logged via televiewer. This information should be incorporated into the 3D model.
2. Fractures should be extended if necessary by hydraulically pressurizing the fractures. Fracture growth should be observed with seismic imaging.
3. Fracture connectivity and conductivity should be characterized by isolating the injection well zone with the target fracture with packers and injecting ambient temperature water (to minimize disturbance of the temperature distribution in the pillar). Instantaneous and cumulative water flow from the production well should be measured to calculate water losses. Production from individual fractures in the fracture zone should be measured if possible. Injectivity/productivity tests on several fracture zones could be done if possible.

A go/no-go decision on the suitability of the established fracture network should be made before proceeding.

4.3 Phase 2.3: Full Circulation Experiments

The goal of this phase is to quantify the efficiency of heat transfer in the fracture network – how much of the fracture network contributes to heat transfer. The experiment consists of injecting heated fluid into the fracture network and observing the produced temperature with time. The heat transfer efficiency is evaluated by comparing expected results, based on the size (surface area) of the fracture network and predictive heat transfer models. Key experimental steps are listed below.

1. Establish circulation experiment key parameters such as flow rate, injected fluid temperature, and target experiment duration. The experiment should be designed so that there is several weeks before thermal breakthrough of the fluid and so that the temperature decline of the fluid can be monitored for several more weeks.
2. Instrument core holes. Key parameters to measure include:
    - Flow through fractures
    - Lost circulation
    - Pressure losses within fracture
    - Produced fluid temperature with time.
3. Perform circulation experiments
    - Inject heated water into cold reservoir at target flow rate.
    - Observe and collect data on produced water temperature and flow rate.
    - Tracer experiments should be considered to further characterize flow through the fracture network.
4. Analyze results compared to predictive models. Post-experiment modeling should aim to validate fracture flow and heat transfer models with the experimental results.

References

Hutchinson, R. M. (1967). *Precambrian basement rocks of the central Colorado Front Range and its 700 million year history.* Golden: Dept. of Publications, Colorado School of Mines.

Miller, N. C. (1993). *Predicting Flow Characteristics of a Lixiviant in a Fractured Chyrstalline Rock Mass.* United States Department of the Interior: Bureau of Mines.

Montazer, P. (1982). *Permeability of Unsaturated, Fractured Metamorphic Rocks near and Underground Opening.* Golden: Colorado School of Mines, Doctor of Philosophy Geological Engineering Thesis.

Scott, W., Tesarik, D., & Knoll, J. (2004). *Geophysical Methods to Detect Stress in Underground Mines.* NIOSH: U.S. Department of Health and Human Services.

Appendix A: Edgar Mine Data Collection

The Edgar Mine (CSM Experimental Mine) Collection (1874-1997, scattered) at the Colorado School of Mines consists of maps, diagrams, documents and photographs on the Edgar Mine and related mine properties. The collection provides information reflecting the history and development of the Mine and its educational role at the School of Mines.

Related collections:
CSM Experimental Mine maps by CSM students for Dr. Charles O. Frush's classes (19--). 32 sheets + 1 text. Map Room G4314.I2H2 svar .F7

The Collection consists of the following:

- Edgar Mine web guide, http://library.mines.edu/Edgar_Mine.
- Series A. Edgar Mine photographs, CSM 01.07
- Series B. Experimental Mine/Edgar Mine, documents, CSM 09.03
- Series C. Edgar Mine maps and diagrams [various locations]

Note: The Edgar Mine Collection was acquired in unconnected pieces, resulting in a somewhat disjointed organization method. The collection will be consolidated and re-organized as time permits.

Edgar Mine Web Guide

- Overview of the Collection
- Collection, fl. 1881-1997.
  200 maps; 133 color slides
- The Colorado School of Mines Experimental Mine (Edgar Mine) Collection provides information on the history and development of the Mine and its educational role at the School of Mines.
- The collection consists of: approximately 200 maps, mostly student mapping projects with the extensions of the Mine (scattered, 1947-1997); plat maps of the area around the Mine (1880s-1950s); and 133 color slides of scenes underground (1989).
- The maps and slides have been cataloged as separate collections in the Library Catalog and are stored in the Russell L. & Lyn Wood Mining History Archive. Of the slides, 114 are digitized and available via the Image Database.

Table 5. List of Maps, Texts and Diagrams

Mine surveys (by Survey Number) include:	*CSM students' projects include:*
294 Kangaroo Lode	Experimental Mine, vertical cross sections
518 Edgar No. 2 [Lode]	Experimental Mine, addition to drafting lab, interior, diagram 1, diagram 2
669 Nonpareil Lode	Experimental Mine, addition to drafting lab, exterior, diagram 1, diagram 2
776 Hub Lode	Idaho Springs, City Survey
939 Rattler Lode	Mine surveys by Idaho Springs Townsite, blueprint
983 Edgar No. 1 Lode	Quartermaster Claim Survey Map
1051 Boreas Lode	
1058 Argo Lode	
1059 Cornucopia Lode	
1066 [text only]	
1144 Edgar Union Lode	
1152 Lightning Streak Lode	
1185 Quartermaster Lode	
1311 Bride Lode	
1312 Cash Lode,map 1, map 2 [amended]	
1313 Dederick [Lode]	
1346 Cricket Lode	
1347 James Lode	
1348 Martha Lode, map 1, map 2 [amended March 1889] text [amended August 1888]	
1349 Ticknor Lode, map 1, map 2 [amended]	
1361 Oakland Lode	
2198 Esmaralda Lode	
5806 Humphrey, Fulton, Fulton Extension & Comstock Lodes	
8264 Summit Lode	
11324 Robson and Little Annabel Lodes	
11562 [text only]	
12158 Newton Lode	
12218 Shaw Lode	
12762 Canton and Competition Lodes	
12861 Virginia Lode	
14034 Bryan Lode	
17139 East Stanley and Golden View Lodes	
18654 Gold Button Lode	
20794 C.S.M. No. 1, No. 2, No. 3 and No. 4 Lodes, [3 maps]	

Series A. Edgar Mine photographs, CSM 01.07

- Slides, 1989 (GI 2007.03) -- One 3-ring binder of color slides numbered consecutively E0001-E0133, on the Edgar Mine, underground scenes, students and instructors, and equipment. [As of 1/2015 the 3-ring binder is cataloged as TN210 .C676.] This set of slides was part of a larger group of materials transferred from the Mine office to the Library in 2007.
    - Slides E0020-E0133 (114 in number) were digitized and added to the Image Database with metadata.
- Photographs – Sources include box of misc. Edgar Mine items (GI 2010.11); previously uninventoried photos.

Series B. Experimental Mine/Edgar Mine, documents, CSM 09.03

- Student papers and projects.
- Newspaper clippings, press releases.
- Survey notes.

Series C. Edgar Mine maps and diagrams [various locations]

Series C, Group 1. Maps of the Colorado School of Mines Edgar Experimental Mine. Consists of plats, surveys and student works [3 map case drawers, multiple sheets.]. Archive G4312.E27 svar .M5.

From this cataloged group, 38 plat maps (1880-1908, 1956) have been ***digitized*** and are accessible via the Edgar Mine web guide:

- 294. Kangaroo Lode, Denis Faire claim, Idaho district, 1873.
- 518. Edgar No. 2, W. L. Campbell & J. F. Seymore claim, Spanish Bar district, 1875.
- 669. Nonpareil Lode, John Collom claim, Idaho district, 1877.
- 776. Hub Lode, Henry Plummer claim, Idaho district, 1875.
- 939. Rattler Lode, Ed. Elisha Mack claim, Idaho district, 1879.
- 983. Edgar No. 1 Lode, A. P. Smith claim, Spanish Bar district.
- 1051. Boreas Lode, W. T. Glaser claim, Idaho district.
- 1058. Argo Lode, Consolidated Seaton Mtn. Mining Co. claim, Idaho district.
- 1059. Cornucopia Lode, Consolidated Seaton Mtn. Mining Co. claim, Idaho district, 1881.
- 1066. [unknown; text only].
- 1144. Edgar Union Lode, Charles H. Morris claim, Spanish Bar district, 1880.
- 1152. Lightning Streak Lode, Consolidated Seaton Mtn. Mining Co. claim, Idaho district, 1881.
- 1185. Quartermaster Lode, John Owen and John P. Davie claim, Paynes Bar and Idaho districts, 1881.
- 1311. Bride Lode, Consolidated Seaton Mtn. Mining Co. claim, Idaho district, 1881.
- 1312. Cash Lode, Consolidated Seaton Mtn. Mining Co. claim, Idaho district, map 1, 1881; map 2 [amended], 1888.

- 1313. Dederick, Consolidated Seaton Mtn. Mining Co. claim, Idaho district, 1881.
- 1346. Cricket Lode, Consolidated Seaton Mountain Mining Co. claim, Idaho district, 1881.
- 1347. James Lode, Consolidated Seaton Mountain Mining Co. claim, Idaho district, 1881.
- 1348. Martha Lode, Consolidated Seaton Mountain Mining Co. claim, Idaho district, map 1, 1883; map 2 [amended], 1889; text [amended], 1888.
- 1349. Ticknor Lode, Consolidated Seaton Mountain Mining Co. claim, Idaho district, map 1, 1881; map 2 [amended], 1888.
- 1361. Oakland Lode, A. P. Smith claim, Spanish Bar district, 1881.
- 2198. Esmaralda Lode, Consolidated Seaton Mountain Mining Co. claim, Idaho district, 1885.
- 5806. Humphrey, Fulton, Fulton Extension & Comstock Lodes, Robert Turner (?) claim, Idaho district, 1889.
- 8264. Summit Lode, Consolidated Seaton Mountain Mining Co. claim, Idaho district, 1893.
- 11324. Robson and Little Annabel Lodes, Edgar Consolidated Gold Mining Co. claim, Spanish Bar district, 1896.
- 11562. Sunnyside Lode [text only].
- 12158. Newton Lode, Miami Mining and Milling Co. claim, Paynes Bar district, 1897.
- 12218. Shaw Lode, J. W. Shaw claim, Idaho and Paynes Bar districts, 1897.
- 12762. Canton and Competition Lodes, Consolidated Seaton Mountain Mining Co. claim, Idaho district, 1898.
- 12861. Virginia Lode, Philip Mixsell claim, Spanish Bar district, 1898.
- 14034. Bryan Lode, Ole H. Walde and Axel M. Nelson claim, Spanish Bar and Idaho districts, 1900.
- 17139. East Stanley and Golden View Lodes, Ole H. Walde and Axel M. Nelson claim, Spanish Bar district, 1901.
- 18654. Gold Button Lode, Lucy A. Salter claim, Paynes Bar district, 1908.
- 20794. C.S.M. No. 1, No. 2, No. 3 and No. 4 Lodes, [3 maps], Ben H. Parker claim, Paynes Bar district, 1956. ***Note—According to this claim, the C.S.M No. 1 Lode comprises 20.661 acres and is in conflict with some of the lodes listed above.***
- Student works:
    - Experimental Mine, vertical cross sections.
    - Experimental Mine, addition to drafting lab, interior, diagram 1, diagram 2.
    - Experimental Mine, addition to drafting lab, exterior, diagram 1, diagram 2.
    - Idaho Springs, City Survey.
    - Mine surveys by Idaho Springs Townsite, blueprint.
    - Quartermaster Claim Survey Map.

Series C, Group 2. Maps and diagrams, 1874-1967 (GI 2013.11) -- The collection consists of approximately 200 maps, mostly student mapping projects with the extensions of the Mine (scattered, 1947-1997); plat maps of the area around the Mine (1880s-1950s). Alpha by group and claim name, Map cases, Vault.

(Note: Many loose items originated from bound folders. Some items are backed with pieces of CSM students' assignments, noted as "obverse".)

(Note: CSM building floor plans: ***Transferred from this collection to a separate collection within the CSM History items; documented under a separate Collection Report.)***

Misc. plats and survey maps from outside sources, 19 items:

Plats:

- Plat (blueprint). 1935. Highlighted—Jo Reynolds group, Argyle, M.S. claims.
- Plat, Sec 25 T3S R73W (reproduction of 1935 map). 1967. Highlighted—Queen City, Seaton, and Tropic claims.
- Supplemental plat, Sec 25 T3S R74W. (nd.) Highlighted—multiple claims, SW corner of plat. Obverse—Survey of section of tunnel. 1962.
- Plat. (nd). Highlighted—Seaton, Prince Henry, Dorina, No Name, Queen City, Tropic claims. Obverse—Survey, Roy Raise and section of tunnel.

Surveys (reproductions) (1874-1904), by survey number:

- 180. Extension Live Yankee Lode, Akron Mining Co. claim, Montana district. 1874. Obverse—Claim survey, Quartermaster. 1955.
- 452. Edgar Lode and Mill Site, T. J. Sale claim, Spanish Bar and Idaho districts. 1874. Obverse—Claim survey, Quartermaster. 1958.
- 518. Edgar No. 2, W. L. Campbell & J. F. Seymore claim, Spanish Bar district. 1875. ***Poor condition.***
- 827. Tropic Lode, Joseph Reynolds and James I. Gilbert claim, Idaho district. 1878. Obverse—Traverse, 1962.
- 983. Edgar No. 1 Lode, A. P. Smith claim, Spanish Bar district. 1880. Amended 1881. ***Poor condition.***
- 2120. Night Hawk Lode, J. E. Dubois et al claim, Montana district. 1884. Obverse—Survey, Miami Tunnel. 1967.
- 4547. Elida Lode, F. H. Laesch et al claim, Montana district. 1887. Obverse—Claim Survey, Quartermaster. 1955.
- 6521. Early Bird, Old Proverbs, Western Index and Judge lodes, E. W. Lowrey et al, Idaho and Paynes Bar districts. 1890.
- 7290. Eccentric Lode, Martin Feeley claim, Montana district, 1891. Obverse—Survey, Roy Raise and tunnel.
- 11562. Sunnyside and Goodyear lodes, Miami Mining and Milling Co. claim, Paynes Bar district. 1897.

- 12157. No. 1, No. 2, No. 3, E.M.D. No. 4, and E.M.D. No. 5 lodes, Jay Morton claim, Montana district. 1897. Obverse—Survey, Claim II.
- 12861. Virginia Lode, Philip Mixsell claim, Spanish Bar district. 1898. ***Poor condition.***
- 15402. E.M.D. No. 6 Lode, Jay Morton claim, Montana district. 1901. Obverse—3-D Problem, 1962.
- 17139. East Stanley and Golden View lodes, Ole Walde and Axel H. Nelson claim, Spanish Bar district. 1904. ***Poor condition; taped.***

Triangulation Survey in Clear Creek County. 1959? Copied from map of Charles L. Harrington and official General Land Office plat by J. W. Andrews.

Student survey work:

Student survey work, unbound (1958-1975), 51 items: *(Note: Many loose items originated from bound folders. Some items are backed with pieces of CSM students' assignments, noted as "obverse".)*

Underground, Experimental Mine:

- Isometric projection of Tropic shaft and stope. 1967.
- Slope staking. 1982
- Underground detail, Main portal, New portal. 1960.

Misc.:

- Folder cover "Joe Reynolds No. 2." Obverse—Survey showing water station and hose room.
- Folder cover "Experimental Mine No. 2." Obverse—Survey, showing Brown Raise and Rebel Stope.

Surveys:

- Argyle claim. 1967.
- Bryan lode. 1967.
- C.S.M. No. 1, claim relocation. 1974.
- C.S.M No. 3 claim, relocation. 1974.
- C.S.M 3. Shows Miami opening and outbuildings. 1962.
- Comstock claim. 1967.
- Comstock, Fulton, Humphrey. 1954.
- Eccentric lode. 1964.
- Edgar No. 2 claim. 1967.
- Edgar Union claim. 1966.
- Elida claim. 1968.
- Fulton Extension claim. 1968.
- Gold Button. 1958.
- Gold Button, relocation. 1975.
- Goodyear claim. 1962.
- Goodyear claim relocation. 1975.

- Humphrey claim. 1966.
- Joe Reynolds. 1965.
- Judge claim. 1967.
- Last Chance #1. 1968.
- Lewis claim. 1969.
- Little Annabel. 1966.
- Little Chief claim. 1962, 1967 (2 maps).
- Little Chief claim, relocation. 1964, 1974 (2 maps).
- Lucky Lad claim. 1968.
- Mt. Royal. 1972.
- Newton claim. 1961. Obverse—Survey notes (reproduction) of original claim?
- Newton claim relocation. 1975.
- Par claim. 1964.
- Quartermaster claim. 1974.
- Roscoe and Hornblende claims. 1964.
- Shaw claim. 1961, 1967, 1970, 1972, 1973, 1974 (11 maps).
- Sunnyside claim. 1959.
- Virginia. 1966.

Student survey work, folder-bound, 183 items. 1973. (1952-1973).

- Claim Maps A. Contains:
    - Arum (3 maps).
- Claim Maps B. Contains:
    - Bryan (7 maps).
- Claim Maps C. Contains:
    - Cleopatra
    - Comstock
    - Coupon
    - C.S.M. No. 1
    - C.S.M. No. 2
    - C.S.M. No. 3
    - C.S.M. No. 4
- Claim Maps E. Contains:
    - Edith South. 1973 (3 maps).
    - Edgar No. 1. 1971, 1973 (6 maps).
    - Edgar. 1967.
    - Edgar No. 2. 1967, 1972 (4 maps).
    - Edgar Union. 27 Jun 1966.
- Claim Maps F. Contains:
    - Fulton. 1966, 1972 (4 maps).

    - Fulton and Pié Enfermo. 1970 (3 maps).
    - Fulton Extension. 1968, 1970 (2 maps)
    - Lucky A-J-P [and Fulton Extension]. 1970.
- Claim Maps G. Contains:
    - Gold Button. 1967, 1971, 1972, 1973 (10 maps).
    - Goodyear. 1969, 1971 (4 maps).
- Claim Maps H. Contains:
    - Humphrey. 1972, 1973, nd (8 maps).
    - North compass composed of a caricature of a student.
- Claim Maps J. Contains:
    - Judge. 1967, 1971, 1972, 1973, nd (8 maps).
- Claim Maps Joe Reynolds #1 [property]. Contains:
    - Candelaria. 1965.
    - Eccentric. 1964.
    - Elida. 1968.
    - Goshen Mill. 1968.
    - Hardware. 1965.
    - Hornblende and Roscoe. 1965.
    - Joe Reynolds #1. 1965.
    - Joe Reynolds #2. 1964.
    - Joe Reynolds #3. 1965.
    - Joe Reynolds #4. ND.
    - Last Chance #1. 1968.
    - La Crosse. 1965.
    - Maggie L. claim, mine dumps. 1964.
    - Maggie L. 1964.
    - Minnehaha. 1964.
    - Native American. 1965.
- [Claim Maps Joe Reynolds (?)] Bound, no cover. Contains:
    - Hardware. 1965.
    - Joe Reynolds No. 1. 1965.
    - Joe Reynolds No. 2. 1964.
    - Joe Reynolds. 1965.
    - Joe Reynolds No. 4. 1965.
    - Last Chance No. 1. 1968.
    - Maggie L. 1964.
    - Minnehaha. 1964.
    - Native American. 1965.
- Joe Reynolds Miscellaneous #1. Contains:
    - Big Stick. 1965.

    - Index. 1968.
    - O.B.S. 1956.
    - Tropic. 1967.
    - Golden View. 1967.
- Joe Reynolds Miscellaneous #2. Contains:
    - Bogey. 1952.
    - Golden View. 1967.
    - Index. 1968.
    - OBS. 1956.
    - Tropic. 1967.
- Claim Maps L. Contains:
    - Lewis. 1969.
    - Little Annabel [Annabelle; Anabelle]. 1966, 1972, 1973 (7 maps).
    - Little Chief. 1961, 1967, 1972, 1973 (6 maps).
    - Lucky Lad. 1968, 1971, 1972 (6 maps).
- Claim Maps M. Contains:
    - Mount Royal. 1972, 1973 (5 maps).
    - Mount Royal, resurvey. 1969.
- Claim Maps N. Contains:
    - Newton. 1961, 1962, 1967, 1970, 1972, 1973, nd (12 maps).
    - Non Pariell [Parielli; Pariel]. 1961, 1967, 1971, 1972 (8 maps). [One of the 1971 maps contains a North arrow comprised of a lunar capsule.]
- Claim Maps O. Contains:
    - Oakland. 1966.
- Claim Maps R. Contains:
    - Robson. 1967, 1972, 1973 (7 maps).
    - Edith South. 1972.
- Claim Maps S. Contains:
    - Shaw. 1971 (2 maps).
    - Sunnyside. 1955, 1970 (4 maps).
- Claim Maps V. Contains:
    - Virginia. 1966.
- [Claim Maps (?)] Bound, no cover (1957-1969). Contains:
    - C.S.M. No. 1. 1969.
    - C.S.M. No. 2. 1957.
    - C.S.M. No. 4. 1956.
    - Edgar Lode. 1967.
    - Newton claim. 1967.

Oversize (both outside creation and student work), 18 items:

- Enlarged reproduction of topographic map showing claim locations.

- Survey showing claim locations.
- Claim Relocation survey. 1974.
- Underground survey map of Experimental Mine, Brown Raise and Roy Raise (nd).
- Student survey work:
    - C.S.M. 1 claim relocation. 1974.
    - C.S.M. 3 claim relocation. 1974.
    - C.S.M. 3 relocation of corner Number 1 of claim. 1974.
    - Edith S. lode. 1974.
    - Edith S. lode claim relocation. 1974.
    - Fulton claim relocation. 1975.
    - Humphrey corner Number 3 claim relocation. 1974.
    - Judge lode claim relocation. 1974 (2 maps).
    - Little Chief claim relocation. 1975.
    - Mount Royal claim relocation. 1974.
    - Newton lode Miami Mining & Milling Co. claim relocation. 1975.
    - Nonpariel. 1951.
    - Shaw claim. 1972.

Appendix B: Raw Scanline Data

Raw Scanline data from Edgar Mine for areas indicated in Figure 2.

Type		Persistence		Aperture/width		Nature of filling			comperssive strength of infilling	
										Mpa
0	Falut zone	1	Very low	1	Very tight (<0.1mm)	1	Clean		S1 Very soft clay	<0.025
1	Fault		Persistence	2	Tight (0.1-0.25 mm)	2	Surface staining		S2 Soft clay	0.025-0.05
2	Joint	2	Low	3	Partly open (0.25-0.5 mm)	3	Non-cohesive		S3 Firm clay	0.05-0.10
3	Cleavage		Persistence	4	Open (0.5-2.5 mm)	4	Inactive clay or clay matrix		S4 Stiff clay	0.10-0.25
4	Schistosity	3	Medium	5	Moderately wide (2.5-10 mm)	5	Sweling clay or clay matrix		S5 Very stiff clay	0.25-0.5
5	Shear		Persistence	6	Wide (>10 mm)	6	Cemented		S6 Hard clay	>0.5
6	Fissure	4	High	7	Very wide (1-10 cm)	7	Chlorite, talc or gypsum		R0 Extremely weak rock	0.25-1.0
7	Tension		Persistence	8	Extermely wide (10-100 cm)	8	Other- specify		R1 Very weak rock	1.0-5.0
8	Foliation	5	Very high	9	Cavemous (>1 m)				R2 Weak rock	5.0-25
9	Bedding		Persistence						R3 Medium rock	25-50
									R4 Strong rock	50-100
									R5 Very strong rock	100-250
									R6 Extremely strong rock	>250
Termination		Surface shape		Surface roughness		Spacing				
0	Niether end visible	1	Stepped	1	Rough	1	Extremely close spacing	<20 mm		
1	One end visible	2	Undulating	2	Smooth	2	Very close spacing	20-60 mm		
2	Both end visible	3	Planar	3	Polished	3	Close spacing	60-200 mm		
				4	Slickensided	4	Moderate spacing	200-600 mm		
						5	Wide spacing	600-2000 mm		
						6	Very wide spacing	2000-6000 mm		

Chainage(ft)	Type	Dip	Dip direction	Persistence	Termination	Aperture	Nature of filling	Strength of filling	Surface roughness	Surface shape	JRC	Schmidt hammer JCS (psi)
B-Right												
0.4	4	54	308	4		6	4	R0	2	2	5	
3.6	2	74	35	3	1	5	3	R1	2	3	3	8500
3.6	2	79	245	2		2	6	R3	1	3	6	5000
12	2	39	345	1		5	6	R4	1	3	18	

Chainage(ft)	Type	Dip	Dip direction	Persistence	Termination	Aperture	Nature of filling	Strength of filling	Surface roughness	Surface shape	JRC	Schmidt hammer JCS (psi)
B-Right												
13.3	2	59	270	2		7	6	R4	1	3	18	4750
15.3	2	39	345	4		5	6	R4	1	3	18	
16.8	2	90	350	2		3	4	R0	1	3	8	8500
17	2	90	340	2		4	4	S6	2	3	6	4000
18.6	2	74	347	1		4	4	S6	2	3	6	5000
19	2	74	347	1		4	4	S6	3	3	6	5000
19.6	2	74	347	1		4	4	S6	4	3	6	
21.5	8	60	332	3		4	4	R0	1	3	16	
22.7	2	60	357	3		4	4	R0	1	3	16	
23.1	2	81	347	1	1	1	4	R4	1	3	8	
23.9	2	70	234	2		3	4	R4	1	2	15	
26.2	2	80	100	2	1	1	4	R4	2	3	6	
27	2	66	235	1		1	1	R4	1	3	4	
27.1	2	75	324	1		1	4	R0	1	2	13	
27.4	2	56	183	1		1	4	R0	1	3	4	
28.3	2	33	266	2		2	4	R0	1	3	10	
28.8	2	33	266	2		2	4	R0	1	3	10	
29.2	2	33	266	2		2	4	R0	1	3	10	
30.4	2	61	352	3		2	4	R0	1	3	15	
31.8	2	52	63	1		2	4	R0	1	3	12	
31.9	2	52	63	1		2	4	R0	1	3	12	
33.7	4	66	358	2		5	4	R0	1	3	8	

Chainage(ft)	Type	Dip	Dip direction	Persistence	Termination	Aperture	Nature of filling	Strength of filling	Surface roughness	Surface shape	JRC	Schmidt hammer JCS (psi)
B-Right												
36.2	2	63	322	2	1	4	4	R0	1	3	6	
37.2	2	53	345	2		4	4	R0	1	3	6	
37.9	2	53	345	2		4	4	R0	1	3	6	
38.1	2	53	345	2		4	4	R0	1	3	6	
19.6	2	74	347	1		4	4	S6	4	3	6	
21.5	8	60	332	3		4	4	R0	1	3	16	
22.7	2	60	357	3		4	4	R0	1	3	16	
23.1	2	81	347	1	1	1	4	R4	1	3	8	
23.9	2	70	234	2		3	4	R4	1	2	15	
26.2	2	80	100	2	1	1	4	R4	2	3	6	
27	2	66	235	1		1	1	R4	1	3	4	
27.1	2	75	324	1		1	4	R0	1	2	13	
27.4	2	56	183	1		1	4	R0	1	3	4	
28.3	2	33	266	2		2	4	R0	1	3	10	
28.8	2	33	266	2		2	4	R0	1	3	10	
29.2	2	33	266	2		2	4	R0	1	3	10	
30.4	2	61	352	3		2	4	R0	1	3	15	
31.8	2	52	63	1		2	4	R0	1	3	12	
31.9	2	52	63	1		2	4	R0	1	3	12	
33.7	4	66	358	2		5	4	R0	1	3	8	
36.2	2	63	322	2	1	4	4	R0	1	3	6	
37.2	2	53	345	2		4	4	R0	1	3	6	

Chainage(ft)	Type	Dip	Dip direction	Persistence	Termination	Aperture	Nature of filling	Strength of filling	Surface roughness	Surface shape	JRC	Schmidt hammer JCS (psi)
B-Right												
37.9	2	53	345	2		4	4	R0	1	3	6	
38.1	2	53	345	2		4	4	R0	1	3	6	
44.1	4	60	354	3		7	6	R4	1	2	8	
44.3	4	55	338	1		7	6	R4	1	2	8	
47	4	50	162	2		4	1	R4	2	3	8	
50.7	2	60	255	2		1	1	R4	1	3	8	
51.4	2	76	351	2		2	4	R0	1	3	10	
52.2	2	60	110	2		2	1	R4	1	3	6	
52.5	2	60	255	2		1	1	R4	1	3	8	
52.8	2	60	110	2		2	1	R4	1	3	6	
53.9	2	60	110	2		2	1	R4	1	3	6	
54.7	2	76	351	2		2	4	R0	1	3	10	
54.9	2	76	351	2		2	4	R0	1	3	10	
58.7	8	75	334	1		1	1	R4	1	3	18	
60.3	2	85	240	1		1	1	R4	1	3	12	
62.2	2	75	247	1		1	1	R4	1	3	10	
62.2	2	70	288	1		1	1	R4	1	3	15	
63.1	2	80	280	2		1	1	R4	2	3	10	
63.8	2	80	280	2		1	1	R4	2	3	10	
64.9	2	90	260	1		1	1	R4	2	3	8	
64.9	2	85	70	1		1	1	R4	2	3	10	
65.6	2	66	342	2		1	1	R4	2	3	8	

Chainage(ft)	Type	Dip	Dip direction	Persistence	Termination	Aperture	Nature of filling	Strength of filling	Surface roughness	Surface shape	JRC	Schmidt hammer JCS (psi)
B-Right												
66.1	2	85	275	1		1	1	R4	2	3	6	
66.1	2	85	200	1		1	1	R4	1	3	10	
66.4	2	60	175	2		1	1	R4	1	3	10	
67	2	46	34	1		1	1	R4	1	3	8	
67	2	60	175	2		1	1	R4	1	3	10	
67.4	2	60	175	2		1	1	R4	1	3	10	
69	2	54	347	2		2	1	R4	1	3	10	
69.3	2	80	160	1		1	1	R4	1	3	8	
71.7	2	35	95	1		2	1	R4	1	3	8	
72	2	78	30	1		1	1	R4	1	3	10	
73.3	2	88	215	1		1	4	R0	2	3	4	
73.6	2	78	30	1		1	1	R4	1	3	10	
74.5	2	80	27	1		1	1	R4	2	3	4	
76.7	2	90	223	1		1	1	R4	1	3	10	
78	2	55	50	2		1	4	R0	1	3	10	
78.2	2	43	80	1		1	1	R4	1	3	8	
78.4	2	55	50	2		1	4	R0	1	3	10	
78.9	2	43	80	1		1	1	R4	1	3	8	
78.9	2	78	146	1		1	1	R4	1	3	6	
79.2	2	55	50	2		1	4	R0	1	3	10	
79.3	2	78	146	1		1	1	R4	1	3	6	
79.7	2	55	50	2		1	4	R0	1	3	10	

Chainage(ft)	Type	Dip	Dip direction	Persistence	Termination	Aperture	Nature of filling	Strength of filling	Surface roughness	Surface shape	JRC	Schmidt hammer JCS (psi)
B-Right												
79.8	2	78	146	1		1	1	R4	1	3	6	
80.1	2	43	80	1		1	1	R4	1	3	8	
80.6	2	78	146	1		1	1	R4	1	3	6	
80.8	2	43	80	1		1	1	R4	1	3	8	
82.1	2	78	146	1		1	1	R4	1	3	6	
82.3	2	43	80	1		1	1	R4	1	3	8	
82.7	2	78	146	1		1	1	R4	1	3	6	
82.9	2	43	80	1		1	1	R4	1	3	8	
83.4	2	55	50	2		1	4	R0	1	3	10	
83.6	2	78	146	1		1	1	R4	1	3	6	
B-Right 1st												
0.4	2	85	10	3	2	4	1	R6	1	3	4	
0.5	2	85	10	3	2	4	1	R6	1	3	4	
1.3	2	90	68	2	0	1	1	R6	1	3	4	
1.4	2	90	68	2	0	1	1	R6	1	3	4	
1.8	2	68	70	1	0	1	1	R6	1	3	3	
2.3	2	68	70	1	0	1	1	R6	1	3	3	
2.5	2	25	200	2	0	3	1	R6	1	2	14	
2.7	2	78	354	3	2	3	1	R6	1	3	8	
2.9	2	80	244	2	0	1	1	R6	1	3	10	
3.1	2	75	3	1	0	1	1	R6	1	3	10	
3.2	2	75	3	1	0	1	1	R6	1	3	10	

Chainage(ft)	Type	Dip	Dip direction	Persistence	Termination	Aperture	Nature of filling	Strength of filling	Surface roughness	Surface shape	JRC	Schmidt hammer JCS (psi)
B-Right 1st												
3.9	2	90	186	2	1	3	1	R6	1	3	14	
4.5	2	87	2	1	0	2	1	R6	1	3	14	
4.8	2	87	2	1	0	2	1	R6	1	3	14	
4.9	2	77	0	3	2	5	1	R6	1	3	6	
5.3	2	77	0	3	2	5	1	R6	1	3	6	
5.5	2	77	0	3	2	5	1	R6	1	3	6	
6.3	2	77	0	3	2	5	1	R6	1	3	6	
6.4	2	74	352	3	2	1	1	R6	1	3	6	
6.45	2	74	352	3	2	1	1	R6	1	3	6	
6.5	2	74	352	3	2	1	1	R6	1	3	6	
7	2	74	352	3	2	1	1	R6	1	3	6	
7.2	2	74	352	3	2	1	1	R6	1	3	6	
7.7	2	70	58	3	2	3	1	R6	1	3	6	
7.8	2	68	202	1	1	1	1	R6	1	3	14	
7.9	2	68	202	1	1	1	1	R6	1	3	14	
8.1	2	70	4	3	2	2	1	R6	1	3	10	
8.4	2	70	4	3	2	2	1	R6	1	3	10	
8.6	2	75	2	3	2	3	1	R6	1	3	14	
8.8	2	75	2	3	2	3	1	R6	1	3	14	
9.3	2	61	344	3	0	3	1	R6	1	3	4	
9.4	2	75	224	1	0	3	1	R6	1	3	12	
9.9	2	80	318	2	2	1	1	R6	1	3	16	

Chainage(ft)	Type	Dip	Dip direction	Persistence	Termination	Aperture	Nature of filling	Strength of filling	Surface roughness	Surface shape	JRC	Schmidt hammer JCS (psi)
B-Right 1st												
9.9	2	80	24	2	0	2	1	R6	1	3	6	
10.1	2	46	354	1	0	3	1	R6	1	3	10	
10.25	2	68	334	3	2	3	1	R6	1	3	6	
10.6	2	68	334	3	2	3	1	R6	1	3	6	
10.8	2	68	334	3	2	3	1	R6	1	3	6	
10.9	2	68	334	3	2	3	1	R6	1	3	6	
11	2	68	334	3	2	3	1	R6	1	3	6	
11.1	2	68	334	3	2	3	1	R6	1	3	6	
11.1	2	19	174	2	0	2	1	R6	1	3	4	
11.7	2	68	334	3	2	3	1	R6	1	3	6	
11.8	2	80	220	2	0	1	1	R6	1	3	10	
11.9	2	70	323	3	2	1	1	R6	1	3	10	
12.6	2 or 4	70	318	2	0	1	1	R6	1	3	18	BIOTITE PRESENT
12.7	2	55	344	1	0	1	1	R6	1	3	10	
12.7	2	60	28	1	0	1	1	R6	1	3	14	
13.4	2	72	140	3	2	1	1	R6	1	3	12	
13.6	2	72	140	3	2	1	1	R6	1	3	12	
13.8	2	72	140	3	2	1	1	R6	1	3	12	
14	2	72	140	3	2	1	1	R6	1	3	12	
14.7	2	65	40	2	0	1	1	R6	1	3	12	
14.7	2	55	326	1	0	3	1	R6	1	3	16	
15.8	2	65	314	3	2	1	1	R6	1	3	10	

Chainage(ft)	Type	Dip	Dip direction	Persistence	Termination	Aperture	Nature of filling	Strength of filling	Surface roughness	Surface shape	JRC	Schmidt hammer JCS (psi)
B-Right 1st												
16.1	2	65	314	3	2	1	1	R6	1	3	10	
16.3	2	65	314	3	2	1	1	R6	1	3	10	
16.4	2	65	314	3	2	1	1	R6	1	3	10	biotite schistosity
17.5	2	12	225	3	2	2	1	R6	1	3	12	
17.9	2	40	330	1	0	1	1	R6	1	3	2	
18.65	2	37	0	1	0	1	1	R6	1	3	10	
18.9	2	56	346	1	0	1	1	R6	1	3	10	
19	2	64	20	1	0	1	1	R6	1	3	10	
19.1	2	56	346	1	0	1	1	R6	1	3	10	
19.3	2	44	350	1	0	1	1	R6	1	3	6	
19.4	2	56	346	1	0	1	1	R6	1	3	10	
19.75	2	56	346	1	0	1	1	R6	1	3	10	
19.75	2	58	128	1	0	1	1	R6	1	3	6	
19.8	2	64	58	1	0	1	1	R6	1	3	12	
20.3	2	85	310	1	0	1	1	R6	1	3	12	borehole above
20.75	2	24	0	3	2	3	1	R6	1	3	10	borehole above
21.1	2	55	310	1	0	1	1	R6	1	3	8	
21.7	2 or 4	60	10	3	2	7	4	55	1	3	6	biotite weather ed to clay
22.5	2 or 4	60	10	3	2	8	4	55	1	3	6	

Chainage(ft)	Type	Dip	Dip direction	Persistence	Termination	Aperture	Nature of filling	Strength of filling	Surface roughness	Surface shape	JRC	Schmidt hammer JCS (psi)
B-Right 1st												
23.5	2 or 4	60	10	3	2	2	4	55	1	3	6	
24.7	2	52	52	1	0	1	1	R6	1	3	6	
25	2	70	270	1	0	1	1	R6	1	3	6	
25.1	2	90	136	1	0	1	1	R6	1	3	6	
26	2	75	115	1	0	1	1	R6	1	3	14	
26.2	2	65	250	2	0	3	6	R5	1	2	8	*the discontinuity is oriented 20 degrees on face measured above 2
26.7	2	65	250	2	0	3	6	R5	1	2	8	27-28.7ft black biotite alteration
28.5	4	44	210	2	0	7	4	56	1	3	10	28.5-30.5 along scanline clay seam 3-5cm thick
29.8	2	82	50	1	0	1	1	R6	1	3	13	
29.9	2	81	212	1	0	1	1	R6	1	3	8	
31.5	2	66	336	2	0	2	6	R6	1	3	14	
31.8	2	66	336	2	0	2	6	R6	1	3	14	
32.2	2	66	336	2	0	2	6	R6	1	3	14	
32.4	2	90	24	2	0	2	4	R3	1	3	12	
33.3	2	75	72	1	0	1	1	R3	1	3	18	

Chainage(ft)	Type	Dip	Dip direction	Persistence	Termination	Aperture	Nature of filling	Strength of filling	Surface roughness	Surface shape	JRC	Schmidt hammer JCS (psi)
B-Right 1st												
33.5	2	90	306	1	0	1	1	R3	1	3	12	33.5-35.5 alteration zone and qtz-mineralization
34.2	2	55	4	3	2	6	4	56+R0	1	3	4	
35.1	2	55	4	3	2	6	4	56+R0	1	3	4	
36	2	64	300	1	0	1	1	R5	2	3	4	
36.6	2	68	116	3	2	1	1	R6	1	3	15	
36.7	2	54	175	3	2	8	56	R2	1	3	10	
36.8	2	54	175	3	2	8	56	R2	1	3	10	
37.3	2	54	175	3	2	8	56	R2	1	3	10	
38.6	1	53	170	3	2	8	4	R2	1	2	8	
39.9	1	53	170	3	2	8	4	R2	1	2	8	
41.4	2	68	230	1	0	1	1	R6	1	3	6	
42.4	1/2	61	335	3	2	35	4/7	R2	1	2	8	
44	2	46	40	1	0	4	1	R6	1	3	8	44-51 has metal supports that affect compass readings
44.2	2	89	350	2	0	4	1	R6	1	3	8	
45.8	2	50	225	1	0	6	2	R6	1	3	8	
46.7	2	50	225	1	0	5	1	R6	1	3	8	
47	2	50	225	1	0	7	3	R6	1	3	8	
49.3	2	36	0	1	0	1	4	R0	1	3	8	
49.6	2	78	68	2	0	1	1	R6	1	3	8	

Chainage(ft)	Type	Dip	Dip direction	Persistence	Termination	Aperture	Nature of filling	Strength of filling	Surface roughness	Surface shape	JRC	Schmidt hammer JCS (psi)
B-Right 1st												
49.7	2	50	225	1	0	8	4	R6	1	3	8	
50.6	2	44	150	3	2	7	1	R6	1	3	8	
51	2	58	117	1	0	4	1	R6	1	3	8	
51.1	2	60	120	2	0	4	1	R6	1	3	8	
51.5	2	85	11	1	0	3	4	R0	1	3	8	
51.6	2	50	195	1	0	4	4	R6	1	3	8	
51.8	2	86	45	1	0	1	1	R6	1	3	8	
52.1	2	44	150	3	2	7	1	R6	1	3	8	
52.5	2	85	11	1	0	3	4	R0	1	3	8	
53	2	50	195	1	0	3	4	R0	1	3	8	
53.2	2	60	120	2	0	4	1	R6	1	3	8	
53.4	2	58	117	1	0	5	1	R6	1	3	8	
54.5	2	70	355	1	0	1	1	R6	1	3	8	
54.6	2	27	180	1	0	4	1	R6	1	3	8	
55.2	2	70	355	1	0	2	2	R6	1	3	8	
55.6	2	27	180	1	0	4	1	R6	1	3	8	
56.3	2	70	355	1	0	3	3	R6	1	3	8	
56.4	2	70	355	1	0	4	4	R6	1	3	8	
56.7	2	70	355	1	0	5	5	R6	1	3	8	
57.2	2	52	123	1	0	4	1	R6	1	3	8	
57.4	2	70	1	1	0	5	4	R0	1	3	8	
57.5	2	70	1	1	0	5	4	R0	1	3	8	

Chainage(ft)	Type	Dip	Dip direction	Persistence	Termination	Aperture	Nature of filling	Strength of filling	Surface roughness	Surface shape	JRC	Schmidt hammer JCS (psi)
B-Right 1st												
57.6	2	70	1	1	0	5	4	R0	1	2	8	
57.7	2	70	1	1	0	5	4	R0	1	3	8	
58.7	2	50	204	1	0	1	4	R0	1	3	16	
59.8	2	50	355	3	2	5	6	R4	1	3	8	
60.2	2	50	355	3	2	5	6	R4	1	3	8	
60.2	2	62	198	1	0	1	1	R6	1	3	8	
60.4	2	48	0	1	0	8	4	R4	1	3	6	57-62.4 lamination
61.7	2	56	179	1	0	1	1	R6	1	3	8	
62.4	2	50	125	1	0	2	1	R6	1	3	8	
64.5	2	50	0	3	2	4	4	R0	1	3	6	
83.2	4	46	125	1	0	1	1	R6	1	3	8	79-82, 84.7-86 Quartz Intrusion
83.8	4	46	125	1	0	1	1	R6	1	3	8	
84.4	4	46	125	1	0	1	1	R6	1	3	8	
87.7	2	44	123	1	0	4	4	R0	1	3	8	
89	2	44	123	1	0	4	4	S6	1	3	8	
89.9	2	47	192	1	0	1	1	R6	1	3	8	
91.3	2	44	123	1	0	4	4	R6	1	3	8	
91.3	2	74	290	1	0	1	1	R6	1	3	8	

Chainage(ft)	Type	Dip	Dip direction	Persistence	Termination	Aperture	Nature of filling	Strength of filling	Surface roughness	Surface shape	JRC	Schmidt hammer JCS (psi)
B-Right 1st												
92.6	2	71	149	1	0	1	1	R6	1	3	8	91.5-92.5 Intrusion
92.8	2	69	323	1	0	7	7/5	R4	1	3	8	
95.7	2	80	320	3	2	4	4	R0	1	3	8	93-Biotite
95.8	2	90	30	3	2	1	1	R6	1	3	8	
96.8	2	80	320	2	0	5	4	R0	1	3	8	
96.9	2	73	331	2	0	5	4	R0	1	3	8	
97.2	2	73	331	2	0	5	4	R0	1	3	8	
97.7	2	73	331	2	0	5	4	R0	1	3	8	97-PYRITE
98.5	2	90	30	1	0	4	4	R0	1	3	8	97.6 SULFUR Weathering
99.7	2	85	45	1	0	1	1	R6	1	3	8	99.4-99.8 Schistoscity
101	2	36	188	3	2	1	1	R6	1	3	16	Schistoscity 101-2
101.7	2	36	188	3	2	1	1	R6	1	3	16	
102.5	2	36	188	3	2	1	1	R6	1	3	16	
103.6	2	59	2	1	0	4	6	R1	1	3	6	104-6 RUSTY ROCK Covering
103.7	2	46	340	3	2	2	6	R2	1	3	14	
104.1	2	59	2	1	0	4	6	R1	1	3	6	
104.8	2	46	340	3	2	2	6	R2	1	3	14	
105.1	2	46	340	3	2	2	6	R2	1	3	14	105.6 GALENA ABOVE SCANLINE

Chainage(ft)	Type	Dip	Dip direction	Persistence	Termination	Aperture	Nature of filling	Strength of filling	Surface roughness	Surface shape	JRC	Schmidt hammer JCS (psi)
B-Right 1st												
105.9	2	46	340	3	2	2	6	R2	1	3	14	
106.6	2	59	2	1	0	4	6	R1	1	3	6	
107.4	2	90	24	2	0	4	4/7	R4	1	2	16	105.2 CARBONATES
107.9	2	36	47	1	0	2	1	R6	1	3	8	
109	2	36	47	1	0	2	1	R6	1	3	8	108-12 MAFIC Intrusions/ GNEISSITY
109.3	2	36	47	1	0	2	1	R6	1	3	8	
111.8	2	81	136	2	0	4	6	R6	1	3	8	
112.3	2	81	136	2	0	4	6	R6	1	3	8	
113	2	68	310	1	0	3	4	R4	1	3	8	113 SULFIDES PRESENT IN FILLING
113.2	2	68	310	1	0	3	4	R4	1	3	8	
113.6	2	72	305	1	0	1	1	R6	1	3	6	
113.6	2	37	175	1	0	1	1	R6	1	3	6	
114.2	2	82	68	1	0	5	1	R6	1	3	2	116.1 PYRITE VEIN
115.6	2	88	20	2	0	4	1	R6	1	3	9	
115.7	2	88	20	2	0	4	1	R6	1	3	9	
116.5	4	68	310	1	0	5	6	R4	1	3	6	
117.1	2	52	193	1	0	2	1	R6	1	3	8	
117.2	2	90	30	2	0	4	1	R6	1	3	8	
118	4	87	321	2	0	7	4	R0	2	2	4	118-19 BIOTITE

Chainage(ft)	Type	Dip	Dip direction	Persistence	Termination	Aperture	Nature of filling	Strength of filling	Surface roughness	Surface shape	JRC	Schmidt hammer JCS (psi)
B-Right 1st												
118.9	2	46	110	3	2	1	1	R6	1	3	9	
121	2	82	68	3	2	2	1	R6	1	3	5	
121.6	2	60	220	3	2	1	1	R6	1	3	6	
121.9	2	56	325	1	0	1	1	R6	1	3	6	
122.9	2	42	117	1	0	1	1	R6	1	3	10	
123.8	2	60	322	3	2	4	1	R6	1	3	8	
125.2	1	77	335	3	2	7	4	R0	1	3	10	
125.3	2	87	160	2	0	1	1	R6	1	3	8	
125.5	2	87	160	2	0	1	1	R6	1	3	8	
126	2	42	117	1	0	1	1	R6	1	3	10	
127.8	2	79	328	3	2	4	1	R6	1	3	8	
127.9	2	79	328	3	2	4	1	R6	1	3	8	
128.6	2	79	328	3	2	4	1	R6	1	3	8	
128.8	2	79	328	3	2	4	1	R6	1	3	8	
129.8	2	79	328	3	2	4	1	R6	1	3	8	
130.4	2	79	328	3	2	4	1	R6	1	3	8	
130.7	2	79	328	3	2	4	1	R6	1	3	8	
131.6	2	79	328	3	2	4	1	R6	1	3	8	
131.8	2	72	95	3	2	1	1	R6	1	3	10	
131.9	2	79	328	3	2	4	1	R6	1	3	8	
132	2	85	192	3	2	1	1	R6	1	3	8	
132.4	2	79	328	3	2	4	1	R6	1	3	8	

Chainage(ft)	Type	Dip	Dip direction	Persistence	Termination	Aperture	Nature of filling	Strength of filling	Surface roughness	Surface shape	JRC	Schmidt hammer JCS (psi)
B-Right 1st												
132.6	2	79	328	3	2	4	1	R6	1	3	8	
132.6	2	40	167	1	0	1	1	R6	1	3	4	
134.1	2	42	220	3	2	1	1	R6	1	3	8	
134.9	2	79	328	3	2	4	1	R6	1	3	8	
139	2	86	273	2	0	2	1	R6	1	3	8	137-44 GNEISSITY
141.1	2	35	7	1	0	1	1	R6	1	3	8	
141.2	2	84	355	1	0	1	1	R6	1	3	8	
142.7	2	55	242	3	2	1	1	R6	1	3	8	
143.8	2	55	242	3	2	1	1	R6	1	3	8	
145	2	55	242	3	2	1	1	R6	1	3	8	
145.1	2	60	110	1	0	1	1	R6	1	3	6	
146.6	2	68	50	1	0	4	1	R6	1	3	8	
147.4	2	68	50	1	0	4	1	R6	1	3	8	
147.8	2	58	190	1	2	1	1	R6	1	3	4	
150.1	2	50	104	1	0	1	1	R6	1	3	8	
150.5	2	73	0	3	2	1	1	R6	1	3	8	
150.9	2	73	0	3	2	1	1	R6	1	3	8	
151.2	2	73	0	3	2	1	1	R6	1	3	8	
151.9	2	33	120	3	2	4	4	R4	1	3	8	
154.8	2	73	0	3	2	1	1	R6	1	3	8	
155.3	2	73	0	3	2	1	1	R6	1	3	8	
155.8	2	73	0	3	2	1	1	R6	1	3	8	157-58 PLAG. VEIN

Chainage(ft)	Type	Dip	Dip direction	Persistence	Termination	Aperture	Nature of filling	Strength of filling	Surface roughness	Surface shape	JRC	Schmidt hammer JCS (psi)
B-Right 1st												
157.8	2	34	192	3	2	1	1	R6	1	3	8	158.2-59 MAFIC Intrusion
160	2	60	90	1	0	1	1	R6	1	3	8	160-76 GNEISS
162.2	2	45	213	1	0	2	1	R6	1	3	6	160-61 BIOTITE
164.3	2	45	213	1	0	2	1	R6	1	3	6	
166.5	2	73	0	3	2	4	1	R6	1	3	8	
167.1	2	81	175	3	2	4	1	R6	1	3	8	
167.7	2	54	150	1	0	4	1	R6	1	3	8	
167.9	4	76	340	3	2	4	4	R0	1	3	7	
168.2	4	76	340	1	2	5	1	R0	1	3	7	
169	2	7	180	1	0	1	1	R6	1	3	8	
171	2	47	291	1	0	1	1	R6	1	3	8	
171.1	2	87	256	1	0	1	1	R6	1	3	8	
172.2	2	77	330	3	2	4	1	R6	1	3	8	
172.6	2	90	70	1	0	4	1	R6	1	3	8	
173.2	2	90	70	1	0	4	1	R6	1	3	8	
173.8	2	80	265	1	0	1	1	R6	1	3	8	
173.8	2	37	111	2	0	2	1	R6	1	3	8	
174.1	2	80	265	1	0	1	1	R6	1	3	8	
174.4	2	80	265	1	0	1	1	R6	1	3	8	

Chainage(ft)	Type	Dip	Dip direction	Persistence	Termination	Aperture	Nature of filling	Strength of filling	Surface roughness	Surface shape	JRC	Note
C-Right												
0	2	31	78	2	0	4	1	R6	1	3	8	
0.5	2	90	82	3	2	4	1	R6	1	3	8	
1.4	2	59	109	1	0	4	1	R6	1	3	8	1 BIOTITE
2.1	2	69	71	2	0	2	1	R6	1	3	8	
2.3	2	17	230	3	2	4	6	R4	1	3	8	
2.5	2	83	220	1	0	5	4	R0	1	3	8	2-4 BIOTITE AND PYRITE
3.2	2	67	52	2	0	5	1	R6	1	3	8	
3.7	2	82	219	1	0	4	1	R6	1	3	6	
4.5	2	54	115	1	0	1	1	R6	1	3	8	
4.8	2	36	208	1	0	4	1	R6	1	3	8	
5.8	2	75	30	2	0	4	4	R0	1	3	8	
6	2	36	208	1	0	4	1	R6	1	3	8	
7.8	2	69	98	1	0	1	1	R6	1	3	8	
7.8	2	32	140	2	0	3	1	R6	1	3	6	
9.5	2	69	98	1	0	1	1	R6	1	3	8	
10.3	2	32	140	2	0	3	1	R6	1	3	8	
10.8	2	32	140	2	0	3	1	R6	1	3	6	
12.6	2	81	0	1	0	4	4	R0	1	3	8	
16.9	2	81	0	1	0	4	4	R0	1	3	8	
17.3	2	88	40	3	2	4	4	R0	1	3	8	
18.2	2	85	60	3	2	4	4	R0	1	3	8	
18.7	2	37	119	1	0	4	4	S6	2	3	8	

Chainage(ft)	Type	Dip	Dip direction	Persistence	Termination	Aperture	Nature of filling	Strength of filling	Surface roughness	Surface shape	JRC	Note
C-Right												
19.4	2	86	270	1	0	4	4	S6	2	3	8	
19.7	2	88	23	1	0	4	4	R0	1	3	12	
20.3	2	55	356	1	0	5	1	R6	1	3	7	
20.7	2	87	350	3	2	6	1	R6	1	3	8	
23	2	87	350	3	2	6	1	R6	1	3	8	
26.5	2	90	231	1	0	2	1	R6	1	3	8	
27.5	2	90	231	1	0	2	1	R6	1	3	8	
27.7	2	34	250	1	0	5	4	R0	1	2	10	
28	2	90	231	1	0	2	1	R6	1	3	8	
28.9	2	90	231	1	0	2	1	R6	1	3	8	
29.3	2	34	250	1	0	5	4	R0	1	2	10	
29.5	2	90	231	1	0	2	1	R6	1	3	8	
29.6	2	39	91	1	0	4	4	R4	1	3	8	
30.5	2	90	231	1	0	2	1	R6	1	3	8	
30.6	2	53	238	1	0	4	4	R4	1	3	10	
30.7	2	50	110	1	0	5	4	R4	1	3	6	
31.1	2	39	91	1	0	4	4	R4	1	3	8	
31.6	2	39	91	1	0	4	4	R4	1	3	8	
32.5	2	53	238	1	0	4	4	R4	1	2	16	
32.6	2	39	91	1	0	4	4	R4	1	3	8	
33.9	2	23	247	1	0	7	1	R6	1	3	8	
35	2	48	343	1	0	4	4	R4	1	3	8	
36.9	2	36	97	1	0	4	4	R4	1	3	8	
37.3	2	36	97	1	0	4	4	R4	1	3	8	

Chainage(ft)	Type	Dip	Dip direction	Persistence	Termination	Aperture	Nature of filling	Strength of filling	Surface roughness	Surface shape	JRC	Note
C-Right												
37.5	2	36	97	1	0	4	4	R4	1	3	8	
38	2	77	356	3	2	5	1	R6	1	3	8	
38.5	2	77	356	3	2	5	1	R6	1	3	8	
38.7	2	48	343	1	0	4	4	R4	1	3	8	
40	2	77	356	3	2	5	1	R6	1	3	8	
42.5	2	77	356	3	2	5	1	R6	1	3	8	
42.7	2	61	89	2	0	1	1	R6	1	3	6	
42.7	2	61	97	3	2	4	4	R4	1	3	8	
43.1	2	83	60	3	2	1	1	R6	1	3	8	
43.8	2	88	78	2	0	1	1	R6	1	3	8	
44.7	2	39	98	3	2	4	4	R4	1	3	8	
45.7	2	80	55	2	0	2	4	R4	1	3	8	
46.5	2	80	55	2	0	2	4	R4	1	3	8	
49.3	2	60	169	1	0	5	4	R0	1	3	8	
50.2	8	86	122	1	0	4	4	R4	1	2	8	
51	2	34	114	1	0	4	1	R6	1	3	8	
51.5	2	34	114	1	0	4	1	R6	1	3	8	
51.8	2	80	0	2	0	3	4	R4	1	3	8	
52	2	54	84	1	0	2	4	R6	1	3	8	
52.7	2	80	0	1	0	3	4	R4	1	3	8	
53	2	42	236	3	2	1	1	R6	1	3	8	
53.7	2	80	0	1	0	3	4	R4	1	3	8	
53.7	2	54	84	1	0	2	4	R6	1	3	8	
54.6	2	54	84	1	0	2	4	R6	1	3	8	

Chainage(ft)	Type	Dip	Dip direction	Persistence	Termination	Aperture	Nature of filling	Strength of filling	Surface roughness	Surface shape	JRC	Note
C-Right												
54.8	2	86	261	1	0	2	4	R6	1	3	8	
55	2	80	0	1	0	3	4	R4	1	3	8	
55.4	2	54	84	1	0	2	4	R6	1	3	8	
56	2	90	211	3	2	4	4	R5	1	3	6	
57.2	2	90	211	3	2	4	4	R5	1	3	6	
58	2	86	230	2	0	4	1	R6	1	3	8	
58.3	2	86	230	2	0	4	1	R6	1	3	8	
58.9	2	56	110	2	0	4	4	R4	1	3	8	
59	2	87	268	1	0	4	1	R6	1	3	8	
59.3	2	87	268	1	0	4	1	R6	1	3	8	
59.3	2	56	110	2	0	4	4	R4	1	3	8	
59.6	2	56	110	2	0	4	4	R4	1	3	8	
60.9	2	56	110	2	0	4	4	R4	1	3	8	
60.9	2	87	250	1	0	1	1	R6	1	3	6	
61.5	2	87	250	1	0	1	1	R6	1	3	6	
61.7	2	14	355	3	2	2	4	R4	1	3	8	
63.8	2	42	113	2	0	1	1	R6	1	3	8	
64.4	2	14	355	3	2	2	4	R4	1	3	8	
65.2	2	35	203	1	0	1	1	R6	1	3	7	
66.4	2	43	98	1	0	1	1	R6	1	3	8	
66.5	2	42	113	2	0	1	1	R6	1	3	8	
67.8	2	72	295	1	0	1	1	R6	1	3	10	
68.2	2	48	219	2	0	1	1	R6	1	3	8	
68.2	2	60	300	2	0	1	1	R6	1	3	8	

Chainage(ft)	Type	Dip	Dip direction	Persistence	Termination	Aperture	Nature of filling	Strength of filling	Surface roughness	Surface shape	JRC	Note
C-Right												
68.3	2	25	226	3	2	4	4	R4	1	3	8	
69.6	2	60	300	2	0	1	1	R6	1	3	8	
70.1	2	42	113	2	0	1	1	R6	1	3	8	
70.7	2	78	208	2	0	4	4	R0	1	3	8	
71.8	2	60	300	2	0	1	1	R6	1	3	8	
72.6	2	60	300	2	0	1	1	R6	1	3	8	
72.6	2	79	270	1	0	1	1	R6	1	3	8	
73.7	2	60	300	2	0	1	1	R6	1	3	8	
74.2	2	44	84	2	0	1	1	R6	1	3	8	
74.3	2	36	226	3	2	3	4	R4	1	3	8	
74.4	2	60	300	2	0	1	1	R6	1	3	8	
74.5	2	41	236	1	0	1	1	R6	1	3	8	
74.7	2	72	7	1	0	1	1	R6	1	3	8	
74.8	2	60	300	2	0	1	1	R6	1	3	8	
75	2	60	300	2	0	1	1	R6	1	3	8	
75.1	2	44	84	2	0	1	1	R6	1	3	8	
75.3	2	60	300	2	0	1	1	R6	1	3	8	
76.9	2	44	84	2	0	1	1	R6	1	3	8	
77.2	2	84	254	3	2	1	1	R6	1	3	8	
77.4	2	47	267	2	0	1	1	R6	1	3	8	
77.6	2	56	135	1	0	1	1	R6	1	3	8	
77.9	2	54	8	1	0	1	1	R6	1	3	8	
78.7	2	54	8	1	0	1	1	R6	1	3	8	
79.4	2	87	255	1	0	1	1	R6	1	3	8	

Chainage(ft)	Type	Dip	Dip direction	Persistence	Termination	Aperture	Nature of filling	Strength of filling	Surface roughness	Surface shape	JRC	Note
C-Right												
80.2	2	71	261	1	0	2	4	R6	1	3	8	
80.2	2	81	222	2	0	4	4	R4	1	3	8	
81	2	81	222	2	0	4	4	R4	1	3	8	
81.8	2	81	222	2	0	4	4	R4	1	3	8	
85.3	2	81	222	2	0	4	4	R4	1	3	8	
85.8	2	30	68	1	0	4	4	R4	1	3	16	
85.8	2	62	60	1	0	4	4	R4	1	3	14	
86	2	81	222	2	0	4	4	R4	1	3	8	
87.5	2	62	60	1	0	4	4	R4	1	3	14	
88.7	2	62	60	1	0	4	4	R4	1	3	14	
89.4	2	62	60	1	0	4	4	R4	1	3	14	
90	2	62	60	1	0	4	4	R4	1	3	14	
90.2	2	42	116	1	0	1	1	R6	1	3	14	
91.3	2	62	60	1	0	4	4	R4	1	3	14	
91.6	2	82	20	1	0	6	4	R4	1	3	10	
91.9	2	82	20	1	0	6	4	R4	1	3	10	
92.8	2	79	43	2	0	5	4	R4	1	3	8	
93.3	2	79	43	2	0	5	4	R4	1	3	8	
93.6	2	79	43	2	0	5	4	R4	1	3	8	
94	2	65	324	2	0	4	4/6	R4	1	3	10	
94.6	8	65	324	2	0	4	4/6	R4	1	3	10	
94.7	2	65	216	1	0	1	1	R6	1	3	10	
94.8	2	79	43	2	0	5	4	R4	1	3	8	
95.6	2	65	324	2	0	4	4/6	R4	1	3	10	

Chainage(ft)	Type	Dip	Dip direction	Persistence	Termination	Aperture	Nature of filling	Strength of filling	Surface roughness	Surface shape	JRC	Note
C-Right												
96.2	2	65	324	2	0	4	4/6	R4	1	3	10	
97.2	2	15	235	2	0	4	4	R4	1	3	8	
97.6	2	65	324	2	0	4	4/6	R4	1	3	10	
100	2	15	235	2	0	4	4	R4	1	3	8	
100.4	2	55	21	2	0	1	1	R6	1	3	10	
101.6	2	78	100	1	0	4	1	R6	1	3	10	
101.8	2	55	21	2	0	1	1	R6	1	3	10	
102.7	2	58	115	1	0	1	1	R6	1	3	8	
103.4	2	55	21	2	0	1	1	R6	1	3	10	
104.3	2	58	115	1	0	1	1	R6	1	3	8	
105.3	2	58	115	1	0	1	1	R6	1	3	8	
106.4	2	49	296	1	0	4	4	R4	1	3	6	
106.8	2	79	214	1	0	1	1	R6	1	3	8	
107.3	2	49	296	1	0	4	4	R4	1	3	6	
108.1	2	61	118	1	0	1	1	R6	1	3	8	
109	2	58	358	3	2	6	6	R4	1	3	10	
109.4	2	47	3	1	0	4	4	R0	1	3	12	
109.9	2	86	45	1	0	2	1	R6	1	3	8	
110.4	2	47	3	1	0	4	4	R0	1	3	12	
111.1	2	41	172	1	0	5	1	R0	1	3	8	
111.7	2	89	240	1	0	4	4	R4	1	3	16	
112	2	71	284	1	0	4	4	R0	1	3	12	
112	2	89	240	1	0	4	4	R4	1	3	16	
112.2	2	89	240	1	0	4	4	R4	1	3	16	

Chainage(ft)	Type	Dip	Dip direction	Persistence	Termination	Aperture	Nature of filling	Strength of filling	Surface roughness	Surface shape	JRC	Note
C-Right												
112.8	2	89	240	1	0	4	4	R4	1	3	16	
113.6	2	80	68	1	0	4	6	R6	1	3	6	
114.2	2	64	28	1	0	1	1	R4	1	3	8	
114.5	2	64	28	1	0	4	6	R4	1	3	8	
114.7	2	73	70	1	0	1	1	R6	1	3	8	
115.5	2	74	214	1	0	5	1	R6	1	3	8	
116.1	2	82	80	1	0	4	4	R6	1	3	8	
116.7	2	83	205	1	0	4	4	R4	1	3	6	
116.9	2	83	220	3	2	4	1	R6	1	3	8	
117.7	2	49	180	3	2	5	1	R6	1	3	10	
117.9	2	85	54	1	0	6	6	R5	1	3	6	
118.4	2	83	205	1	0	4	4	R4	1	3	6	
118.7	2	83	205	1	0	4	4	R4	1	3	6	
118.8	2	49	180	3	2	5	1	R6	1	3	10	
118.8	2	48	15	1	0	4	1	R6	1	3	8	
119	2	49	180	3	2	5	1	R6	1	3	10	
119.7	2	48	15	1	0	4	1	R6	1	3	8	
119.7	2	86	61	3	2	4	4	R4	1	3	10	
120	2	48	15	1	0	4	1	R6	1	3	8	
120.3	2	85	14	1	0	4	4	R4	1	3	10	
120.4	2	48	15	1	0	4	1	R6	1	3	8	
121.2	2	48	15	1	0	4	1	R6	1	3	8	
121.4	2	33	21	3	2	4	4	R0	1	3	6	
122.7	2	33	21	1	0	4	4	R0	1	3	6	

Chainage(ft)	Type	Dip	Dip direction	Persistence	Termination	Aperture	Nature of filling	Strength of filling	Surface roughness	Surface shape	JRC	Note
C-Right												
124.2	2	32	78	1	0	4	4	R0	1	3	8	
124.2	2	79	230	1	0	4	4	R4	1	3	7	
125.4	2	86	80	1	0	5	4	R0	1	3	6	
125.6	2	81	272	1	0	5	4	R0	1	3	8	
126.7	2	56	36	2	0	3	4	R0	1	3	8	
126.9	2	56	36	2	0	3	4	R0	1	3	8	
127.5	2	56	36	2	0	3	4	R0	1	3	8	
128.4	2	48	25	1	0	5	4	R4	1	3	8	
129	2	72	232	3	2	1	6	R4	1	3	6	
129.5	2	51	35	3	2	1	4	R4	1	3	8	
129.7	2	57	139	1	0	5	4	R4	1	3	8	
129.8	2	40	84	1	0	4	1	R6	1	3	8	
129.9	2	57	139	1	0	5	4	R4	1	3	8	
130.3	2	77	250	3	2	4	4	S6	1	3	6	
130.3	2	54	24	1	0	4	1	R6	1	3	10	
130.4	2	40	84	1	0	4	1	R6	1	3	8	
131.4	2	86	85	1	0	4	4	R4	1	3	8	
133.7	2	53	117	3	2	4	6	R5	1	3	10	
133.8	2	53	117	3	2	4	6	R5	1	3	10	
134.3	2	82	67	1	0	4	6	R5	1	3	8	
135	2	40	216	2	0	5	4	R0	1	3	6	
135.1	2	82	67	1	0	4	6	R5	1	3	8	
135.7	2	53	117	3	2	4	6	R5	1	3	10	
135.9	2	40	216	2	0	5	4	R0	1	3	6	

Chainage(ft)	Type	Dip	Dip direction	Persistence	Termination	Aperture	Nature of filling	Strength of filling	Surface roughness	Surface shape	JRC	Note
C-Right												
136.6	2	75	323	3	2	1	1	R6	1	3	6	
136.9	2	75	323	3	2	1	1	R6	1	3	6	
136.9	2	84	70	2	0	4	4	R4	1	3	10	
137.6	2	61	118	3	2	4	4	R0	1	3	8	
137.8	2	61	118	3	2	4	4	R0	1	3	8	
138.7	2	81	245	3	2	4	6	R5	1	3	8	
136.6	2	75	323	3	2	1	1	R6	1	3	6	
136.9	2	75	323	3	2	1	1	R6	1	3	6	
136.9	2	84	70	2	0	4	4	R4	1	3	10	
137.6	2	61	118	3	2	4	4	R0	1	3	8	
137.8	2	61	118	3	2	4	4	R0	1	3	8	
138.7	2	81	245	3	2	4	6	R5	1	3	8	
138.9	2	61	118	3	2	4	4	R0	1	3	8	
140.2	2	84	234	1	0	1	1	R6	1	3	12	
140.3	2	84	298	3	0	1	1	R6	1	3	10	
141.8	2	61	118	3	2	4	4	R0	1	3	8	
142	2	30	135	3	0	4	4	R0	1	3	8	
142	2	63	276	3	2	4	4	R0	1	3	8	
143.1	2	90	66	3	2	4	4	R0	1	3	8	
143.2	2	68	294	3	2	4	1	R6	1	3	8	
143.2	2	35	272	3	2	1	1	R6	1	3	10	
143.8	2	68	294	3	2	5	1	R6	1	3	8	
143.9	2	56	57	3	0	4	6	R4	1	3	10	
144	2	68	294	3	2	4	1	R6	1	3	8	

Chainage(ft)	Type	Dip	Dip direction	Persistence	Termination	Aperture	Nature of filling	Strength of filling	Surface roughness	Surface shape	JRC	Note
C-Right												
144	2	74	206	1	0	4	1	R6	1	3	8	
144	2	35	272	3	2	1	1	R6	1	3	10	
144.4	2	68	294	3	2	4	1	R6	1	3	8	
144.6	2	56	57	3	0	4	6	R4	1	3	10	
144.8	2	35	272	3	2	1	1	R6	1	3	10	
145	2	35	100	3	2	4	4	R0	1	3	8	
145.2	2	56	57	3	0	4	6	R4	1	3	10	
146.2	2	35	100	3	2	4	4	R0	1	3	8	
146.4	2	68	294	3	2	5	1	R6	1	3	8	
146.8	2	35	100	3	2	4	4	R0	1	3	8	
147.1	2	35	272	3	2	1	1	R6	1	3	10	
147.2	2	52	120	1	0	6	4	S6	1	3	8	
147.4	2	68	294	3	2	5	1	R6	1	3	8	
147.7	2	40	317	3	2	1	1	R6	1	3	8	
148.2	2	40	317	3	2	1	1	R6	1	3	8	
148.4	2	40	317	3	2	1	1	R6	1	3	8	
148.4	2	35	272	3	2	1	1	R6	1	3	10	
148.7	2	40	317	3	2	1	1	R6	1	3	8	
149.6	2	35	272	3	2	1	1	R6	1	3	10	
149.9	2	40	317	3	2	1	1	R6	1	3	8	
151.1	2	35	272	1	0	4	1	R6	1	3	10	
151.4	2	84	218	1	0	1	1	R6	1	3	8	
152	2	68	115	3	2	4	1	R6	1	3	8	

Chainage(ft)	Type	Dip	Dip Direction	Persistence	Termination	Aperture	Nature of filling	Strength of filling	Surface roughness	Surface shape	JRC	Note
C-Right Spur												
0.3	2	69	225	1	0	5	4	R0	1	3	10	
0.5	2	75	318	3	2	8	4	R0	1	3	14	water
1.1	2	50	120	1	0	5	4	R0	1	3	8	water at 1, 2.5, 3.5, 5, 6, 8, 10
1.7	2	55	116	1	0	4	4	R0	1	3	8	
2.4	2	71	6	3	2	4	1	R4	1	3	10	
2.9	2	71	20	3	2	4	4	R0	1	3	8	
3.3	2	59	131	2	0	6	4	R6	1	3	8	
3.5	2	43	150	1	0	4	4	R0	1	3	6	
3.5	2	72	220	1	0	4	4	R4	1	3	10	
4.3	2	58	226	3	2	4	4	R4	1	3	8	
4.4	2	72	220	1	0	4	4	R4	1	3	10	
4.8	2	79	331	1	0	4	4	R4	1	3	10	
4.9	2	86	228	1	0	4	4	R4	1	3	6	
5.2	2	86	228	1	0	4	4	R4	1	3	6	
6.3	2	55	138	3	2	4	1	R6	1	3	6	
7.5	2	86	228	1	0	4	4	R4	1	3	6	
7.8	2	50	351	3	2	4	1	R6	1	3	8	
8.6	2	62	127	1	0	4	4	R4	1	3	6	
8.8	2	86	228	1	0	4	4	R4	1	3	6	
9	2	62	127	1	0	4	4	R4	1	3	6	
9.2	2	34	137	3	2	4	4	R4	1	3	10	
9.6	2	42	123	1	0	4	4	R4	1	3	8	
10.4	2	42	128	1	0	4	4	R4	1	3	8	

Chainage(ft)	Type	Dip	Dip Direction	Persistence	Termination	Aperture	Nature of filling	Strength of filling	Surface roughness	Surface shape	JRC	Note
C-Right Spur												
10.5	2	86	228	1	0	4	4	R4	1	3	6	
10.7	2	54	27	3	2	4	4	R4	1	3	10	wet
11	2	61	235	1	0	4	4	R4	1	3	8	
11.2	2	34	137	3	2	4	4	R4	1	3	8	
11.7	2	52	6	3	2	4	4	R4	1	3	8	
12.4	2	44	173	1	0	4	4	R4	1	3	8	
12.5	2	52	6	3	2	4	4	R4	1	3	8	
13.5	2	52	6	3	2	4	4	R4	1	3	8	
14	2	52	6	3	2	4	4	R4	1	3	8	
14	2	72	130	3	2	5	4	R4	1	3	12	
15.1	2	52	6	3	2	4	4	R4	1	3	8	
15.2	2	70	46	3	2	2	4	R4	1	3	12	
15.4	2	52	6	3	2	4	4	R4	1	3	8	
15.6	2	55	135	3	2	4	4	R4	1	3	8	
17.6	2	55	135	3	2	4	4	R4	1	3	8	
17.9	2	15	10	3	2	4	4	R4	1	3	8	
18	2	55	135	3	2	4	4	R4	1	3	8	
18.2	2	15	10	1	0	4	4	R4	1	3	8	
20.5	2	30	8	3	2	5	1	R6	1	3	6	
21.6	2	46	26	2	0	4	4	R4	1	3	10	
21.9	2	15	10	3	2	4	4	R4	1	3	8	
22	2	15	10	3	2	4	4	R4	1	3	8	
23.2	2	33	133	3	2	6	6	R5	1	3	10	
24.4	2	33	133	3	2	6	6	R5	1	3	10	

Chainage(ft)	Type	Dip	Dip Direction	Persistence	Termination	Aperture	Nature of filling	Strength of filling	Surface roughness	Surface shape	JRC	Note
C-Right Spur												
24.5	2	15	10	3	2	4	4	R4	1	3	8	
24.5	2	33	133	3	2	6	6	R5	1	3	10	
24.6	2	62	122	2	0	5	1	R6	1	3	8	
26	2	42	190	3	2	4	1	R6	1	3	12	
29.6	2	72	330	3	2	4	1	R6	1	3	8	
30	2	72	330	3	2	4	1	R6	1	3	8	
30.3	2	72	330	3	2	4	1	R6	1	3	8	
30.7	2	90	342	1	0	4	4	R4	1	3	8	
30.7	2	72	330	3	2	4	1	R6	1	3	8	gneiss
31.5	2	72	330	3	2	4	1	R6	1	3	8	
31.7	2	90	342	1	2	4	4	R4	1	3	8	
32.1	2	39	351	1	0	4	4	R4	1	3	6	
34.4	2	56	22	3	2	4	4	R4	1	3	8	
35.1	2	56	22	3	2	4	4	R4	1	3	8	
39.3	2	50	25	2	0	1	1	R6	1	3	8	
39.4	2	50	25	2	0	1	1	R6	1	3	8	
39.8	2	50	25	2	0	1	1	R6	1	3	8	
42.8	2	42	208	3	2	4	1	R4	1	3	8	
43.4	2	84	7	3	2	1	1	R6	1	3	6	
43.5	2	74	147	3	2	4	4	R4	1	3	8	
44.2	2	90	56	2	0	1	1	R6	1	3	8	
45	2	74	147	3	2	4	4	R4	1	3	8	
45.4	2	74	147	3	2	4	4	R4	1	3	8	
45.8	2	90	56	2	0	1	1	R6	1	3	8	

Chainage(ft)	Type	Dip	Dip Direction	Persistence	Termination	Aperture	Nature of filling	Strength of filling	Surface roughness	Surface shape	JRC	Note
C-Right Spur												
46	2	57	141	1	0	3	4	R4	1	3	8	
46.1	2	81	53	1	0	4	4	R4	1	3	8	
46.3	2	90	56	2	0	1	1	R6	1	3	8	
46.9	2	57	141	1	0	3	4	R4	1	3	8	
48.4	2	49	222	3	2	2	4	R4	1	3	8	
49.1	2	63	26	3	0	4	4	R4	1	3	8	
51.3	2	78	226	3	2	4	4	R4	1	3	9	55 smithsonite
52.2	2	78	226	3	2	4	4	R4	1	3	8	
52.3	2	78	226	3	2	4	4	R4	1	3	8	
54.3	2	51	244	1	0	2	1	R6	1	3	14	
54.7	2	82	54	2	0	4	4	R4	1	3	10	
55	2	90	154	3	2	4	4	R6	1	3	12	
55.4	7	51	244	1	0	2	1	R6	1	3	14	
55.6	2	90	154	3	2	4	4	R6	1	3	12	
55.7	2	72	123	3	2	1	1	R6	1	3	8	
56.1	2	90	41	2	0	3	4	R6	1	3	16	
56.1	2	90	154	3	2	4	4	R6	1	3	12	
56.7	2	72	123	3	2	1	1	R6	1	3	8	
57.7	2	4	43	1	0	4	4	R4	1	3	8	
57.8	2	52	140	3	2	5	1	R6	1	3	10	
58.7	2	72	123	3	2	1	1	R6	1	3	8	
59	2	72	123	3	2	1	1	R6	1	3	8	
60.9	2	40	167	3	2	4	4	R4	1	3	8	
61.2	2	50	329	3	2	4	4	R4	1	3	6	

Chainage(ft)	Type	Dip	Dip Direction	Persistence	Termination	Aperture	Nature of filling	Strength of filling	Surface roughness	Surface shape	JRC	Note
C-Right Spur												
61.3	2	55	135	3	2	4	4	R6	1	3	8	
62.1	2	66	351	1	0	1	1	R6	1	3	8	
62.2	2	55	135	3	2	4	4	R6	1	3	8	
62.4	2	86	80	1	0	1	1	R6	1	3	8	
62.5	2	66	351	1	0	1	1	R6	1	3	8	
62.6	2	66	351	1	0	1	1	R6	1	3	8	
62.8	2	86	80	1	0	1	1	R6	1	3	8	
62.9	2	66	351	1	0	1	1	R6	1	3	8	
63	2	86	80	1	0	1	1	R6	1	3	8	
63.9	2	86	80	1	0	1	1	R6	1	3	8	
64.4	2	86	80	1	0	1	1	R6	1	3	8	
64.9	2	21	216	3	2	4	4	R6	1	3	7	
65.4	2	80	215	3	2	2	4	R6	1	3	6	
65.7	2	86	254	3	2	4	4	R6	1	3	6	
65.8	2	86	80	1	0	1	1	R6	1	3	8	
65.9	2	69	9	3	2	4	1	R6	1	3	12	
66.5	2	46	18	3	2	4	6	R6	1	3	10	
66.5	2	49	144	3	2	4	4	R4	1	3	8	
66.8	2	46	18	3	2	4	6	R6	1	3	10	
68.3	2	60	335	3	2	5	4	R4	1	3	10	
68.6	2	49	144	3	2	4	4	R4	1	3	8	
68.8	2	60	335	3	2	5	4	R4	1	3	10	FOLIATION IN THIS ORIENTATION 68-70

Chainage(ft)	Type	Dip	Dip Direction	Persistence	Termination	Aperture	Nature of filling	Strength of filling	Surface roughness	Surface shape	JRC	Note
C-Right Spur												
69.3	2	49	144	3	2	4	4	R4	1	3	8	
69.7	2	60	335	3	2	5	4	R4	1	3	10	
69.8	2	49	144	3	2	4	4	R4	1	3	8	
70.3	2	60	335	3	2	5	4	R4	1	3	10	
76.9	2	62	313	3	2	5	1	R6	1	3	10	74-76 FOL0
77.6	2	41	158	3	2	4	1	R6	1	3	12	72-77 WEATHERE0 ZONE, HEAVILY METAMORPHOSE0, PLAG. AN0 BIOT.
78.2	2	61	326	3	2	4	1	R6	1	3	8	
78.6	2	90	196	1	0	4	4	R4	1	3	12	
78.9	2	61	326	3	2	4	1	R6	1	3	8	
79.7	2	47	200	3	2	4	4	R4	1	3	12	
79.8	2	61	326	3	2	4	1	R6	1	3	8	
80.4	2	61	30	3	2	4	1	R6	1	3	8	
81.2	2	58	219	3	2	4	4	R4	1	3	6	
82	2	55	355	3	2	4	1	R6	1	3	10	
84	2	78	315	3	2	6	4	R4	1	3	8	WATER AND MINERALIZED VEIN (CONTAINS PYRITE)
84.1	2	42	212	3	2	4	4	R4	1	3	8	
85	2	42	212	3	2	4	4	R4	1	3	8	
85	2	78	315	3	2	6	4	R4	1	3	8	
85.3	2	42	212	3	2	4	4	R4	1	3	8	
85.6	2	42	212	3	2	4	4	R4	1	3	8	
85.8	2	78	315	3	2	6	4	R4	1	3	8	
86.9	2	42	212	3	2	4	4	R4	1	3	8	
87.2	2	78	315	3	2	6	4	R4	1	3	8	

Chainage(ft)	Type	Dip	Dip Direction	Persistence	Termination	Aperture	Nature of filling	Strength of filling	Surface roughness	Surface shape	JRC	Note
C-Right Spur												
87.6	2	78	315	3	2	6	4	R4	1	3	8	
87.8	2	42	212	3	2	4	4	R4	1	3	8	
88.5	2	42	212	3	2	4	4	R4	1	3	8	
89	2	78	315	3	2	6	4	R4	1	3	8	
90	2	78	315	3	2	6	4	R4	1	3	8	
90.4	2	78	315	3	2	6	4	R4	1	3	8	
90.6	2	58	231	1	0	1	1	R6	1	3	8	
92.4	2	75	38	1	0	4	4	R6	1	3	8	
92.8	2	87	303	3	2	1	1	R6	1	3	8	94-96 FOLIATION
94.1	2	87	303	3	2	1	1	R6	1	3	8	
95.9	2	62	213	2	0	4	4	R4	1	3	12	
96.9	2	69	44	3	2	1	1	R6	1	3	8	93.5-94 BIOTITE
97.2	2	69	44	3	2	1	1	R6	1	3	8	
97.3	2	69	44	3	2	1	1	R6	1	3	8	
97.9	2	61	223	1	0	1	1	R6	1	3	9	
98.9	2	61	223	1	0	1	1	R6	1	3	9	
99.7	2	85	32	3	2	4	1	R6	1	3	8	
100	2	55	30	1	0	3	4	R4	1	3	10	
101.4	2	55	30	1	0	3	4	R4	1	3	10	
102.4	2	30	161	3	2	4	4	R4	1	3	10	
102.9	2	50	91	2	0	4	4	R4	1	3	6	
103.3	2	64	310	3	2	1	1	R6	1	3	6	

Chainage(ft)	Type	Dip	Dip Direction	Persistence	Termination	Aperture	Nature of filling	Strength of filling	Surface roughness	Surface shape	JRC	Note
C-Right Spur												
104.1	2	90	45	3	2	4	4	R4	1	3	7	
104.8	2	45	176	3	2	4	4	R4	1	3	8	
104.8	2	46	180	3	2	1	1	R6	1	3	6	
105.2	2	56	11	1	0	4	4	R4	1	3	8	
106.1	2	52	335	1	0	1	1	R6	1	3	8	
106.7	2	61	120	2	0	3	4	R6	1	3	6	
106.9	2	62	354	1	0	2	4	R6	1	3	8	
107.3	2	62	354	1	0	2	4	R6	1	3	8	
108.2	2	46	229	1	0	2	4	R6	1	3	14	
109.3	2	18	10	1	0	4	1	R6	1	3	16	
111	2	35	75	3	2	5	4	R4	1	3	14	
111.2	2	18	10	1	0	4	1	R6	1	3	16	
111.6	2	66	351	3	2	4	4	R4	1	3	7	
111.8	2	66	351	3	2	4	4	R4	1	3	7	
112	2	66	351	3	2	4	4	R4	1	3	7	
112.2	2	50	236	3	2	4	4	R4	1	3	8	
112.4	2	66	351	3	2	4	4	R4	1	3	7	
112.9	2	85	128	3	2	3	1	R6	1	3	14	
114.4	2	69	55	3	2	5	4	R4	1	3	10	
115.2	2	69	55	3	2	5	4	R4	1	3	10	
115.2	2	38	147	1	0	1	1	R6	1	3	8	
116.6	2	69	55	3	2	5	4	R4	1	3	10	
116.9	8	68	335	3	2	5	4	R4	1	3	6	
117.1	2	69	55	3	2	5	4	R4	1	3	10	

Chainage(ft)	Type	0ip	0ip 0irection	Persistence	Termination	Aperture	Nature of filling	Strength of filling	Surface roughness	Surface shape	JRC	Note
C-Right Spur												
117.2	8	68	335	3	2	5	4	R4	1	3	6	
117.5	2	69	55	3	2	5	4	R4	1	3	10	
117.8	8	68	335	3	2	5	4	R4	1	3	6	
118.4	8	68	335	3	2	5	4	R4	1	3	6	18.5 PYRITE
118.5	2	52	212	3	2	5	4	R4	1	2	14	
119	8	68	335	3	2	5	4	R4	1	3	6	
119.6	8	68	335	3	2	5	4	R4	1	3	6	
119.7	8	68	335	3	2	5	4	R4	1	3	6	
119.8	8	68	335	3	2	5	4	R4	1	3	6	
120	8	68	335	3	2	5	4	R4	1	3	6	
120.4	8	68	335	3	2	5	4	R4	1	3	6	
120.6	2	26	165	1	0	1	1	R6	1	3	8	
121.2	8	68	335	3	2	5	4	R4	1	3	6	
123.7	8	68	335	3	2	5	4	R4	1	3	6	22.5-23 8cm FRACTURE
124.2	8	68	335	3	2	5	4	R4	1	3	6	
124.6	2	55	343	3	2	4	4	R4	1	3	8	WHITE COVERING AT 25
124.9	2	60	200	3	2	4	4	R4	1	3	8	
125.4	8	68	335	3	2	5	4	R4	1	3	6	
125.4	2	55	343	3	2	4	4	R4	1	3	8	
126.4	2	83	212	3	2	4	4	R4	1	3	8	
126.5	2	68	335	3	2	5	4	R4	1	3	6	
127.4	2	68	335	3	2	5	4	R4	1	3	6	
127.5	2	62	99	3	2	5	4	R4	1	3	14	
127.6	2	83	212	3	2	4	4	R4	1	3	8	

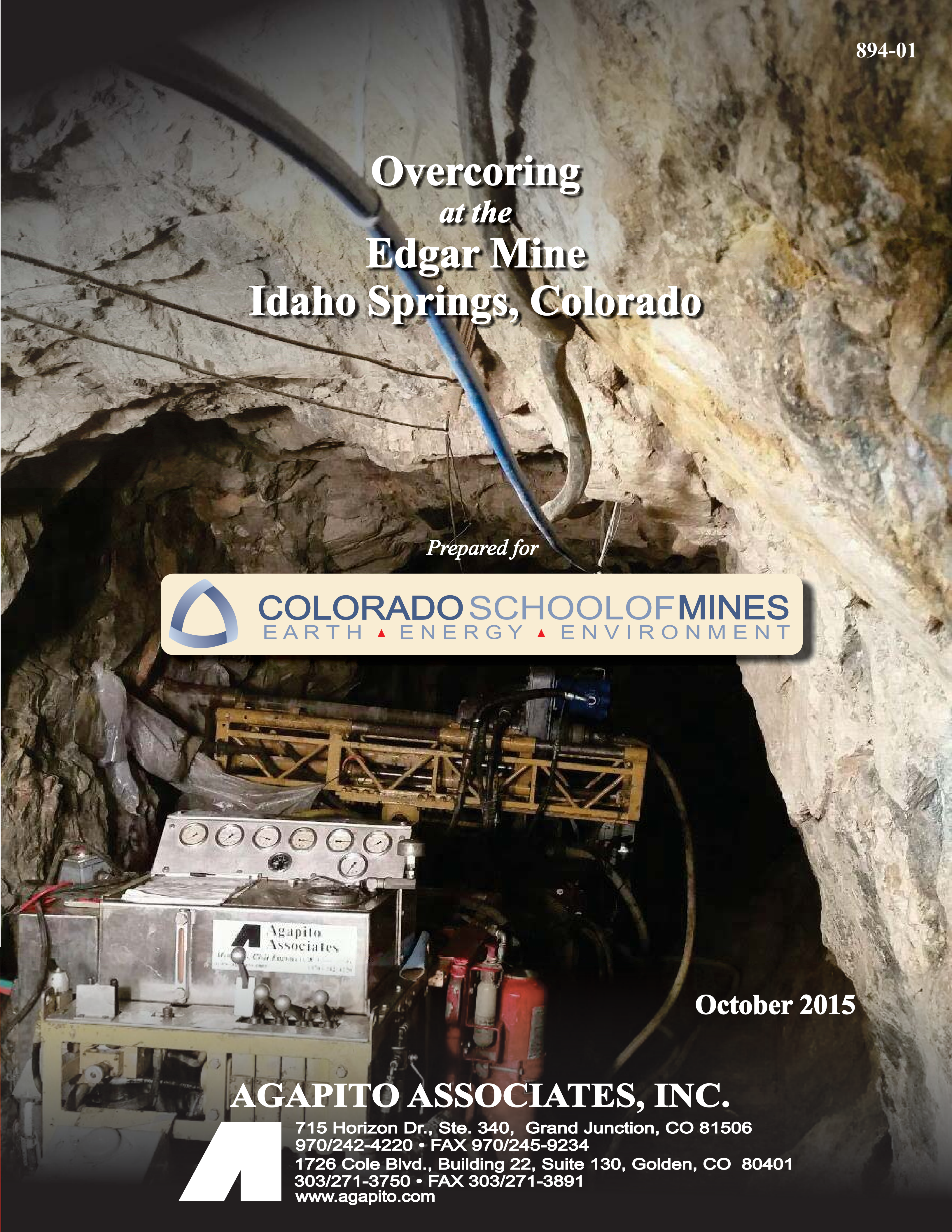
Chainage(ft)	Type	Dip	Dip Direction	Persistence	Termination	Aperture	Nature of filling	Strength of filling	Surface roughness	Surface shape	JRC	Note
C-Right Spur												
127.8	2	68	335	3	2	5	4	R4	1	3	6	
128.5	2	83	212	3	2	4	4	R4	1	3	8	
128.8	2	87	238	2	0	4	4	R4	1	3	8	
131.5	2	53	129	3	2	4	4	R4	1	3	8	30-33 PLASTER ABOVE
134.7	2	55	94	3	2	4	1	R6	1	3	8	36 SULFUR
135.1	2	53	129	3	2	4	4	R4	1	3	8	37 CARBONATE
136.6	2	82	210	1	0	4	4	R4	1	3	8	
137	2	82	210	1	0	4	4	R4	1	3	8	35-37.5 BLUE MINERAL, SULFUR VEIN
137.6	2	77	49	1	0	1	1	R6	1	3	8	
138	2	77	49	1	0	1	1	R6	1	3	8	
138.3	2	77	49	1	0	1	1	R6	1	3	8	
139.7	2	90	15	3	2	4	4	R4	1	3	9	
140.2	2	46	81	3	2	4	1	R6	1	3	8	
140.3	2	51	54	3	2	4	4	R4	1	3	8	
140.9	2	54	193	2	0	4	4	R4	1	3	12	
141	2	51	54	3	2	4	4	R4	1	3	8	
141.4	2	51	54	3	2	4	4	R4	1	3	8	
141.7	2	54	193	2	0	4	4	R4	1	3	12	
141.9	2	51	54	3	2	4	4	R4	1	3	8	
142.2	2	54	193	2	0	4	4	R4	1	3	12	
142.9	2	54	193	2	0	4	4	R4	1	3	12	
142.9	2	54	193	2	0	4	4	R4	1	3	12	
144.7	2	51	54	3	2	4	4	R4	1	3	8	

Chainage(ft)	Type	0ip	0ip 0irection	Persistence	Termination	Aperture	Nature of filling	Strength of filling	Surface roughness	Surface shape	JRC	Note
C-Right Spur												
144.9	2	76	208	1	0	4	4	R4	1	3	10	
146.2	2	68	220	3	2	5	4	R4	1	3	8	FOLIATION 42-49
146.3	2	52	40	1	0	4	4	R4	1	3	14	
147.1	2	58	50	1	0	4	1	R6	1	3	8	
147.6	2	58	50	1	0	4	1	R6	1	3	8	MIGMATITE 46-48
149.4	2	48	44	2	0	4	4	R4	1	3	9	
150.1	2	37	210	2	0	4	4	R4	1	3	12	
151.4	2	37	210	2	0	4	4	R4	1	3	12	
152.4	2	78	210	3	2	5	1	R6	1	3	12	
153.1	2	78	210	3	2	5	1	R6	1	3	12	
154.7	2	77	215	3	2	4	1	R6	1	3	10	
155.8	2	61	245	1	0	4	1	R6	1	3	10	
156.7	2	64	0	3	2	7	4	R5	1	3	10	
157.5	2	64	0	3	2	6	4	R5	1	3	10	
157.5	2	58	222	1	0	2	1	R6	1	3	8	
158.2	2	64	0	3	2	6	4	R5	1	3	10	
158.2	2	58	222	1	0	2	1	R6	1	3	8	ABOVE 59-60 CLAYEY SEAMS 2 cm
158.8	2	64	0	3	2	5	4	R5	1	3	10	

Appendix C: Agapito Drilling Report

The drilling report from Agapito Associates, Inc. is included below.

894-01



Overcoring *at the* Edgar Mine Idaho Springs, Colorado

Prepared for

COLORADO SCHOOL OF MINES
EARTH ▲ ENERGY ▲ ENVIRONMENT

October 2015

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IN SITU STRESS MEASUREMENT AND CORING AT THE EDGAR EXPERIMENTAL MINE—IDAHO SPRINGS, CO

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1.0 INTRODUCTION

Agapito Associates, Inc. (AAI) was commissioned by the Colorado School of Mines (CSM) to conduct coring work and measure the *in situ* stress state on behalf of Sandia National Labs (Sandia) at the Edgar Experimental Mine located in Idaho Springs, Colorado (Figure 1). The scope of work is described in AAI's (2015) proposals for CSM dated June 5. Commonwealth Scientific and Industrial Research Organization (CSIRO)'s hollow inclusion stress cells (HI cells) strain measurement method was used in conjunction with overcoring techniques to measure *in situ* stresses.

AAI conducted the coring and stress measurement campaign between the dates of July 13 and July 28, 2015. Work at the mine was completed by two AAI personnel: Senior Rock Mechanics Technician Katoka Case and Assistant Rock Mechanics Technician Taylor Case. Dr. Steve Bauer, Sandia, Dr. Chad Augustine, National Renewable Energy Laboratory (NREL), and Dr. Masami Nakagawa (CSM) were the contacts for the project while AAI personnel were on site at the mine. AAI's shifts averaged approximately 12 hours, including travel time to and from the mine.

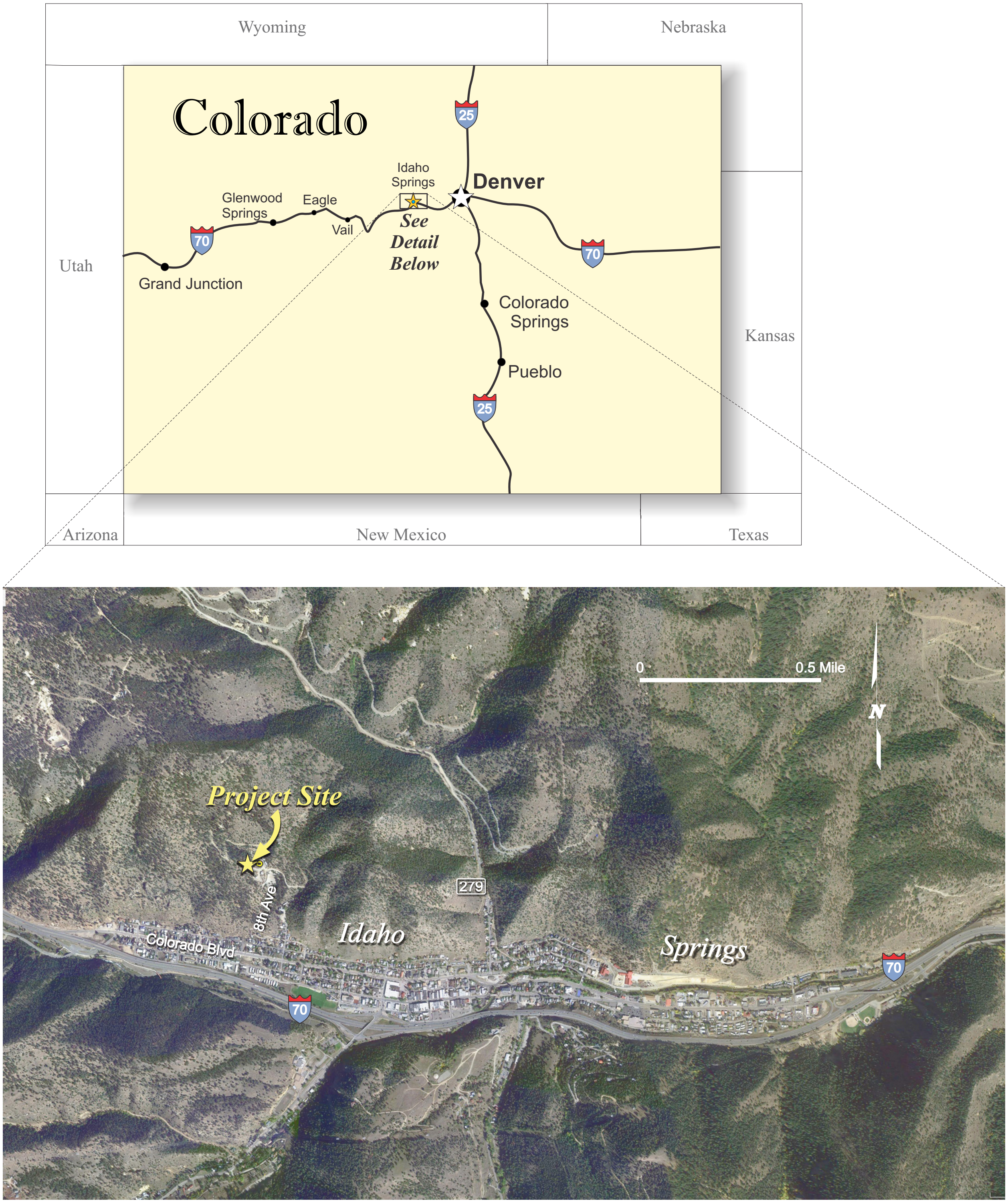
AAI's SD-1500 electric/hydraulic modular drill rig was specially configured on flat cars supplied by CSM for the coring and the overcoring work. Because there was no mine dewatering line, drilling water was recirculated during drilling and cuttings were settled out and disposed of. A combination of Series 7 and Series 14 HQ core bits were used during coring activities and a 6-inch, thin kerf, diamond-impregnated bit was used for overcoring. For more details, see the drill reports which describe daily activities, included as Appendix A.

Both coring and overcoring work at CSM was undertaken in the C-Right Drift near the C-Right Spur. Both locations and orientations were specified by CSM. HQ corehole (2.50-inch-diameter core and 3.875-inch-diameter hole) C-R-Center was drilled at an angle of approximately 2.0 degrees (°) (up) from horizontal at an azimuth of 135° to a total depth of 93 ft, and the overcoring hole CR1-6 was drilled at an angle of approximately 1.0° (up) from horizontal at an azimuth of 140° (Figure 2).

The HQ core was boxed and left on site at the mine and the overcoring core was sectioned at AAI's Grand Junction, Colorado, laboratory, and was subsequently returned to CSM after inspection.

2.0 CSIRO HI CELL TEST DETAILS

The design and construction of the 9- and 12-strain-gauge HI cell is described by Worotnicki (1993). A twelve-strain-gauge HI cell were used for this project. The main body of the cell includes an epoxy pipe and strain gauges as shown in Figures 3 and 4, respectively. An assembled cell is shown in Figure 5. The stress measurement procedure included first drilling a 6-inch-diameter access hole to the test location where an HI cell was installed and bonded in a cored 1.5-inch-diameter (EX) pilot hole. The HI cell was then overcored, and the strain response and temperature variation were monitored as the stresses on the core were relieved. After



849-01 CSM[Colorado-Idaho Springs_CSM Overcoring.cdr]:rjl(8-5-2015)
Image Reference: Google Earth Pro 2011

Figure 1. Location Map—Edgar Experimental Mine, Idaho Springs, Colorado

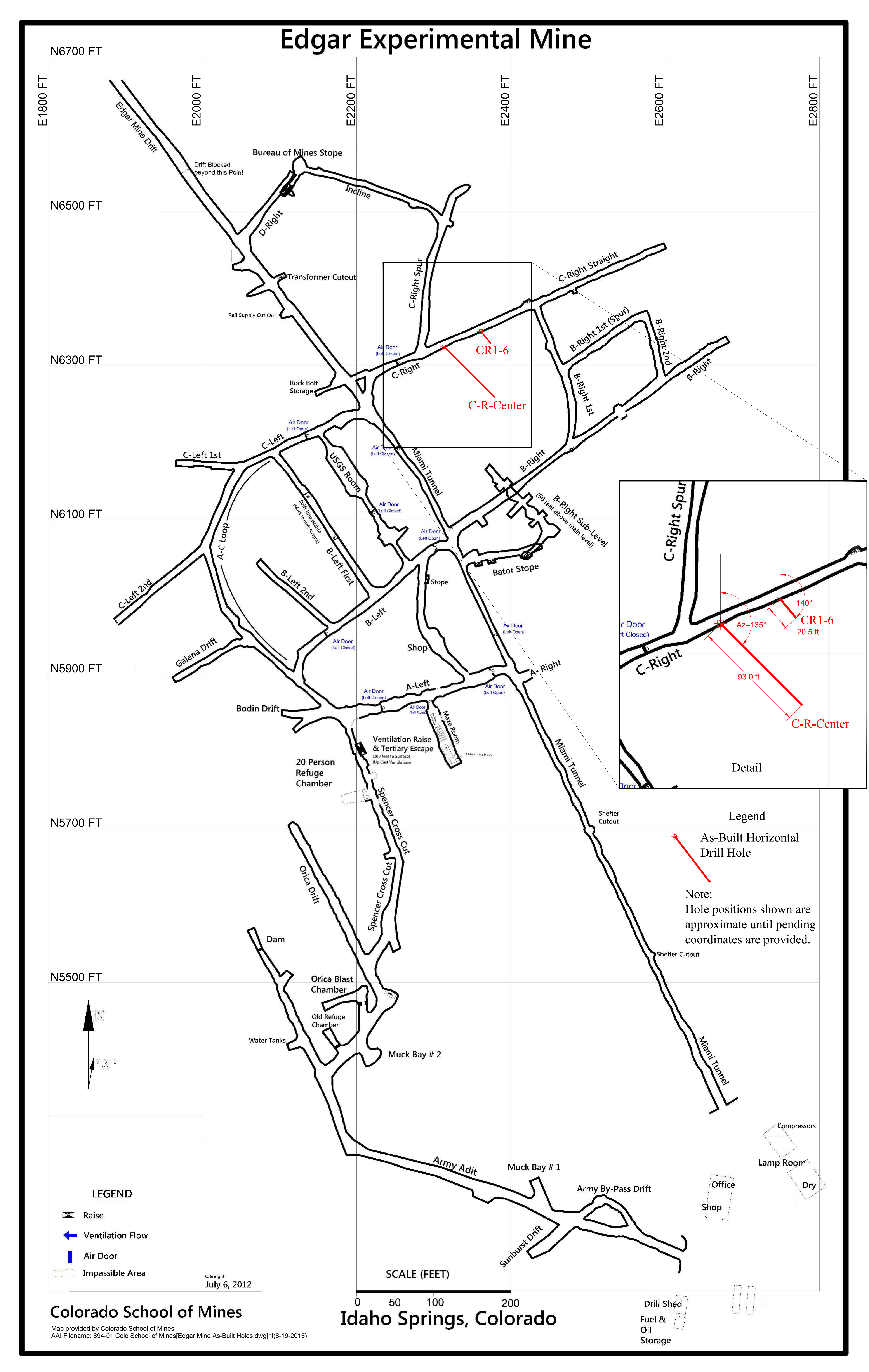


Figure 2. Edgar Experimental Mine Coring and Overcoring Locations

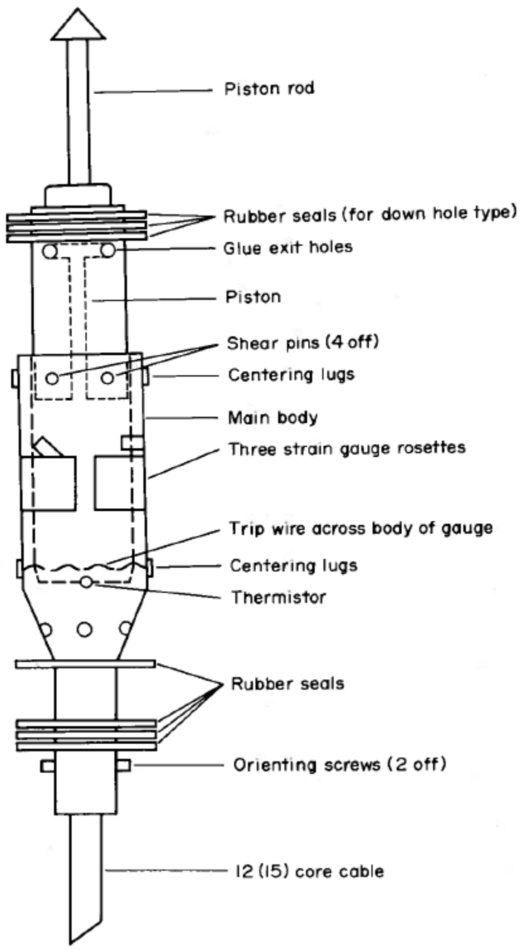


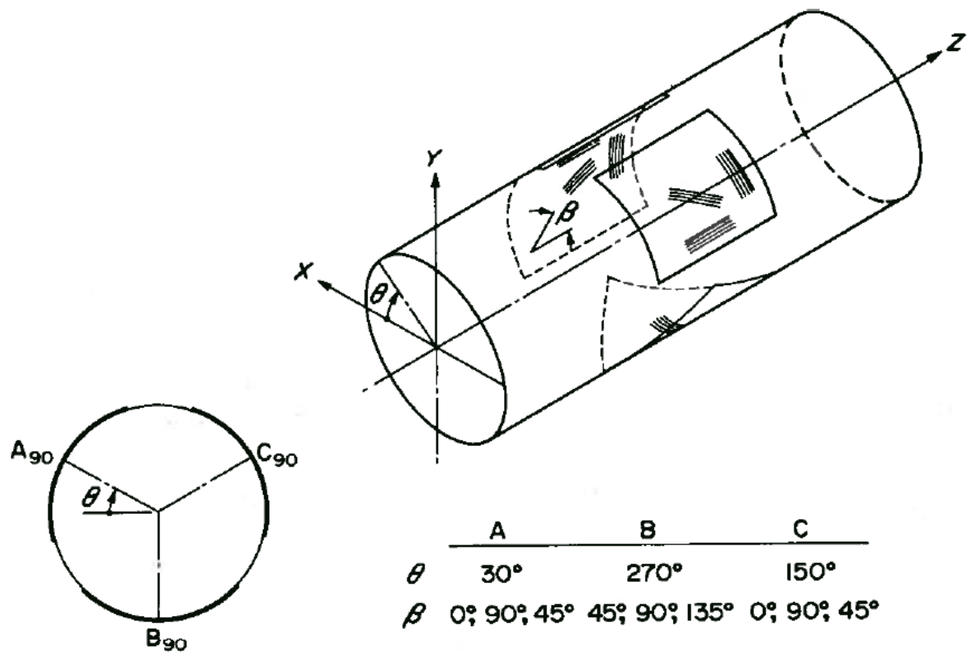
Figure 3. CSIRO HI Stress Cell (after Worotnicki 1993)

recovering the 6-inch rock core with the HI cell, a biaxial pressure test was conducted to determine the Young's modulus and Poisson's ratio of the rock.

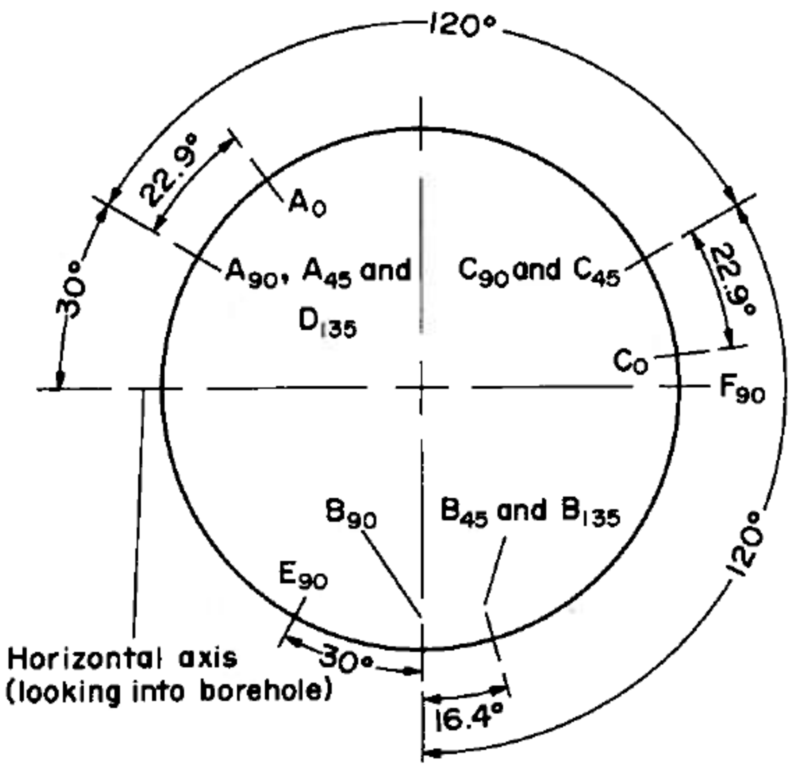
2.1 CSIRO HI Cell Overcoring

One overcoring run was completed in Hole CR1-6 in the C-Right Drift. Table 1 describes details specific to the installation of the HI cells for the overcoring run.
The cell was subjected to a temperature rise on the order of 20 degrees Celsius (°C) during overcoring due to slow drilling in hard rock and a buildup of heat in the drill water recirculating through the heat exchanger on the SD-1500 rig. A temperature correction was applied to the data reduction to account for the thermal strains. The temperature correction was derived from a controlled biaxial temperature test on the HI Cell and core at AAI's laboratory, as discussed in Section 4.0 and described in more detail in Appendix B. Appendix C contains photographs of the overcoring core.

The HI cell and glue pack were manufactured by Environmental Systems and Services (ES&S). Epoxy pack from ES&S for temperatures of 50–64 degrees Fahrenheit (°F) (10–18°C)



a. Isometric View of Strain Gauge



b. Strain Gauge Axial Position and Orientation

Figure 4. CSIRO HI Stress Cell Schematic

Figure 5. CSIRO HI Stress Cell with Cable Attached

Table 1. HI Cell Installation Summary

Hole No.	Azimuth	Run No.	Glue Pack Temperature Range (°C)	Overcore Date	Temperature Change During Test (°C)
CR1-6	140°	1	10–18	7/28/2015	20.0

were used. A sample of epoxy for the HI cell run was examined before testing to ensure adequate curing before subsequent overcoring activities.

Overcoring completed on site was conducted at a rate of approximately 0.3–0.4 inches per minute (about 1 centimeter [cm] per minute) and the voltage variation in each strain gauge for each run was recorded every 5 seconds using a Campbell Scientific CR1000 data logger for each test. The strain versus overcoring distance plot is shown in Appendix B.

2.2 Measurement Accuracy

The HI cell and CR1000 data logger system used to collect the data are constructed and calibrated to resolve a borehole strain to 1×10^{-6} (or one microstrain). Ultimately the Stress 1.0 Programme, Version 1.0, developed by ES&S (2003) converts the raw readings in microvolts to microstrain.

The accuracy of the deformation measurements is estimated to be on the order of ±10 microstrain (ES&S 2013). The accuracy of calculated stresses is a function of deformation measurement errors, errors in the determination of the elastic modulus, errors (eccentricity) in the diameter of the EX hole, errors (eccentricity) in the diameter of the overcored hole, and errors associated with the assumed, linear-elastic homogeneous nature of the rock. The error in the elastic modulus determination could be similar to the error in the stress measurement because the same sources of error are present during the biaxial test of the core, i.e., the HI cell is still bonded into the EX pilot hole. For the biaxial test, the deformation measurement could be in error by 10 microns in 400 microns or 2.5%. To this must be added the error in pressure measurements, diameter, thermal stress, HI cell bond and rock linearity; hence, an error of ±10% in the elastic deformation measurement is possible.

In the evaluation of the overall error in the stress determination, errors associated with all aspects of the procedure must be combined. The individual errors are estimated as follows:

- Measurement error 10 microns in 400 = 2.5%
- Elastic modulus ±10%
- Borehole diameter ±5%
- Thermal stress ±5%*
- HI cell bonding ±2%
- Poisson's ratio ±1%
- Isotropy *small*
- Homogeneity *small*(combined effect 5%)
- Linearity *small*

*When thermal stress (as discussed in Section 4.0 and Appendix B) is considered, the estimate of error in an ideal overcoring procedure could become larger if not accounted for.

The error in the stress measurement could be ±14% if all errors are random and independent (calculated as the square root of the sum of the squares of each component of error). The error could be greater than 14% if non-homogeneity, anisotropy, and nonlinearity effects are higher than estimated and are interrelated. For engineering purposes, an error band of up to ±20% is recommended.

3.0 CSIRO HI CELL TEST RESULTS

Table 2 summarizes the measured *in situ* principal stresses and orientation. Table 2 also resolves the *in situ* stresses to the standard compass directions (north-south, east-west, and vertical directions). The resulting shear stress components are also included in Table 2.

4.0 DISCUSSION OF RESULTS

In situ stresses were measured historically by the United States Geological Survey (USGS) and others at the Edgar Experimental Mine using the United States Bureau of Mines Borehole Deformation Gauge (USBM BDG) and other techniques (Lee et al. 1976). These

Table 2. HI Cell Overcoring Three-Dimensional Stress Measurement

Hole No.	Run No.	Depth (ft)		Principal Stresses[1] Magnitude (psi)	Dip[2] (°)	Bearing (°)	Resolved Stresses[1] N-S (psi)	E-W (psi)	Vertical (psi)	Shear Stresses[1] NS-EW (psi)	EW-Vert (psi)	Vert-NS (psi)
			Major	3,346	17	142	2,625	1,989	304	-684	947	-470
CR1-6	1	19.5	Intermediate	1,701	15	47						
			Minor	-130	67	279						

[1]Stress convention: "+" = compression, "–" = tension.
[2]A positive value indicates down, from horizontal .

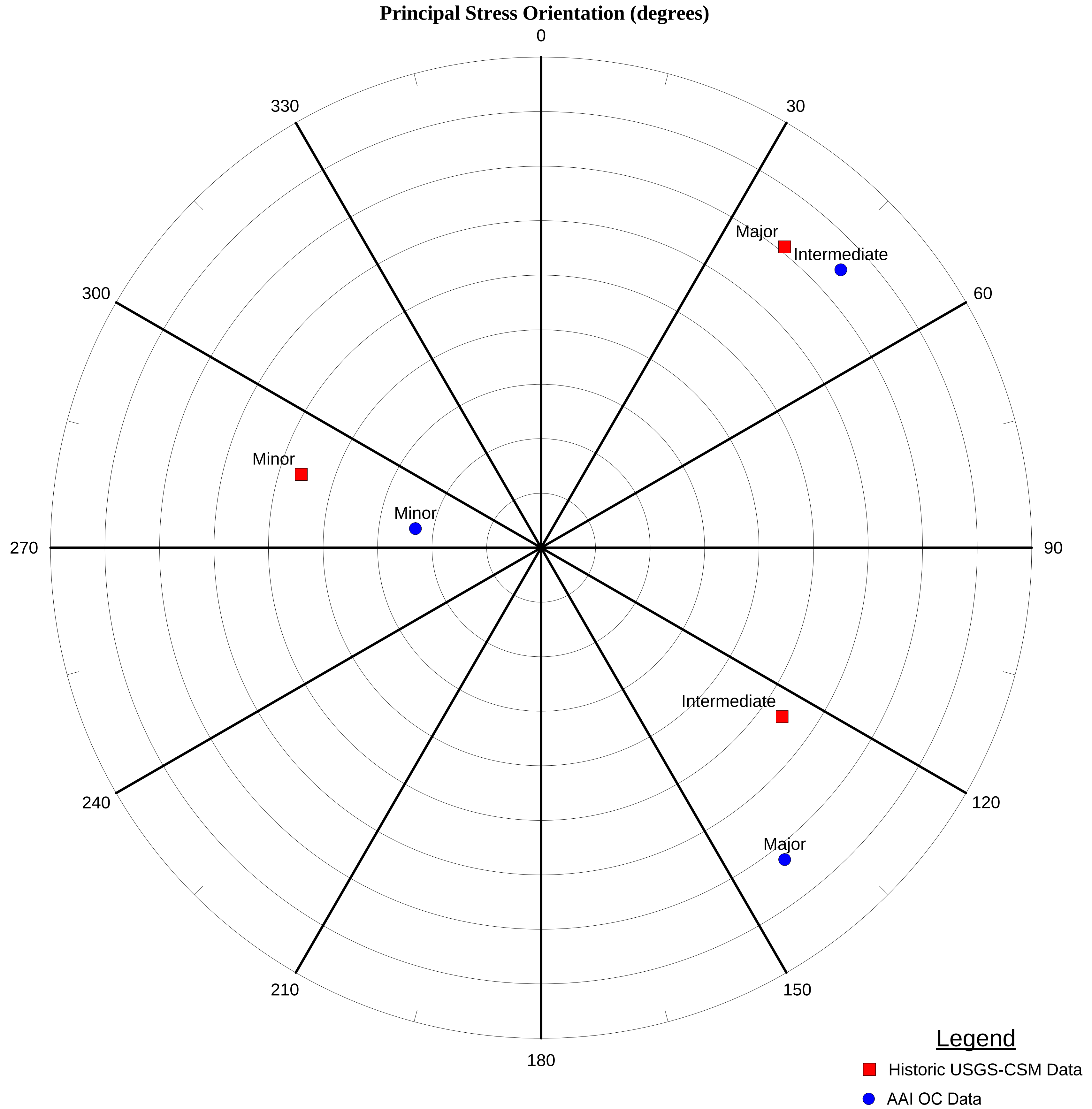
measurements took place in various locations around the USGS classroom, which is adjacent (west) to the Miami Tunnel. While there was notable variability in the individual stress measurements, the consensus stress state is summarized as 1) a vertical stress of 650 pounds per square inch (psi) (depth of cover approximately 350 feet [ft]), 2) horizontal stresses on the order of about 1,000–1,100 psi, and 3) orientations as shown in Figure 6.

The current overcoring run completed in July of 2015 compares reasonably well with the historical measurements considering the degree of variability observed by the USGS. This relative agreement is illustrated in Figure 6 which plots the principal stresses for the 2015 measurement and the USGS consensus stress state on a pole projection.

The USGS (Lee 1976) concluded that there were multiple factors contributing to the observed variation between individual stress measurements, including localized faulting, differences in rock type, and a complex tectonic history at the Edgar Mine. This may explain some of the differences between the USGS consensus stress state and the 2015 measurement, including the nearly double magnitude of the 2015 horizontal stress components.

Some uncertainty regarding the accuracy of the 2015 measurement is also introduced by the rise in temperature during overcoring. While it is not ideal to have a significant rise in temperature during an overcoring test, the temperature correction calibrated at AAI's laboratory is believed to have eliminated a substantial part of the thermal error. The rejection of three suspect strain gauges from the stress reduction is believed to have eliminated additional error, possibly related to gauge overheating or unusual localized thermal expansion in the rock mass. There is reasonable confidence that the final stress tensor is representative of local conditions within a relatively wide margin of error. Additional measurements could be expected to reduce the margin of error.

The uncertainties identified with this single overcore run reaffirm the value of redundant measurements. We believe that the issues with gauge heating can be avoided with future measurements given the knowledge of local conditions gained during this initial attempt. For future programs, a minimum of three or more overcoring runs per site are recommended.



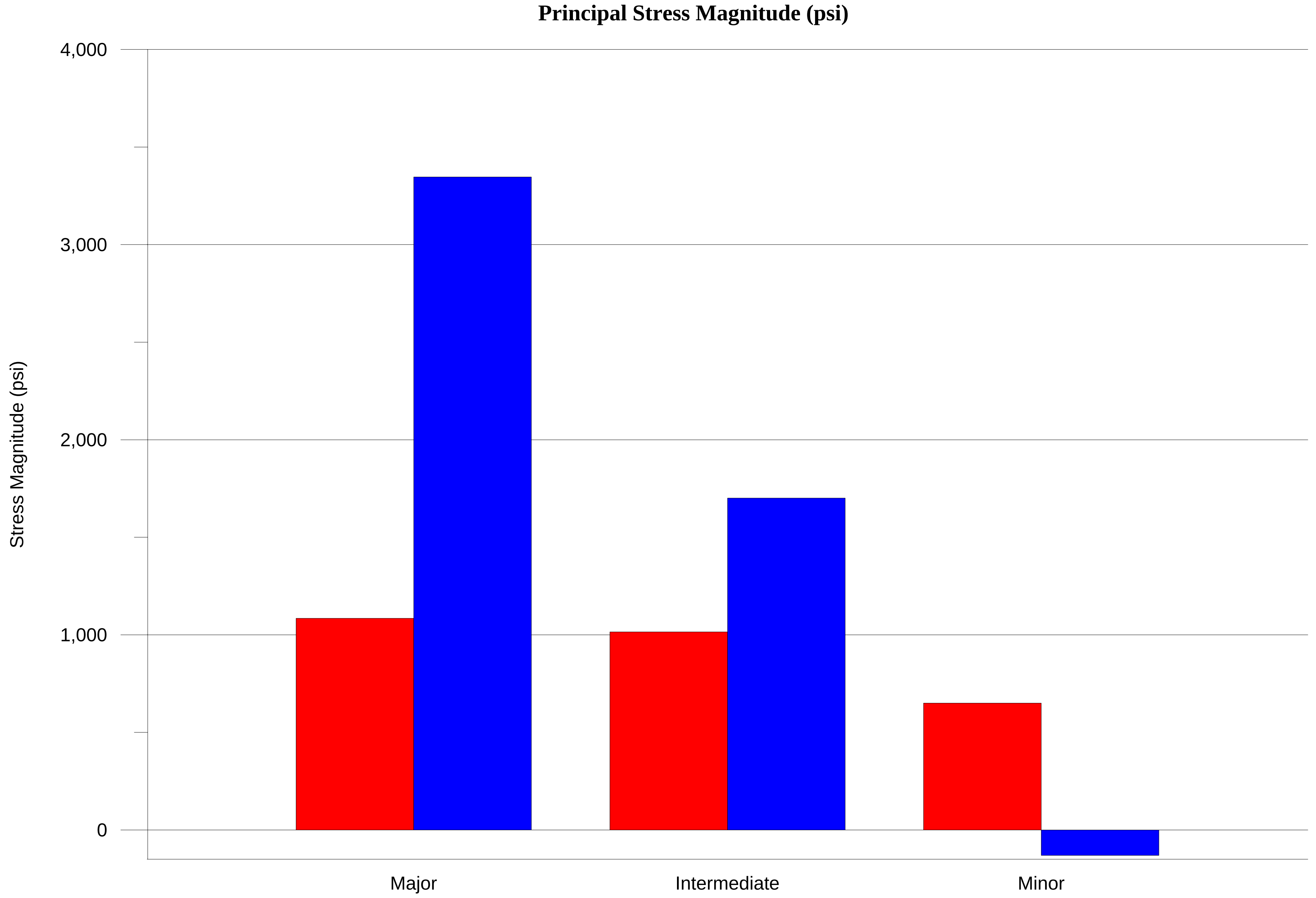


Figure 6. Historic and 2015 AAI Stress Measurement Data

5.0 REFERENCES

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APPENDIX A

DAILY DRILL REPORTS

AGAPITO ASSOCIATES, INC.
715 Horizon Drive, Suite 340 • Grand Junction, CO 81506
970-242-4220 • Fax 970-245-9234 • www.agapito.com

DRILL REPORT

Company: CSM

Property: EDGAR MINE

Hole #: MOB

Date: 7/6/15

Job #: 894-01

Driller: KATOKA CASE

Helper: STEVE KISSNER

Helper: TAYLOR CASE

Pre-Shift Safety Mtg: ______

Pre-Shift Inspection: ______

Run #	Rods in Hole	Stick Up	Amount Cored	Amount Rec'd	Hole Depth	Time Start	Time End	Time Required	Remarks
		Load at Shop				4:30	5:00		
		Travel to Idaho Springs				5:00	8:45		
		meeting w/ Matt & Clint				8:45	9:15		
		MOB Equipment into mine & supply/support for the electricians				9:15	2:45		
		Set up & Secure Drill				2:45	4:00		
		Travel & Check into the hotel				4:00	4:30		

Equipment Used (check)

- ☐ CP-65
- ☑ SD-1500
- ☐ Ingetrol 75E
- ☐ JKS 300
- ☑ 4x4 Pickup X 2
- ☑ 10,000 lb. Trailer
- ☐ 7,000 lb. Trailer
- ☑ Bean 20
- ☐ ______
- ☐ ______
- ☐ ______

Supplies Used

Bits

Size ______
Make ______
S.N. ______
On ______
Off ______ Total ______

Casing Shoe

Size ______
Make ______
S.N. ______
On ______

Casing

Size ______
Depth ______

Water Loads

Hole depth begin shift ______

Hole depth end shift ______

Total depth drilled ______

Time spent on hourly: 12

Standby time ______

Signatures - Driller: [signature]

Client Representative ______

White & Green - ACCOUNTING   Canary - CLIENT   Pink - PROJECT FILE   Gold - DRILLING CHRON

AGAPITO ASSOCIATES, INC.
715 Horizon Drive, Suite 340 • Grand Junction, CO 81506
970-242-4220 • Fax 970-245-9234 • www.agapito.com

DRILL REPORT

Company: CSM
Hole #: Travel Date: 7/7/15 Job #: 894-01
Pre-Shift Safety Mtg:
Pre-Shift Inspection:

Property: EDGar mine
Driller: LATOKA CASE
Helper: STEVE Kissner
Helper: Taylor CASE

Run #	Rods in Hole	Stick Up	Amount Cored	Amount Rec'd	Hole Depth	Time Start	Time End	Time Required	Remarks
	Travel from IS CO.								
	TO Grand Junction Shop								
	offLoad & fuel					10:00	2:00		

Equipment Used (check)
- ☐ CP-65
- ☑ SD-1500
- ☐ Ingetrol 75E
- ☐ JKS 300
- ☑ 4x4 Pickup X 2
- ☑ 10,000 lb. Trailer
- ☐ 7,000 lb. Trailer
- ☑ Bean 20
- ☐ ______
- ☐ ______
- ☐ ______

Supplies Used

Bits
Size ______
Make ______
S.N. ______
On ______
Off ______ Total ______

Casing Shoe
Size ______
Make ______
S.N. ______
On ______

Casing
Size ______
Depth ______

Water Loads

Hole depth begin shift ______
Hole depth end shift ______
Total depth drilled ______
Time spent on hourly 4 Standby time ______

Signatures - Driller [signature]
Client Representative ______

White & Green - ACCOUNTING Canary - CLIENT Pink - PROJECT FILE Gold - DRILLING CHRON

AGAPITO ASSOCIATES, INC.
715 Horizon Drive, Suite 340 • Grand Junction, CO 81506
970-242-4220 • Fax 970-245-9234 • www.agapito.com

DRILL REPORT

Company: CSM
Property: Edgar mine
Hole #: CR-Center Date: 7/13/15 Job #: 894-01
Driller: KATOKA CASE
Pre-Shift Safety Mtg:
Helper: Taylor Case.
Pre-Shift Inspection:
Helper:

Run #	Rods in Hole	Stick Up	Amount Cored	Amount Rec'd	Hole Depth	Time Start	Time End	Time Required	Remarks
		Travel To mine				5:00	8:30		
		Set up Drill & Anchor				8:30	12:45		
		Run hoses, Set up TANKS							
		for water/stage Area for							
		Drilling/Attach plastic				12:45	3:20		
		Drill Collar & Set Casing.							
		Re-aply plastic				3:20	4:30		
		Travel out				4:30	4:45		
		Travel To Hotel				4:45	5:00		

Equipment Used (check)
- [ ] CP-65
- [x] SD-1500
- [ ] Ingetrol 75E
- [ ] JKS 300
- [x] 4x4 Pickup
- [ ] 10,000 lb. Trailer
- [ ] 7,000 lb. Trailer
- [x] Bean 20
- [ ]
- [ ]
- [ ]

Supplies Used

Bits
Size
Make
S.N.
On
Off Total

Casing Shoe
Size
Make
S.N.
On

Casing
Size
Depth

Water Loads

Hole depth begin shift
Hole depth end shift
Total depth drilled
Time spent on hourly: 12 Standby time

Signatures - Driller: [signature]
Client Representative

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DRILL REPORT

Company: CSM
Hole #: CR-Center Date: 7/14/15 Job #: 894-01
Pre-Shift Safety Mtg: ____
Pre-Shift Inspection: ____

Property: EDGar Mine
Driller: Katona Case
Helper: Taylor Case
Helper: ____

Run #	Rods in Hole	Stick Up	Amount Cored	Amount Rec'd	Hole Depth	Time Start	Time End	Time Required	Remarks
	Travel	TO	mine			6:00	6:30		
	Drill Starter		Bit		3.55	6:30	8:49		
	Break Core Retrieve -					8:49	9:30		
	Load Core Barrel					9:30	9:50		
#4	Drill	TO			7.55	9:50	10:30		
#5	Drill	TO			12.0'	10:30	1:00		
	Drill head will not hold RODS								
	Check slips / Pull off and								
	Travel out of mine.								
	Change out					1:00	1:45		
	Travel TO hotel					1:45	2:00		
	Taylor Travels TO meet ROD								
	TO TRADE OUT heads								

Equipment Used (check)
- ☐ CP-65
- ☑ SD-1500
- ☐ Ingetrol 75E
- ☐ JKS 300
- ☑ 4x4 Pickup
- ☐ 10,000 lb. Trailer
- ☐ 7,000 lb. Trailer
- ☑ Bean 20
- ☐ ____
- ☐ ____
- ☐ ____

Supplies Used

Bits
Size ____
Make ____
S.N. ____
On ____
Off ____ Total ____

Casing Shoe
Size ____
Make ____
S.N. ____
On ____

Casing
Size ____
Depth ____

Water Loads

Hole depth begin shift ____
Hole depth end shift ____
Total depth drilled ____
Time spent on hourly 8 + Taylor Drive O/H Standby time ____

Signatures - Driller [signature]
Client Representative ____

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DRILL REPORT

Company: CSM
Hole #: C Right cuto Date: 7/15/15 Job #: 849-07
Pre-Shift Safety Mtg: ____
Pre-Shift Inspection: ____
Property: Edgar mine
Driller: KATOKA CASE
Helper: TAYLOR CASE
Helper: ____

Run #	Rods in Hole	Stick Up	Amount Cored	Amount Rec'd	Hole Depth	Time Start	Time End	Time Required	Remarks
		Travel TO mine				6:45	7:00		
		MOB Drill head into mine				7:00	8:00		
		Change motor/setup to drill				8:00	9:30		
#6		Drill TO			15.4'	9:30	10:15		Blocked
#7		Drill TO			16.2	10:15	11:45		Low Feed Pressure
#8		Drill TO			19.0	11:45	4:12		Low Feed pressure
		Trip Rods Check BT				4:12	5:00		
#9		Drill — Cannot get feed above 1500 psi							
		will not Drill				5:00	6:00		
		Travel out			Change	6:00	6:30		
		Travel TO			hotel	6:30	6:45		

Equipment Used (check)

- ☐ CP-65
- ☑ SD-1500
- ☐ Ingetrol 75E
- ☐ JKS 300
- ☑ 4x4 Pickup
- ☑ 10,000 lb. Trailer
- ☐ 7,000 lb. Trailer
- ☑ Bean 20
- ☐ ____
- ☐ ____
- ☐ ____

Supplies Used

Bits
Size ____
Make ____
S.N. ____
On ____
Off ____ Total ____

Casing Shoe
Size ____
Make ____
S.N. ____
On ____

Casing
Size ____
Depth ____

Water Loads

Hole depth begin shift ____
Hole depth end shift ____
Total depth drilled ____
Time spent on hourly 12 Standby time ____

Signatures - Driller [signature]
Client Representative ____

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DRILL REPORT

Company: CSM
Property: Edgar mine
Hole #: ______ Date: 7/16/15 Job #: 894-01
Driller: KATOKA CASE
Pre-Shift Safety Mtg: ______
Helper: Rob henderson
Pre-Shift Inspection: ______
Helper: TAYOR Case

Run #	Rods in Hole	Stick Up	Amount Cored	Amount Rec'd	Hole Depth	Time Start	Time End	Time Required	Remarks
8:00am – 4:00 pm Work on Drill Repair									
O/H									

Equipment Used (check)
- ☐ CP-65
- ☑ SD-1500
- ☐ Ingetrol 75E
- ☐ JKS 300
- ☑ 4x4 Pickup
- ☑ 10,000 lb. Trailer
- ☐ 7,000 lb. Trailer
- ☑ Bean 20
- ☐ ______
- ☐ ______
- ☐ ______

Supplies Used

Bits
Size ______
Make ______
S.N. ______
On ______
Off ______ Total ______

Casing Shoe
Size ______
Make ______
S.N. ______
On ______

Casing
Size ______
Depth ______

Water Loads

Hole depth begin shift ______
Hole depth end shift ______
Total depth drilled ______
Time spent on hourly: 8
Standby time ______

Signatures - Driller: [signature]
Client Representative ______

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DRILL REPORT

Company: CSM — Property: Edgar mine
Hole #: O/H — Date: 7/17/15 — Job #: 894-01 — Driller: KATOKA CASE
Pre-Shift Safety Mtg: — — Helper: Rob Henderson
Pre-Shift Inspection: — Helper:

Run #	Rods in Hole	Stick Up	Amount Cored	Amount Rec'd	Hole Depth	Time Start	Time End	Time Required	Remarks
		Work on Drill Repair.							
			8:00 am — 5:00 pm						

Equipment Used (check)
- [ ] CP-65
- [x] ~~SD-1500~~
- [ ] Ingetrol 75E
- [ ] JKS 300
- [x] 4x4 Pickup
- [x] 10,000 lb. Trailer
- [ ] 7,000 lb. Trailer
- [x] Bean 20
- [ ]
- [ ]
- [ ]

Supplies Used

Bits
Size:
Make:
S.N.:
On:
Off: Total:

Casing Shoe
Size:
Make:
S.N.:
On:

Casing
Size:
Depth:

Water Loads

Hole depth begin shift:
Hole depth end shift:
Total depth drilled:
Time spent on hourly: 9 — Standby time:

Signatures - Driller: [signature]
Client Representative:

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DRILL REPORT

Company CSM
Hole # C-R-Center Date 7/20/15 Job # 894-01
Pre-Shift Safety Mtg ______
Pre-Shift Inspection ______

Property EDGar Mine
Driller KATOKA CASE
Helper TAYLOR CASE
Helper ______

Run #	Rods in Hole	Stick Up	Amount Cored	Amount Rec'd	Hole Depth	Time Start	Time End	Time Required	Remarks
		Travel from GJ				5:30	9:00		
		Change out Travel in				9:00	9:30		
		PreShift				9:30	9:40		
#8		Drill	TO		20.5	9:40	10:20		
#9		"	"		24.0	10:20	11:12		
#10		"	"		27.9	11:12	11:50		
#11		"	"		32.3	11:50	12:44		
#12		"	"		36.5	12:44	2:06		
#13		"	"		40.55	2:06	3:19		
#14		"	"		44.4	3:19	4:40		
	Shut Down Secure tools					4:40	5:00		
	Travel out Change					5:00	5:15		
	Travel TO hotel					5:15	5:30		

Equipment Used (check)

- [ ] CP-65
- [x] SD-1500
- [ ] Ingetrol 75E
- [ ] JKS 300
- [x] 4x4 Pickup
- [x] 10,000 lb. Trailer
- [ ] 7,000 lb. Trailer
- [x] Bean 20

Supplies Used

Bits
Size ______
Make ______
S.N. ______
On ______
Off ______ Total ______

Casing Shoe
Size ______
Make ______
S.N. ______
On ______

Casing
Size ______
Depth ______

Water Loads

Hole depth begin shift ~~44.4~~ 20.5
Hole depth end shift 44.4
Total depth drilled ______
Time spent on hourly 12 Standby time ______

Signatures - Driller [signature]
Client Representative ______

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DRILL REPORT

Company: CSM
Property: Edgar mine
Hole #: CR-Center Date: 7/21/15 Job #: 89401
Driller: KATOKA CASE
Pre-Shift Safety Mtg:
Helper: TAYLOR CASE
Pre-Shift Inspection:
Helper:

Run #	Rods in Hole	Stick Up	Amount Cored	Amount Rec'd	Hole Depth	Time Start	Time End	Time Required	Remarks
		Travel to mine				6:30	6:45		
		Change out/Tail in				6:45	7:15		
#15		Drill to			48.8	7:15	8:06		
#16					52.55	8:06	9:33		
#17					56.7	9:33	11:00		
	O/H Blown Hydraulic hose, Repair								
	and Replace					11:00	1:00		
#18		Drill to			60.0	1:00	2:10		
#19					64.5	2:10	2:56		
#20					67.0	2:56	4:09		
#21					69.7	4:09	5:30		
	Tripped out/Change and Check								
	Bit for wear				5:30	5:50			
	Travel out/Change				5:50	6:15			
	Travel to hotel				6:15	6:30			

Equipment Used (check)
- [ ] CP-65
- [x] SD-1500
- [ ] Ingetrol 75E
- [ ] JKS 300
- [x] 4x4 Pickup
- [x] 10,000 lb. Trailer
- [ ] 7,000 lb. Trailer
- [x] Bean 20
- [ ]
- [ ]
- [ ]

Supplies Used

Bits
Size
Make
S.N.
On
Off Total

Casing Shoe
Size
Make
S.N.
On

Casing
Size
Depth

Water Loads

Hole depth begin shift: 44.4
Hole depth end shift: 69.7
Total depth drilled:
Time spent on hourly: 12 Standby time:

Signatures - Driller: [signature]
Client Representative:

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DRILL REPORT

Company: CSM
Hole #: C-R-Center Date: 7/22/15 Job #: 994-01
Pre-Shift Safety Mtg:
Pre-Shift Inspection:

Property: EDGar Mine
Driller: KATOKA CASE
Helper: TAYLOR CASE
Helper:

Run #	Rods in Hole	Stick Up	Amount Cored	Amount Rec'd	Hole Depth	Time Start	Time End	Time Required	Remarks
		Travel TO mine				6:30	6:45		
		Change out/Travel in				6:45	7:15		
		Trip Rods in.				7:15	7:45		
#22		Blocked			72.6	7:45	9:15		Blocked
~~#23~~	Triped Rods Chaged TO Series 7								
	Bit					9:15	9:38		
#23					73.8	9:38	10:00		Blocked.
	Triped Rods Changed Bits BACK								
	TO Series 14					10:00	10:30		
#24		Drill	TO		76.4	10:30	12:42		
#25		"	"		80.65	12:42	2:35		
#26		"	"		83.5	2:35	4:10		Blocked
#27		"	"		84.1	4:10	4:40		Blocked
	Shut Down Secure Tools					4:40	5:00		
	Travel out/Change					5:00	5:15		
	Travel TO hotel					5:15	5:30		

Equipment Used (check)

- [ ] CP-65
- [x] SD-1500
- [ ] Ingetrol 75E
- [ ] JKS 300
- [x] 4x4 Pickup
- [x] 10,000 lb. Trailer
- [ ] 7,000 lb. Trailer
- [x] Bean 20
- [ ]
- [ ]
- [ ]

Supplies Used

Bits
Size:
Make:
S.N.:
On:
Off: Total:

Casing Shoe
Size:
Make:
S.N.:
On:

Casing
Size:
Depth:

Water Loads

Hole depth begin shift: 69.7
Hole depth end shift: 84.1
Total depth drilled:
Time spent on hourly: 11 Standby time:

Signatures - Driller: [signature]
Client Representative:

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DRILL REPORT

Company: CSM
Property: EDGar MiNe

Hole #: CR-Center   Date: 7/23/15   Job #: 894-01
Driller: KATOKA CASE

Pre-Shift Safety Mtg:
Helper: TAYLOR CASE

Pre-Shift Inspection:
Helper:

Run #	Rods in Hole	Stick Up	Amount Cored	Amount Rec'd	Hole Depth	Time Start	Time End	Time Required	Remarks
		Travel TO MiNe				6:30	6:45		
		Change - Travel iN				6:45	7:15		
#28		Drill TO			86.3	7:15	8:10		Blocked
		Trip Rods / Check B.H.				8:10	10:00		
#29		Drill TO			89.0	10:00	11:03		
#30		" "				11:03	12:00		
		Trip Rods Tear Down				12:00	2:10		
	move Drill & Set up for OC hole								
	& move equip. in					2:10	5:00		
	Collar and hilte plastic					5:00	6:00		
		Travel Out Change				6:00	6:15		
		Travel TO Hotel				6:15	6:30		

Equipment Used (check)

- ☐ CP-65
- ☑ SD-1500
- ☐ Ingetrol 75E
- ☐ JKS 300
- ☑ 4x4 Pickup
- ☑ 10,000 lb. Trailer
- ☐ 7,000 lb. Trailer
- ☑ Bean 20
- ☐
- ☐
- ☐

Supplies Used

Bits

Size:
Make:
S.N.:
On:
Off: Total:

Casing Shoe

Size:
Make:
S.N.:
On:

Casing

Size:
Depth:

Water Loads

Hole depth begin shift:
Hole depth end shift:
Total depth drilled:
Time spent on hourly: 12   Standby time:

Signatures - Driller: [signature]
Client Representative:

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DRILL REPORT

Company: CSM
Property: EDGAR MINE
Hole #: CR-1-6CB Date: 7/24/15 Job #: 894-01
Driller: KATOKA CASE
Pre-Shift Safety Mtg: ____
Helper: TAYLOR CASE
Pre-Shift Inspection: ____
Helper: ____

Run #	Rods in Hole	Stick Up	Amount Cored	Amount Rec'd	Hole Depth	Time Start	Time End	Time Required	Remarks
		Travel	TO	mine		6:30	6:45		
	Change	Travel	in.			6:45	7:15		
#1		Drill	TO		2.6	7:15	8:00		
#2		"	"		3.6	8:00	8:40		
#3		"	"		6.7	8:40	9:35		
#4		"	"		7.65	9:35	10:50	→	Broke Rod
#5		"	"		8.9	10:50	11:45		
#6		"	"		10.25	11:45	1:06		Broke Rod
#7		"	"		11.1	1:06	2:15		
#8		"	"		12.7	2:15	3:09		
#9		"	"		14.2	3:09	3:52		
#10		"	"		15.8	3:52	4:38		Fractured
#11		"	"		16.7	4:38	5:35		Core
	travel	out	Change			5:35	6:05		
	Travel	TO	GJ			6:05	9:30		

Equipment Used (check)
- [ ] CP-65
- [x] SD-1500
- [ ] Ingetrol 75E
- [ ] JKS 300
- [x] 4x4 Pickup
- [x] 10,000 lb. Trailer
- [ ] 7,000 lb. Trailer
- [x] Bean 20
- [ ] ____
- [ ] ____
- [ ] ____

Supplies Used

Bits
Size ____
Make ____
S.N. ____
On ____
Off ____ Total ____

Casing Shoe
Size ____
Make ____
S.N. ____
On ____

Casing
Size ____
Depth ____

Water Loads

Hole depth begin shift: 0
Hole depth end shift: 16.7
Total depth drilled: ____
Time spent on hourly: 15 Standby time: ____

Signatures - Driller: [signature]
Client Representative: ____

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DRILL REPORT

Company: CSM
Property: EDGar Mine
Hole #: CRI-6 Date: 7/27/15 Job #: 894-01
Driller: Katoka Case
Pre-Shift Safety Mtg:
Helper: Taylor Case
Pre-Shift Inspection:
Helper:

Run #	Rods in Hole	Stick Up	Amount Cored	Amount Rec'd	Hole Depth	Time Start	Time End	Time Required	Remarks
		Travel TO mine				5:00	8:30		
		Chng Travel			MW	8:30	8:45		
		pull Core from			16.7	and	Try		Fractured
		TO Clean hole				8:45	10:20		
#2		Drill TO			18.6	10:20	11:15		
		Break/pull Core & Clean hole.							
		for EX				11:15	12:45		
		Drill EX hole				12:45	1:15		
		Flush/prepare Cell				1:15	2:00		
		Set Cell @ 19.5'				2:00	2:30		
		Secured/Clean/up				2:30	2:45		
		Travel out				2:45	3:00		
	O/H	Work on Truck				3:00	5:00		

Equipment Used (check)
- [ ] CP-65
- [x] SD-1500
- [ ] Ingetrol 75E
- [ ] JKS 300
- [x] 4x4 Pickup
- [x] 10,000 lb. Trailer
- [ ] 7,000 lb. Trailer
- [x] Bean 20
- [ ]
- [ ]
- [ ]

Supplies Used

Bits
Size:
Make:
S.N.:
On:
Off: Total:

Casing Shoe
Size:
Make:
S.N.:
On:

Casing
Size:
Depth:

Water Loads

Hole depth begin shift:
Hole depth end shift:
Total depth drilled:
Time spent on hourly: 10 + 2 O/H Standby time:

Signatures - Driller: [signature]
Client Representative:

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DRILL REPORT

Company CSM

Property EDGar mine

Hole # CR1-6 Date 7/28/15 Job # 894-01

Driller KATOKA CASE

Pre-Shift Safety Mtg ____

Helper TAYLOR CASE

Pre-Shift Inspection ____

Helper ____

Run #	Rods in Hole	Stick Up	Amount Cored	Amount Rec'd	Hole Depth	Time Start	Time End	Time Required	Remarks
	Travel TO mine					6:30	~~7:45~~ 6:45		
	Check out/Travel in					6:45	7:15		
	putt RODS in Set up DATA								
	Logger & Secure Cable					7:15	8:59		
	Pressure water to 20'					8:59	9:19		
	Start OC Run @					9:19	10:50		
	Clean hole SAVE DATA					10:50	11:30		
	pull RODS Break & Retrieve								
	Core					11:30	12:14		
	Box & Stripe Core					12:14	2:30		
	Tear Down / mob out					2:30	6:30		
	Travel TO GJ					6:30	10:00		

Equipment Used (check)

- ☐ CP-65
- ☐ SD-1500
- ☐ Ingetrol 75E
- ☐ JKS 300
- ☐ 4x4 Pickup
- ☐ 10,000 lb. Trailer
- ☐ 7,000 lb. Trailer
- ☐ Bean 20
- ☐ ____
- ☐ ____
- ☐ ____

Supplies Used

Bits

Size ____
Make ____
S.N. ____
On ____
Off ____ Total ____

Casing Shoe

Size ____
Make ____
S.N. ____
On ____

Casing

Size ____
Depth ____

Water Loads

Hole depth begin shift ____

Hole depth end shift ____

Total depth drilled ____

Time spent on hourly 15.5 Standby time ____

Signatures - Driller [signature]

Client Representative ____

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APPENDIX B

CSIRO HI CELL OVERCORING AND BIAXIAL DATA

B.1 Overcoring Response

The HI cell temperature rose by approximately 20 degrees Celsius (°C) during the overcoring run. This rise exceeds manufacturer recommendations. In order to correct for thermal strains, a controlled temperature test was conducted on the intact biaxial core at AAI's laboratory to establish a temperature-strain relationship for each strain gauge. No mechanical stress was applied to the biaxial core for the test. The test produced a relatively linear temperature-strain response for each of the three strain gauge orientations (0°, 45° and 90°) around the HI Cell, shown in Figure B-1. The temperature-corrected overcoring microstrain response is shown in Figure B-2.

The 3D stress tensor was calculated from the overcoring microstrains using the spreadsheet macro Stress 1.0 Programme (ES&S 2003). The stress tensor was based on the microstrain response at the end of overcoring (overcore distance 50 cm, Figure B-2) where stress relief is maximal and the response is most linear.

The C45 and C90 strain gauges were omitted from the stress computation because their response is deemed anomalous relative to their redundant partner gauges and the magnitude of strain relief is not believable. Similarly, gauge A90 appears suspect because it introduces an unbelievable bias in the computed stress magnitudes and was omitted. In general, it is not uncommon for individual gauges to produce invalid responses for various reasons, often associated with local defects in the rock mass. Redundant gauges built into the HI Cell allow invalid gauges to be omitted and the stress tensor to still be calculated.[1]

In this circumstance, the anomalous gauge responses are suspected to be related to the temperature rise during overcoring. The biaxial test performed in the laboratory after overcoring did not reproduce any of the unusual behavior in the suspect gauges (Section B.2), suggesting that the anomalous responses were of a transient nature only during overcoring. The fact that the other gauges appear less affected by temperature during overcoring is not readily explainable. It may be possible that, instead of rock mass defects, local variation in the rock mass' thermal expansion properties could introduce differences between gauges.

B.2 Biaxial Testing

A biaxial test was undertaken on the recovered core containing the HI cell after the overcoring was complete. The strain changes were recorded during a loading and unloading cycle from 0 psi to approximately 2,000 psi (only the loading cycle was plotted). The biaxial plot is shown in Figure B-3.

[1] Since each HI cell contains redundant strain gauge configurations, the number and orientation of strain readings required to compute the full three-dimensional stress state and properties is greater than what is needed.

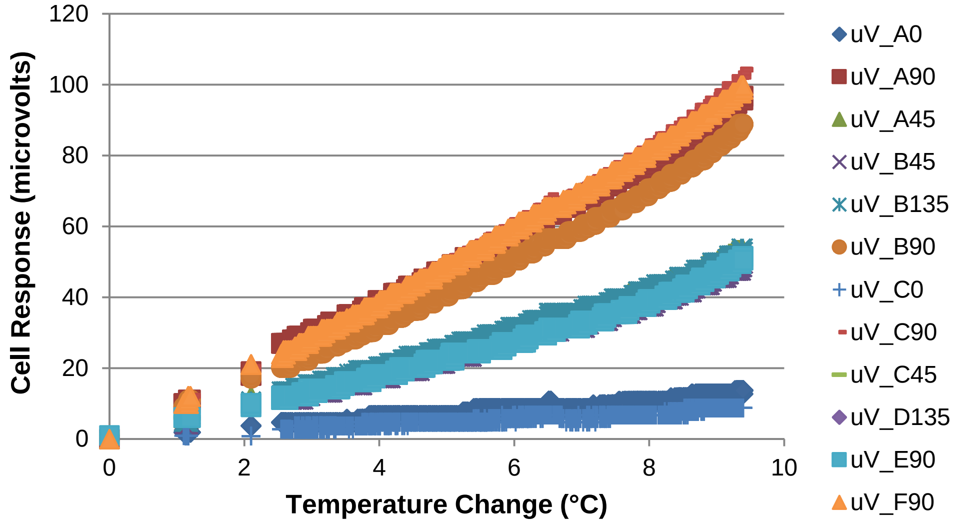


Figure B-1. Temperature Correction Obtained During Testing

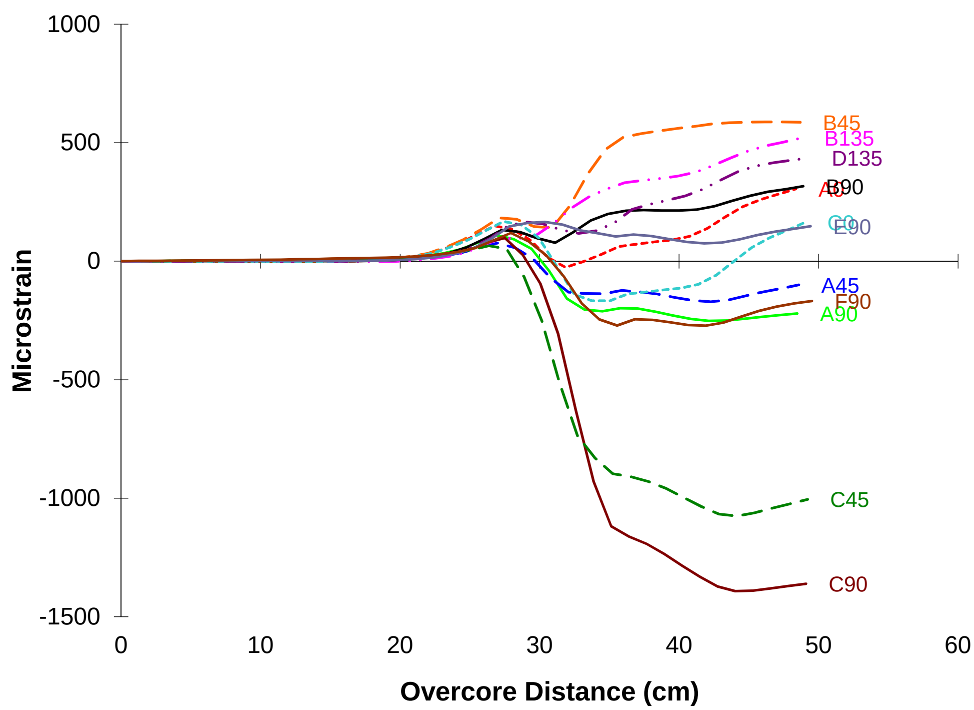


Figure B-2. Run 1 Overcoring Response—Microstrain versus Overcoring Distance

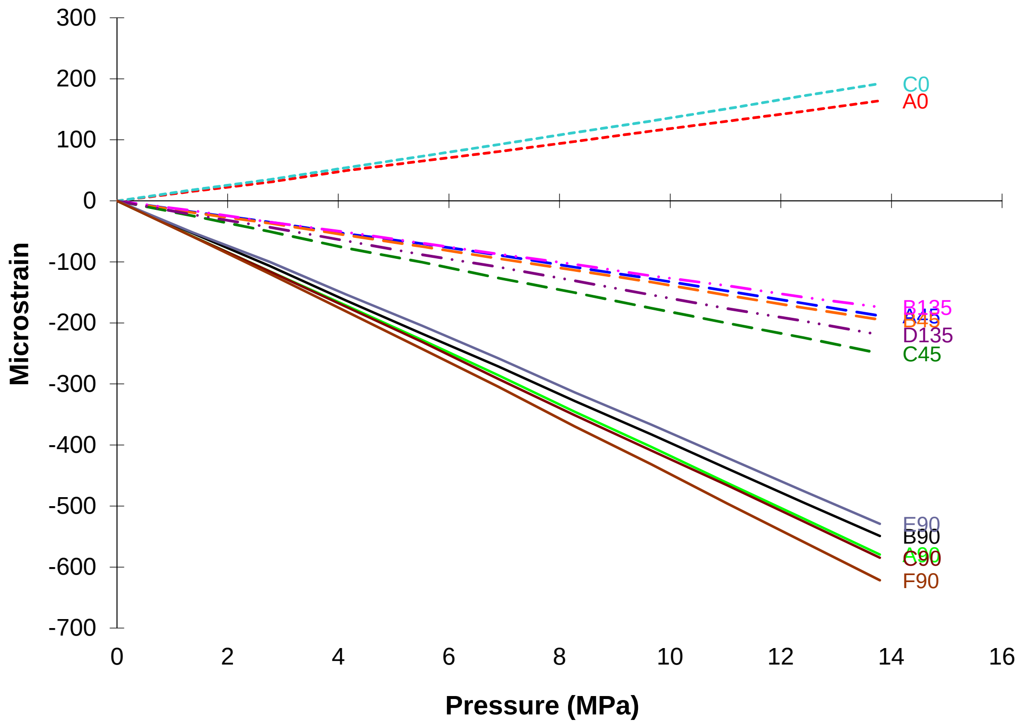


Figure B-3. Run 1 Biaxial Testing Plot—Microstrain versus Pressure

The pressure-strain curves obtained from the biaxial test results were used to compute the Young’s modulus and Poisson’s ratio of the rock. Loaded strains at a biaxial pressure of 1,800 psi (12.4 megapascals [MPa]) were used in the calculations. Over this range, the measured response is nearly perfectly linear and thus considered valid for determination of the elastic properties. Table B-1 summarizes the Young’s modulus and Poisson’s ratio determined from the biaxial test.

Table B-1. HI Cell Results of Biaxial Testing

Hole No.	Run No.	Elastic Modulus (million psi)	Poisson's Ratio
CR1-6	1	8.41	0.34

Table B-1 properties were used for the computation of stresses with the Stress 1.0 Programme.

B.3 Cell Inspection

After biaxial and temperature testing, the HI cell and surrounding core was cut in half at the AAI laboratory in Grand Junction, Colorado, to inspect the quality of the epoxy bond and condition of the cell, shown in Figure B-4. Intact core is shown in Figure B-5.

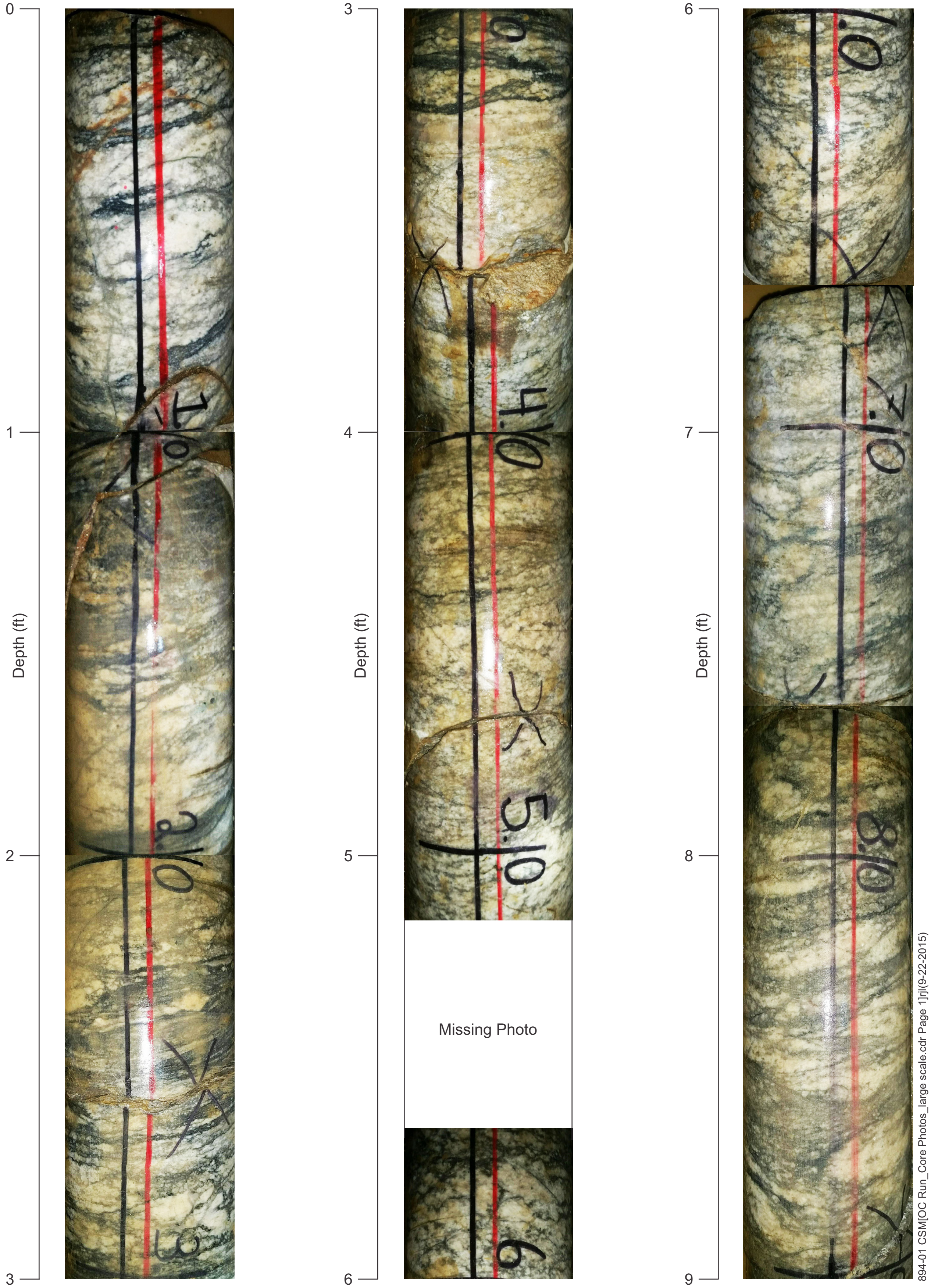
Figure B-4. Cutaway of HI Cell Run 1

Figure B-5. HI Cell Run 1

The epoxy interface between the HI cell and the EX borehole was inspected at the AAI laboratory after demobilization activities. This process involved cutting the recovered HI cell core axially and photographing the sectioned cores (Figure B-4). Upon inspection of the sectioned core, the epoxy bond was free from bubbles or inclusions.

APPENDIX C

OVERCORING CORE PHOTOGRAPHS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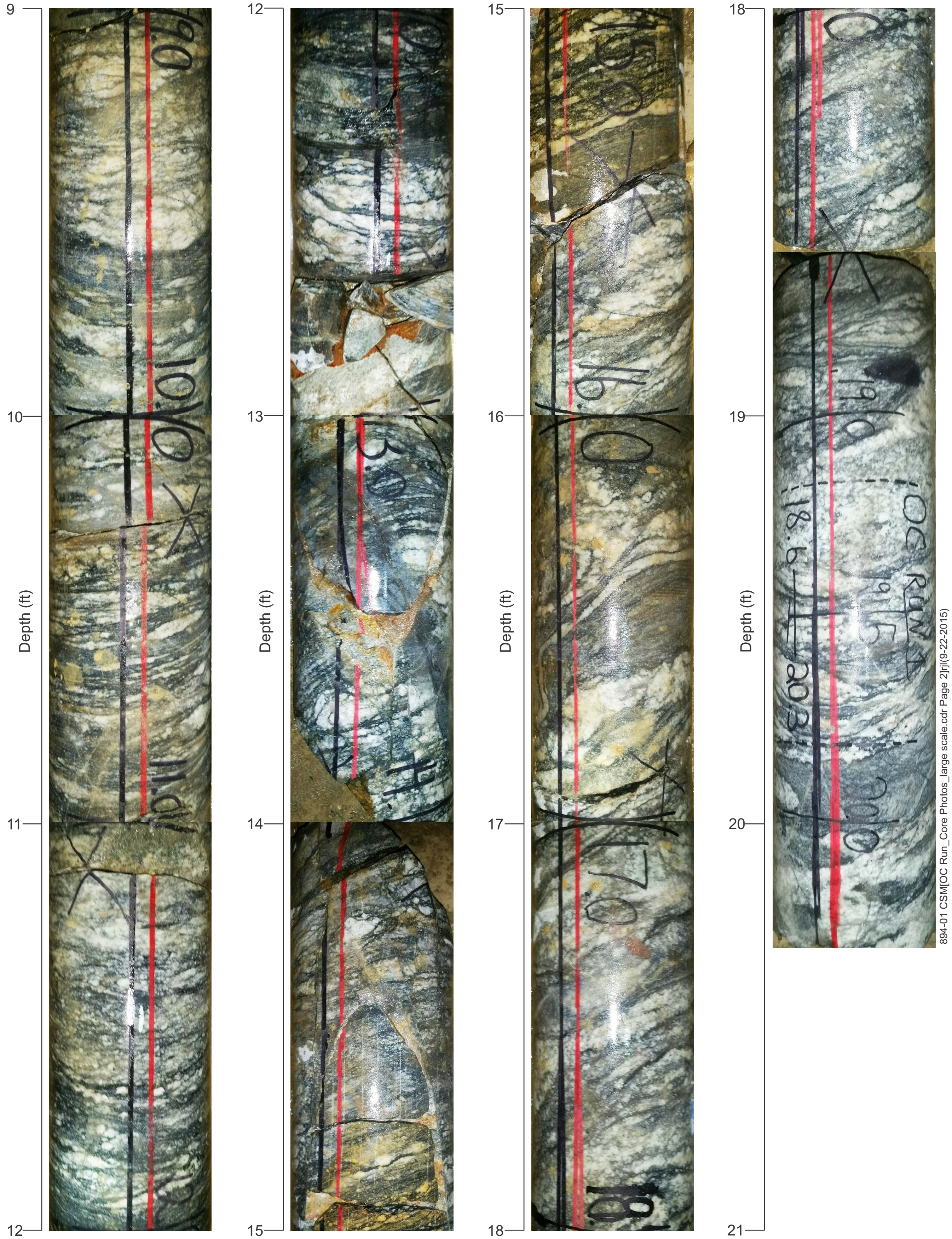
894-01 CSM[OC Run_Core Photos_large scale.cdr Page 1]rj(9-22-2015)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894-01 CSM[OC Run_Core Photos_large scale.cdr Page 2]rj(9-22-2015)

Appendix D: Core Log

Appendix D is attached.