

2022 ANNUAL REPORT STRUCTURAL GEOLOGY EVALUATION SPECIFICATIONS AGGREGATE QUARRY

**Martin Marietta Materials
Golden, Colorado**

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Mr. Phillip J. Courtney
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**Subject: Project 21C64003.00, 2022 Annual Report, Structural Geology Evaluation,
Specification Aggregates Quarry, Golden, Colorado**

Dear Mr. Courtney:

LACHEL & ASSOCIATES, INC. (Lachel) is pleased to submit our geological engineering report of the annual structural geologic evaluation for the Specification Aggregates Quarry located in Golden, Colorado. This report documents the results and conclusions of our 2021 field mapping effort and structural geology evaluation. This study was performed in accordance with our proposal dated May 7, 2021 and authorized by David Jordan on May 19, 2021.

Lachel appreciates the opportunity to work with you on this project. Please call us if you have any questions regarding this report.

Sincerely,

LACHEL & ASSOCIATES, INC.



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**2022 ANNUAL REPORT
STRUCTURAL GEOLOGY EVALUATION
SPECIFICATIONS AGGREGATE QUARRY
GOLDEN, COLORADO**

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1.0 INTRODUCTION

Lachel & Associates, Inc. (Lachel) has prepared this independent annual structural geology evaluation for the Specification Aggregates (Spec-Agg) Quarry located in Golden, Colorado for the 2022 reporting year. This study was conducted at the request of Martin Marietta Materials, Inc. (Martin Marietta), the owner of the quarry, as a requirement for the State of Colorado, Permit Number M-74-004. The structural geology evaluation presented herein includes observations and measurements from the quarry that have been obtained annually by Lachel staff over the past 24 years (1997-2021), as well as results of the detailed geotechnical investigation conducted by Lachel in 2003.

2.0 PURPOSE AND SCOPE OF WORK

The purpose of the annual evaluation is to monitor the influence the bedrock structural geology has on pit wall stability as mining progresses. The data collected during this annual assessment was obtained during site visits in June 2021 and December 2021.

The scope of this study is as follows:

- Observe recent rock mass exposures for large-scale instability and collect geologic rock structure data.
- Document the orientation and character of rock mass discontinuities (e.g. joints, foliations, faults) where recent exposures are accessible to supplement the existing structural geology database.
- Document groundwater observations at mapped locations.
- Photograph significant findings at the mapped rock mass exposures and discontinuity conditions.
- Compare the new rock structure data collected during site visits in 2021 with the previously collected data to identify potential changes to the previously analyzed discontinuity sets and possible new sets that may need to be considered for the mine highwall structural discontinuity analysis.
- Based on the new rock structure data, update the rock structural discontinuity analyses for the final mine highwall slopes.
- Summarize the field observations, mapping data, and structural discontinuity analyses results in an annual report.

3.0 LOCATION AND GEOLOGIC SETTING

The Spec-Agg Quarry is located to the north of Interstate 70 near Jackson Gulch on the east flank of the Rocky Mountain Front Range, approximately 3 miles south of downtown Golden, Colorado (Figure 1). The natural topography of the property increases significantly in elevation to the west, with elevations within the planned mining pit area that vary from approximately EL 6,425 feet (ft) along the mine's eastern boundary to EL 7,110 ft on the western boundary (Figures 1 and 2).

This region of the Rocky Mountain Front Range was deformed during the Laramide orogeny in the late Cretaceous and early Tertiary periods. The gneissic bedrock within the quarry is believed to have undergone two to three episodes of deformation during Precambrian time (Gable, 1968). During this time, the bedrock material was intruded by several distinct igneous bodies and dikes. The gneisses are mapped as a series of folds, which are oriented roughly east-west, and have been broken and displaced by faults believed to range in age from Precambrian to Tertiary.

The bedrock within the mined portions of the quarry is mapped as migmatitic quartzo-felspathic gneiss with intrusions of granitic pegmatite veins (Scott, 1972). The granitic gneiss found in the quarry is generally hard and relatively competent. The gneiss varies in color from grayish orange to dark gray, with occasional banding visible along the foliation of the rock. The term foliation refers to the realignment of minerals into a parallel orientation as a result of the intense heat and/or pressure of metamorphism. The rock mass tends to be weakest along the foliation planes, which ultimately results in a discontinuity set parallel to the orientation of the foliation. The foliation orientation is the most prominent discontinuity set identified in the quarry. The foliation undulates across rock exposures in some locations. The rock mass also exhibits several other joint sets that are locally prominent and varied with elevations as mining progress to lower elevation. However, the joints are generally not as regular or as laterally continuous at the foliation.

Two regional fault orientations, trending approximately east-west and north-south, have been mapped within the property by others (Gable, 1968; Scott 1972), and multiple fault orientation measurements have been recorded in our site visits over the years, as shown in Figure 3.

An approximately east-west trending fault is mapped by Gable (1968) across the northern margin of the quarry. This fault is exposed in the northern portion of the main quarry pit (Figure 3).

A second approximately east-west trending fault was previously identified in Jackson Gulch (informally named the Jackson Gulch fault). However, this fault is not mapped due to the uncertainty in the orientation of the fault trace.

A mapped reverse fault trending roughly north-south is located within the quarry property and constitutes the boundary between the metamorphosed Precambrian bedrock to the west and the Pennsylvanian sedimentary rocks to the east (Smith, 1964; Scott, 1972). The quarry property straddles this boundary, with the majority of the processing plant and the entire asphalt plant located east of the fault (Figure 3). The bedrock material east of the fault is dominantly composed of upturned sandstones and shales of the Fountain Formation (Scott, 1972). West of this fault, the material is mapped as migmatitic quartzo-felspathic gneiss with intrusions of granitic pegmatite veins (Scott, 1972).

Two other approximately north-south trending faults have been exposed in the northern quarry walls, as shown on Figure 3 and discussed in our 2013 report (Lachel, 2013). They roughly parallel the Golden

Fault, which is a major fault that forms the north-northwest trending hogback immediately east of the quarry property. These two faults remain unchanged since there are no mining activities in the main pit area.

In the Southern Expansion Area, Gable (1968) mapped a third fault that also trends roughly east-west (Figure 3). This fault was initially exposed during the 2006 investigation, and was noted by a distinct pegmatite vein that was surrounded by decomposed weak biotite rich gneiss. The fault was exposed in temporary excavation walls along the southwestern and southern margin of the Southern Expansion Area during previous year site visits. There were no apparent large shear zones observed in this report year. However, previous GPS measurements taken along the margin of the fault exposure were registered in Google Earth to the existing fault map yielding a good match with the previously mapped trace (Figure 3).

4.0 MINING PLAN AND PROGRESS

Mining activities have typically been focused in two distinct areas: the Main Pit and the Southern Expansion Area (Figure 2). It is our understanding that minimal or no mining activity has occurred in the Main Pit Area since the last report with the exception of minimal pumping of the impounded water.

Significant mining activity has taken place in the Southern Expansion Area since our last annual report and between our June 2021 and December 2021 site visits (Photos 1 to 3). The mining is being accomplished with three active temporary benches with reclamation occurring in stages following excavation along permanent benches. The uppermost bench exists near the western margin of the Southern Expansion Area (see Stations 22-01 and 22-02 in Figure 2). The next bench to the east is in the vicinity of Station 22-05 (Figure 2). The lowest bench observed during our June 2021 and December 2021 site visit is in the vicinity of Stations 22-03 and 22-06 (Figure 2) and is at approximately EL 6,545 ft, based on GPS measurement and information provided by on-site personnel. Each bench appears to be approximately 35 feet lower than the bench to its west.

Based on the current mine plan developed by Martin Marietta (formerly Lafarge West, Inc.) in December, 2003, and the current Colorado Division of Minerals and Geology mine plan, we understand that the mine will eventually be excavated to an approximate final mine floor elevation of EL 6,200 ft as approved in the permit. The orientations of the final planned highwalls are the basis for our rock structural discontinuity assessment, as discussed in Section 6.0.

5.0 FIELD OBSERVATIONS

Field observations for the 2022 Annual Report consisted of rock structure mapping and the collection of information regarding areas of visible, large-scale instability; seepage; and mining activity. Observations for the current annual report were made during two site visits, which took place in June 2021 and December 2021.

During our visits, we performed rock structure mapping to collect representative discontinuity measurements from recently mined rock exposures in the Southern Expansion Areas (Figure 2; Photos 1 through 3). Orientation measurements (i.e., dip/dip direction) of joints, foliation, and faults were taken from the faces of advancing benches. A geological compass was used to obtain discontinuity measurements by sighting along the discontinuity surfaces. A handheld GPS was used to record the location of data collection points (Figure 2).

A total of 77 discontinuity measurements were collected in 2021 at five (5) data collection points (Figure 2), and were added to the measurements from previous years. When combined with data collected from previous annual reports (1997-2002, 2004-2021) and with borehole geophysical data collected during the 2003 geotechnical investigation, a total of 3,866 discontinuity orientation measurements have been obtained over the past 24 years. Figure 5 presents these data. Figure 6 shows the 77 discontinuity orientation measurements collected for this annual report overlain on a contour stereonet plot of the entire SpecAgg structural dataset.

During our 2021 site visits, no major shear zone or fault exposure along the temporary excavation walls in the Southern Expansion Area were observed. Localized small scale shear zones were observed at approximately Station 22-05 and Station 22-06. The localized shear zones at Station 22-05 were oriented approximately north-south with a high angle dip to the west and were exposed in the north to northwest facing temporary wall of the Expansion Area. The localized shear zone consisted of yellowish-brownish weathered, broken granitic rock, with parallel close spaced fractures. The localized shear zone near approximately Station 22-06 (Figure 2, and Photo 3) was observed in a southwest-southeast orientation with a high angle dipping to the north along the southwest-west temporary excavation wall. These shear zones are likely localized and not associated with previously reported faults. Previous fault measurements are shown in Figure 4.

Minor raveling conditions resulting from rock fragmentation during blasting and subsequent freeze/thaw conditions exist along each wall in the quarry, but appear more prevalent along the south wall possibly due to the north facing exposure.

The quarry walls observed during the 2021 site visits appeared to be relatively dry; with the exception of minor seepage visible in the southwest corner of the Main Pit, which has been documented in the past. Other than minor seepage observed along the temporary access road to the Southern Expansion Areas, no major seepage was observed. Additionally, we observed impounded water in the Main Pit floor (Photo 4). It is our understanding that there has been intermittent pumping of the impounded water to maintain water level during the past year.

After planar failure along foliation planes in 1998 and 1999, the overall effective angle of the last three benches of the Northeast Wall 1 and the Northwest Wall were reduced to an overall angle of 35°, which is consistent with the 2003 Lachel geotechnical evaluation (Lachel, 2003). The failure surfaces (i.e., the

surfaces along which movement has occurred) remain at a “residual strength” and therefore are less resistant to additional loading. Based on visual inspection from the access road and bottom of the pit, these slopes did not appear to show signs of additional movement during the site visits for this study (Photo 5). Although the slope configuration is currently stable, the failure mechanism could potentially be reactivated, resulting in movement of additional material. The Northwest Wall, Northeast Wall 1, and Northeast Wall 3 (Figure 2) should continue to be visually monitored for indications of instability.

6.0 ANALYSIS OF STRUCTURAL DISCONTINUITIES

The stability of the rock mass that forms the quarry walls is primarily controlled by the presence of rock discontinuities, such as joints, foliation, and faults. Discontinuities can create surfaces for toppling, sliding, and the intersections of multiple discontinuities can define the boundaries of wedges or blocks that have the potential to slide. The orientations of discontinuity sets vary considerably throughout the quarry. Therefore, it is possible that discontinuity orientations in a specific location of the quarry could deviate from the discontinuity orientations assumed for the analyses presented in this report.

6.1 Evaluation of Discontinuity Measurements

Representative discontinuity orientations for the quarry walls are required in order to evaluate the stability of the rock mass that forms the mine walls. Representative orientations for each discontinuity set observed were developed by analyzing the thousands of measurements collected since the beginning of the project. For the 2022 Annual Report, we evaluated how the data collected over the past year compares with the previous geologic structure dataset and the representative orientations of observed discontinuity sets previously selected for analysis. Using this approach, we are able to assess possible emerging trends related to the shift in orientation of the various observed discontinuity sets as more of the rock mass is exposed during mining operations.

We analyzed the discontinuity orientation data using DIPS 8.0 (Rocscience, 2020). The program enables plotting of individual data points, and offers several methods of data analysis, including contouring and cluster analyses.

We plotted the individual data points collected during the June 2021 and December 2021 site visits over contours for the entire dataset (from all previous years), and alongside representative discontinuity orientations used for the previous 2021 annual report (Figure 5). We also plotted this year's individual data points over contours for just this year's data (Figure 6). These figures show that the latest data is generally consistent with the representative orientations of discontinuity sets observed in previous years. Joint set P-6 has emerged over more recent years. A foliation set F3 was identified in previous years (prior to 2013), but has not been observed in the past seven (7) years. Joint set P-5 was not observed this year and has not been observed since 2019. Joint set P-7 was identified in the 2013 report and was again observed at a few locations this year. A few localized joint data points identified in the previous reports (2017-2021) were observed again this year, but there are not a sufficient number to form a cluster. These joints may be localized and varied with elevation. We will continue to monitor for the presence of these joint trends during next year's study. Generally, joint sets P-1, P-2, and P-3 are the dominant joint sets observed this year (Figure 6). Arrows shown in Figure 6 indicate the shifts in representative orientations of the observed discontinuity sets based on our evaluation of the new data acquired during the 2022 report year.

Ultimately, a total of eight (8) discontinuity sets (two foliation sets and six joint sets) were identified and analyzed for this annual report's structural discontinuity analysis. The discontinuity orientations are shown in Figure 7 and summarized in Table 1 below.

Table 1: Representative Discontinuity Orientations

Discontinuity Set	Representative Orientation (Dip/Dip Direction)		
	2020 Annual Report	2021 Annual Report	2022 Annual Report
F-1 (Foliation)	33°/171° (unchanged)	33°/171° (unchanged)	33°/171° (unchanged)
F-2 (Foliation)	22°/300° (unchanged)	22°/300° (unchanged)	22°/300° (unchanged)
F-3 (Foliation)	Not observed	Not observed	Not observed
P-1 (Joint)	70°/174°	72°/171°	72°/174°
P-2 (Joint)	59°/084°	60°/083°	58°/085°
P-3 (Joint)	68°/256° (unchanged)	68°/256° (unchanged)	68°/256° (unchanged)
P-4 (Joint)	74°/299°(unchanged)	74°/299°(unchanged)	74°/299°(unchanged)
P-5 (Joint)	Not Observed	Not Observed	Not Observed
P-6 (Joint)	61°/025° (unchanged)	63°/029°	63°/029° (unchanged)
P-7 (Joint)	61°/215° (unchanged)	61°/215° (unchanged)	61°/215° (unchanged)

6.2 Slope Geometry

Wall orientations used in this report are based on the mine plan developed by Martin Marietta in December, 2003 (Figure 2). The wall designations, slope angles, and slope dip directions used to represent the final quarry walls are presented in Table 2 below.

Table 2: Representative Quarry Wall Orientations

Wall Designation	Slope Angle ⁽¹⁾	Slope Direction of Wall ⁽²⁾
East Wall 1	45°	242°
East Wall 2	45°	270°
Northeast Wall 1	35°	175°
Northeast Wall 2	45°	225°
Northeast Wall 3	45°	176°
Northwest Wall	35°	151°
West Wall 1	45°	091°
West Wall 2	45°	120°
West Wall 3	45°	091°
Southwest Wall 1	45°	016°
Southwest Wall 2	45°	036°
South Wall	45°	000°
Southeast Wall	45°	335°

Notes:

- 1 Slope angles are measured relative to the horizontal.
- 2 Slope orientations are presented as dip directions measured from true north (0°).

6.3 Friction Angle

A representative angle of friction ($\phi + i$) = 33° was used for our kinematic analysis, where “ ϕ ” is the basic friction angle and “ i ” is the surface roughness angle (Hoek and Bray, 1977). The surface roughness angle is the angle between the basic plane of the joint and the planes representing the surface of undulations on the joint surface. This value was based on the results of the direct shear testing performed as part of the 2003 geotechnical investigation (Lachel, 2003). The test results produced only a basic friction angle, ϕ , and results indicated that the basic friction angle of the discontinuities ranged from 13.7° to 49.3° with a mean value of 28°. These results do not include the two direct shear tests conducted on samples with clay material along the foliation plane, which produced an average friction angle of 5°. A generally accepted and conservative value of 5° was selected for the surface roughness angle, “ i ”.

6.4 Kinematic Analysis

We performed kinematic structural discontinuity analyses for each of the representative quarry wall orientations presented in Table 2. The analyses were performed to evaluate potential rock slope failure modes controlled by planar rock mass discontinuities based exclusively on the geometric relationships of the discontinuities measured. Potential rock slope failure modes include sliding of wedges formed in the slope by the intersection of two discontinuity planes, sliding of rock blocks along a single planar discontinuity, and toppling rock blocks. The computer program DIPS 7.0 (Rocscience, 2018) was used for the kinematic stability analysis. Inputs for the analyses include the following:

- 1) Representative discontinuity orientations (dip and dip direction) determined from all previous years’ data and updated utilizing data collected during the 2021 site visits (Table 1).
- 2) Mine Slope Orientations (dip and dip direction) as presented in Table 2 and shown in Figure 2. A total of 13 slope orientations were considered.
- 3) Estimated Rock Mass Discontinuity Interface Friction Angle. A typical interface friction angle of 33 degrees was considered in all cases for the kinematic analysis, as discussed in Section 6.3.

The kinematic analysis stereonet plots are presented in Figures 8 through 15. Representative discontinuity orientations are shown as green lines. The orientation of the slope face for the considered wall is shown as an orange great circle. The friction circle is shown as a black line. The limits of the “critical zone” are defined by the area of overlap between the friction circle and the great circle representing the plane of the slope face and is shown as a light orange shaded area. Each kinematic analysis plot is evaluated based on where discontinuities plot in relation to the critical zone.

6.4.1 Potential Failure Modes

6.4.1.1 Planar Failure

The following four conditions, defined by Hoek & Bray (1977) and Wyllie & Mah (2004), must be met in order for planar failure to occur:

- 1) The plane on which sliding occurs must strike parallel or nearly parallel to the slope face. Typically, discontinuity planes with a dip direction within 30 degrees of the slope dip direction are considered.

- 2) The failure plane must “daylight” in the slope face (i.e., the dip of the failure plane must be smaller than the dip of the slope face).
- 3) The dip of the failure plane must be greater than the angle of friction of the plane.
- 4) Release surfaces, which provide negligible resistance to sliding, must be present in the rock mass to define the lateral boundaries of the slide.

On the stereonet, criteria for planar sliding are satisfied when the dip vector of a discontinuity plots within the critical zone (and the dip direction of the discontinuity plane is within 20 degrees of the slope dip direction).

6.4.1.2 Wedge Failure

Wedge failure is characterized by sliding that occurs along the line of intersection of two discontinuities (Hoek & Bray, 1977). According to the analysis method developed by Markland (1972), a wedge failure can occur when the following criteria are satisfied:

- 1) The plunge of the lines of intersection is less than the dip of the slope face.
- 2) The plunge of the lines of intersection exceeds the angle of friction.

On the stereonet, Markland’s criteria for wedge sliding are satisfied when the intersection of two discontinuities plot within the critical zone.

6.4.1.3 Toppling Failure

Toppling failures can occur where planes share a similar dip direction to the slope face and where they dip relatively steeply into the slope face. In our opinion, toppling failure is not likely to be associated with large-scale instability on the scale of an entire mine highwall at the existing and currently-planned slopes. Therefore, toppling was not considered in our kinematic analysis. However, small-scale toppling failures are likely to occur locally in the temporary walls (vertical wall of each bench) since a majority of the joints exposed in this assessment are steeply inclined.

6.4.2 **East Walls**

For the 2022 Annual Report, we analyzed two east wall orientations based on the locations shown in Figure 2 and Table 2: East Walls 1 and 2 corresponds to the same wall location and orientation analyzed in the previous 2013-2021 annual reports (Figure 2). There is currently mining activity (near Stations 22-03 and 22-06) in the east walls area.

The stereonet plots for East Walls 1 and 2 each show one discontinuity intersection that falls within the failure envelope, suggesting that wedge failure is kinematically possible for these slope orientations (Figure 8). The intersecting set that may result in wedge failure are joint sets P-5 and joint P-7.

The development and size of these wedge failures will be controlled by the variability and limited lateral extent of the discontinuities. Based on the current and previous years’ data sets, these two joint sets (P-5 and P-7) have weak signatures represented by relatively few measured orientations and no measurements of P-5 this year (Figure 6). As excavation proceeds in the vicinity of the eastern walls, additional measurements are needed to refine the representative discontinuity orientations of these joint and foliation sets in this area to evaluate their potential to contribute to large-scale slope failure modes.

As shown in Figure 8, the stereonet plot for East Walls 1 and 2 do not indicate the possibility of planar failure.

6.4.3 Northern Walls

For the 2022 Annual Report, we analyzed four northern wall orientations based on the locations shown in Figure 2 and Table 2: Northeast Walls 1 through 3, and the Northwest Wall correspond to the same wall locations and orientations analyzed in the previous 2013-2021 annual reports (Figure 2). There is currently no mining activity in the northern walls area.

The stereonet plot for Northeast Wall 1 indicates a potential planar failure mode along foliation F-1 for this slope orientation (Figure 9). This is the same foliation orientation that was believed to contribute to the 1998 slope instability (Photo 5). The stereonet plot for Northeast Wall 1 also shows one discontinuity intersection that falls within the failure envelope, suggesting that wedge failure is kinematically possible for this slope orientation (Figure 9). The intersecting sets that may result in wedge failure include foliation F-1 and joint set P-3.

The stereonet plot for Northeast Wall 2 shows one discontinuity intersection that falls within the failure envelope, suggesting that wedge failure is kinematically possible for this slope orientation (Figure 9). The intersecting sets that may result in wedge failure are foliation F-1 and joint set P-3. As described above, the development and size of wedge failures will be controlled by the variability and limited lateral extent of the discontinuities. If excavation proceeds in the vicinity of the northeastern walls, additional measurements are needed to refine the representative discontinuity orientations of these joint and foliation sets in this area to evaluate their potential to contribute to large-scale slope failure modes. Currently there is no additional excavation planned near the northeastern wall. Planar failure is not indicated in the stereonet plot for Northeast Wall 2.

The stereonet plot for Northeast Wall 3 indicates a potential planar failure mode along foliation F-1 for this slope orientation (Figure 9). This is the same foliation orientation that was believed to contribute to the 1998 slope instability. The stereonet plot for Northeast Wall 3 shows two discontinuity intersections that fall within the failure envelope, suggesting that wedge failure is kinematically possible for this slope orientation (Figure 9). The intersecting sets that may result in wedge failure are foliation F-1 and joint set P-3, and joint sets P-2 and P-7. Based on the current and previous years' data sets, joint set P-7 has weak signatures represented by relatively few measured orientations representing these features (Figure 6). The Northeast Wall 3 was not accessible for direct measurements or observations during our site visits. Additional measurements and observations are needed to assess the potential for large scale planar sliding along foliation F-1 as excavation continues to extend below Northeast Wall 3 in the future (there is currently no mining activity in this area).

The stereonet plot for the Northwest Wall shows a potential planar failure mode along foliation F-1 for this slope orientation and one discontinuity intersection that falls within the failure envelope, suggesting that wedge failure is kinematically possible for this slope orientation (Figure 10). The intersecting sets that may result in wedge failure are joint sets P-2 and P-7. Based on the current and previous years' data sets, joint set P-7 has weak signatures represented by relatively few measured orientations representing these features (Figure 6). Furthermore, even a slight variability of the orientation of joint sets P-2, P-7 and foliation F-1 would create the potential to form wedges within the critical zone for this wall.

For the previous 2004 analysis (Lachel, 2004), the long-term impact of foliation F-1 on the stability of the northern walls was further investigated using discontinuity data that included elevation information for the foliation orientation. This data was plotted on a chart showing dip angle in degrees versus elevation in feet (for chart see Lachel, 2004). The data resulted in an increase in the number of daylighting foliation planes that start at EL 6,325 ft and continue with increased frequency to below the planned final pit elevation. Due to the possibility of a lower friction angle along the foliation plane (as low as 5°, average 28°) as determined from the 2003 Geotechnical Study (Lachel, 2003), the potential exists for future instabilities to occur on the northern walls as the pit is excavated to its final depth. These shallow dipping discontinuities along the foliation can have a significant impact on the stability of the north wall and should be monitored closely as future excavation progresses. As discussed previously, an east-west striking unnamed fault zone was previously exposed in the northwest corner of the Main Pit. In addition, a north-south trending fault has been newly mapped based on our observations from site visits in 2013. Due to the presence of faults and potentially adverse discontinuity orientations on the northern walls, the slopes should be closely monitored as mining continues in the future.

6.4.4 West Walls

For the 2022 Annual Report, we analyzed three west wall orientations based on the locations shown in Figure 2 and Table 2: West Wall 1, West Wall 2, and West Wall 3. The wall locations and orientations correspond to the same wall locations and orientations analyzed in previous 2013-2021 annual reports (Figure 2). There is currently no mining activity in the west walls area except near West Wall 3 (Stations 22-01 and 22-02).

The stereonet plot for West Wall 1 (Figure 11), adjacent to the Main Pit area, shows a discontinuity intersection that falls within the failure envelope, suggesting that wedge failure is kinematically possible for this slope orientation (Figure 11). The intersecting sets that may result in wedge failure are joint sets P-1 and P-6. Based on the current and previous years' data sets, joint sets P-1, P-2, and P-3 are the dominant joint sets observed in the Southern Expansion Area (Figure 6) in the recent years. Joint set P-6 has a weak signature represented by relatively few measured orientations representing this feature (Figure 6). Planar failure is not indicated in the stereonet plot for the West Wall 1 (Figure 11).

The stereonet plot for West Wall 2, adjacent to the access road in the Southern Expansion Area, shows two discontinuity intersections that fall within the failure envelope, suggesting that wedge failure is kinematically possible for this slope orientation (Figure 12). The intersecting sets that may result in wedge failure include joint sets P-2 and P-7 and joint sets P-1 and P-6. Based on the current and previous years' data sets, joint set P-7 has a weak signature represented by relatively few measured orientations representing this feature (Figure 6). Planar failure is not indicated in the stereonet plot for West Wall 2 (Figure 12).

The stereonet plot for West Wall 3 shows a discontinuity intersection that falls within the failure envelope, suggesting that wedge failure is kinematically possible for this slope orientation (Figure 12). The intersecting sets that may result in wedge failure are joint sets P-1 and P-6. Planar failure is not indicated in the stereonet plot for the West Wall 3 (Figure 12).

The development and size of wedge failures will be controlled by the variability and limited lateral extent of the discontinuities. As excavation proceeds in the west walls area, additional measurements are

needed to refine the representative discontinuity orientations of these joint and foliation sets in this area to evaluate their potential contribute to large-scale slope failure modes.

6.4.5 Southern Walls

For the 2022 Annual Report, we analyzed four southern wall orientations based on the locations shown in Figure 2 and Table 2: Southwest Walls 1 and 2, the South Wall, and the Southeast Wall. The wall locations and orientations for all four southern walls correspond to the same wall locations and orientations analyzed in previous 2013-2021 annual reports (Figure 2). Current mining activities are mainly in the southern walls area. The current temporary benches are being advanced to approximately EL 6,475 ft (Figure 2, Stations 22-03 and 22-06).

The stereonet plots for the Southwest Wall 1, Southwest Wall 2, and South Wall show one discontinuity intersection that falls within the failure envelope, suggesting that wedge failure is kinematically possible for this slope orientation (Figures 13 and 14). The intersecting sets that may result in wedge failure are joint sets P-2 and P-4. Based on the current as well as previous year's data set, joint set P-4 has a weak signature represented by relatively few measured orientations representing this feature (Figure 6). Planar failure is not indicated in the stereonet plot for these three walls (Figures 13 and 14).

The stereonet plot for Southeast Wall shows two discontinuity intersections that fall within the failure envelope, suggesting that wedge failure is kinematically possible for this slope orientation (Figure 15). The intersecting sets that may result in wedge failure are joint sets P-2 and P-4 and joint sets P-3 and P-6. Based on the current and previous years' data sets, joint sets P-4 and P-6 have weak signatures represented by relatively few measured orientations representing these features (Figure 6). Additional measurements and observations are needed to assess the potential wedge formed by joint sets P-3 and P-6 as excavation continues to extend below Southeast Wall in the future.

As described above, the development and size of wedge failures will be controlled by the variability and limited lateral extent of the discontinuities. As excavation proceeds in the vicinity of the southern walls, additional measurements are needed to refine the representative discontinuity orientations of these joint and foliation sets in this area to evaluate their potential contribute to large-scale slope failure modes.

7.0 CONCLUSIONS AND RECOMMENDATIONS

The results of the structural geologic evaluations and kinematic structural discontinuity analyses for the Spec-Agg Quarry do not indicate any immediate concerns with respect to large-scale instabilities in the current final quarry wall faces based on our field observations and current rock mass assumptions. The stability of the slopes is enhanced by the absence of significant hydrostatic pressure, by current mining procedures, and by the current reclamation process being implemented by Martin Marietta at the site. While large-scale failures are not anticipated, the slopes will likely continue to experience minor raveling as a result of small-scale failures (planar or wedge failure), particularly in near-vertical temporary bench faces prior to reclamation.

For the 2022 Annual Report, kinematic analyses are based on discontinuity measurements derived principally from data collected from the historic dataset supplemented with data collected during the June 2021 and December 2021 site visits. The 2022 analysis is not intended to supersede results of analyses performed for prior years. Rather, they are meant to compliment previous years' analyses and enable monitoring of possible new trends in the data that could result in previously unconsidered failure modes.

In general, the data collected during the 2021 site visits correspond reasonably well with representative discontinuity orientations used in previous reports; we have not noted any major difference that will change our kinematic analyses for the 2022 Annual Report.

The kinematic analysis for East Walls 1 and 2; Northeast Walls 1, 2 and 3; Northwest Wall; West Walls 1, 2 and 3; Southwest Walls 1 and 2; South Wall; and Southeast Wall each indicate the possibility for wedge failures to occur. Additionally, the analysis for Northeast Walls 1 and 3 and Northwest Wall shows the potential for planar failure. The walls of the quarry in these areas should continue to be monitored closely as mining continues to assess the potential for the indicated failure modes to contribute to large-scale slope instability of a final mine highwall based on the properties, continuity, regularity, and variation in orientations of the discontinuities involved.

We also recommend that known faults are tracked and observed in new exposures to confirm orientation and character for supplemental stability analysis, as needed. We expect the southern fault identified by Gable (1968) and in previous years site visits (Figure 3) may be exposed in other locations as excavation continues in the Southern Expansion Area. Additionally, the unmapped fault generally located in the central portion of the quarry may be exposed for mapping in the future. As recommended in the previous reports, evaluations will be conducted during future investigations to assess whether or not any of the foliation sets (F-1 through F-3) are caused due to localized faulting that may have resulted in “structural regions” that have created areas in which the varying orientation of the foliation planes occur. These questions will continue to be addressed as more data is collected.

Localized raveling, especially along the south walls, is likely to continue. Continuation of the safety-minded policies already in place, which limit the height of the exposed highwalls as well as the reclamation of exposed highwalls as soon as possible following blasting and rock haulage, will aid in minimizing the potential for instabilities to occur. The quarry walls appear to be relatively dry and noticeably absent of any major seepage. However, any major changes in ground water seepage or hydrostatic conditions observed either from the quarry walls or during production drilling activities should be characterized and reported to Lachel.

Lastly, the impounded water in the Main Pit creates no immediate concerns, but a rapid drawn-down of the water level could create a potential for slope instabilities. Any plans to pump the water out of the Main Pit causing rapid drawdown of water of more than half of the current water level should be relayed to Lachel for an evaluation of the effects on the slopes’ stability.

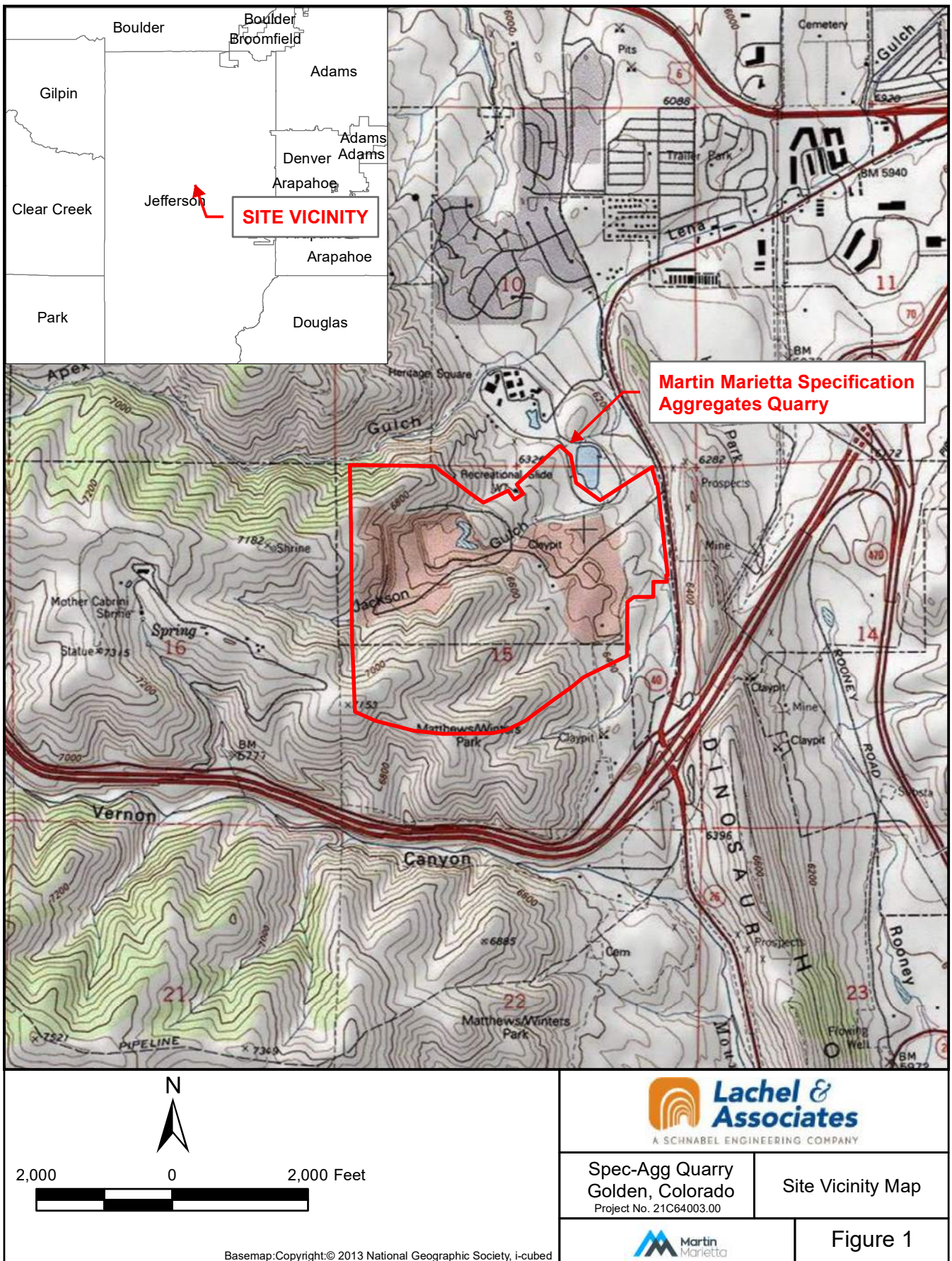
8.0 REFERENCES

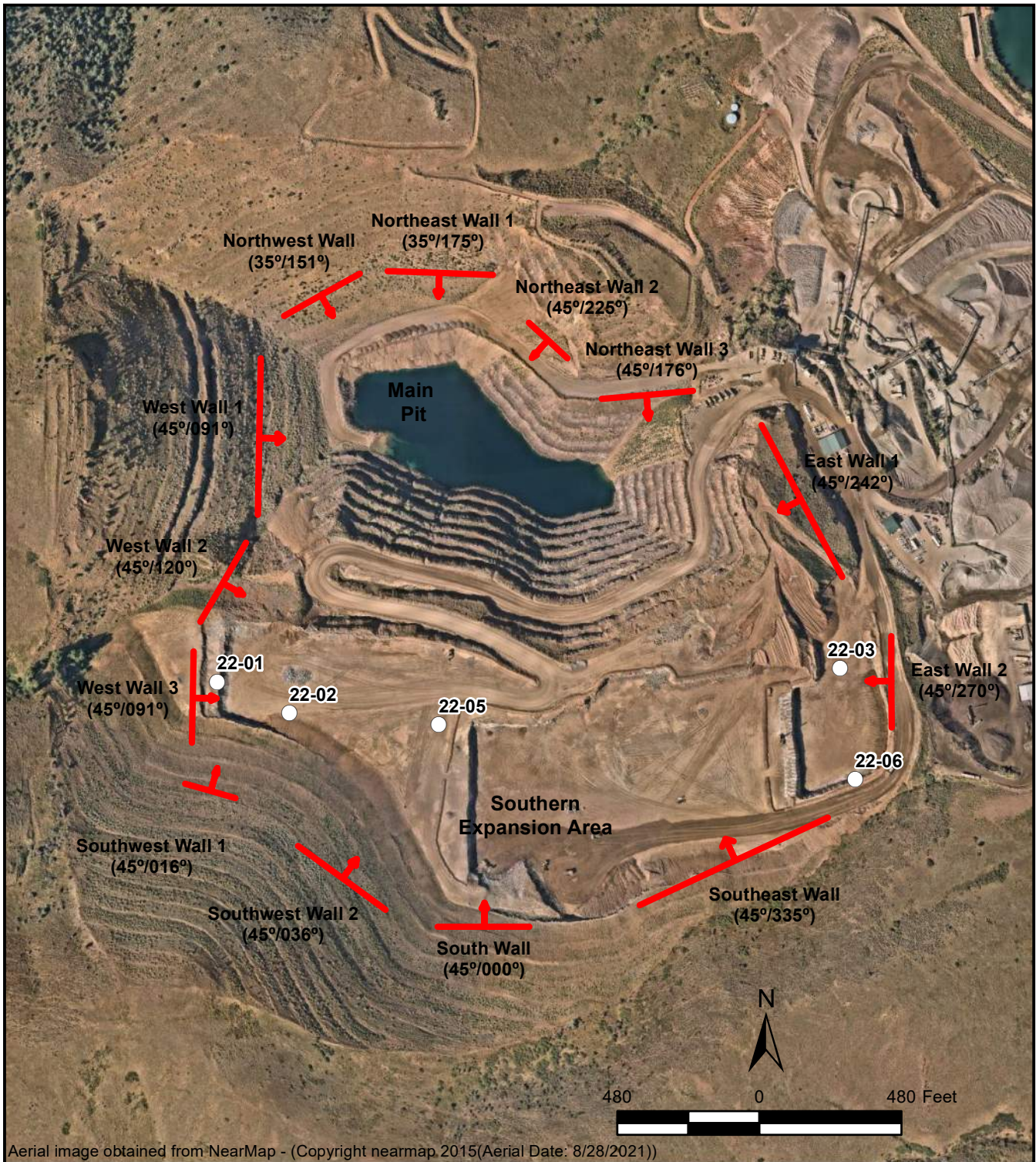
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Aerial image obtained from NearMap - (Copyright nearmap 2015(Aerial Date: 8/28/2021))

Legend



Approximate Structure Mapping Location



Planned Final Mine Wall Orientation (dip/dip direction)

Note: Topographic contours reflect the current 2003 mine plan showing the approximate final configuration of the mine wall

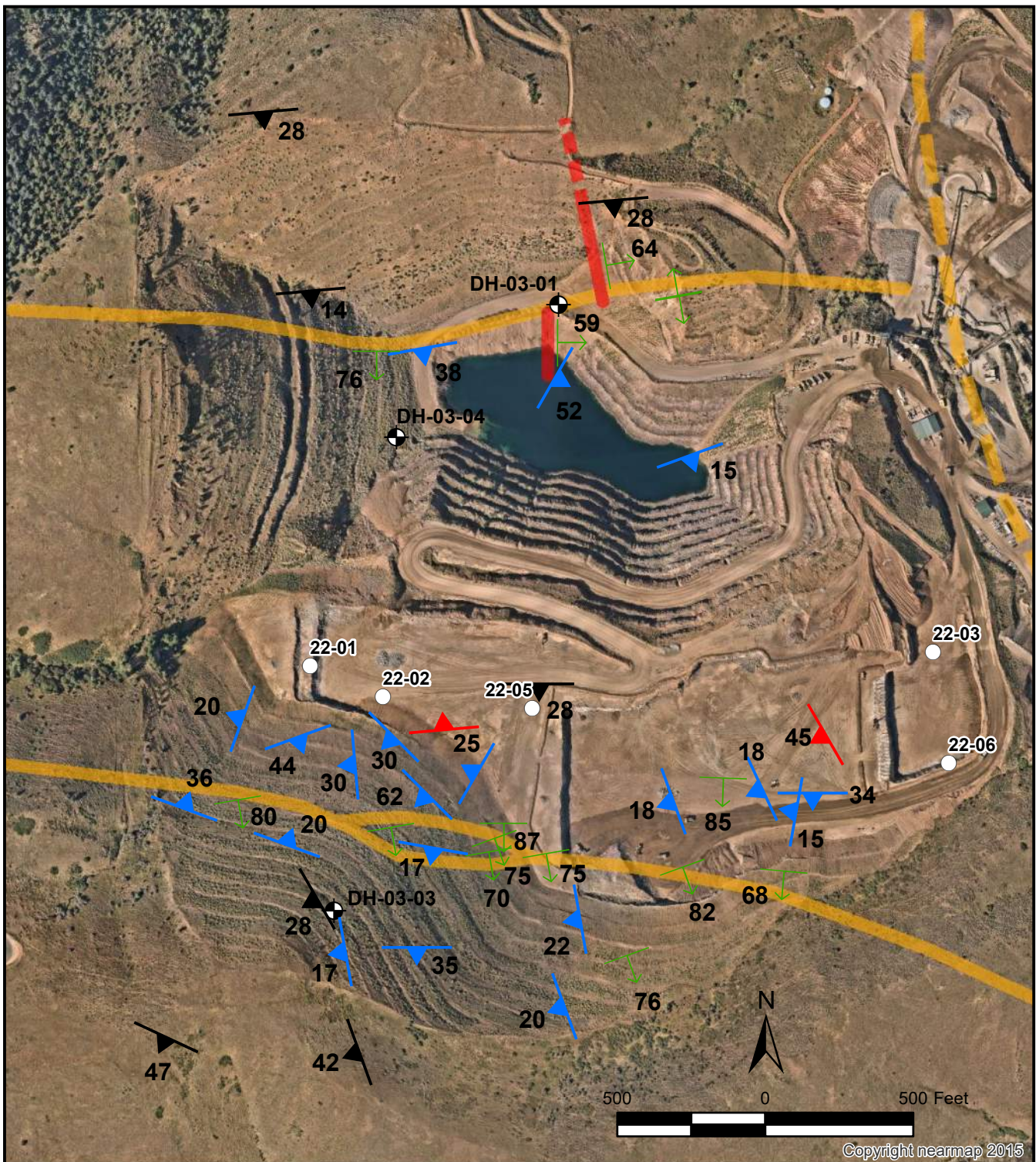


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Golden, Colorado
Project No. 21C64003.00

Mining Plan and
2021
Mapping Locations



Figure 2



- Legend**
- Approximate Fault Locations from Gable (1968) and Scott (1972)
 - Fault Observed during March 2013 Site Visit
 - ↕ Fault Strike and Dip (previous)
 - ↕ Fault Strike and Dip (this study)
 - ▲ Foliation Orientations from Gable (1968)
 - ▲ Foliation Orientations (previous)
 - ▲ Foliation Orientations (this study)
 - Borehole Drilled During 2003 L&A Investigation

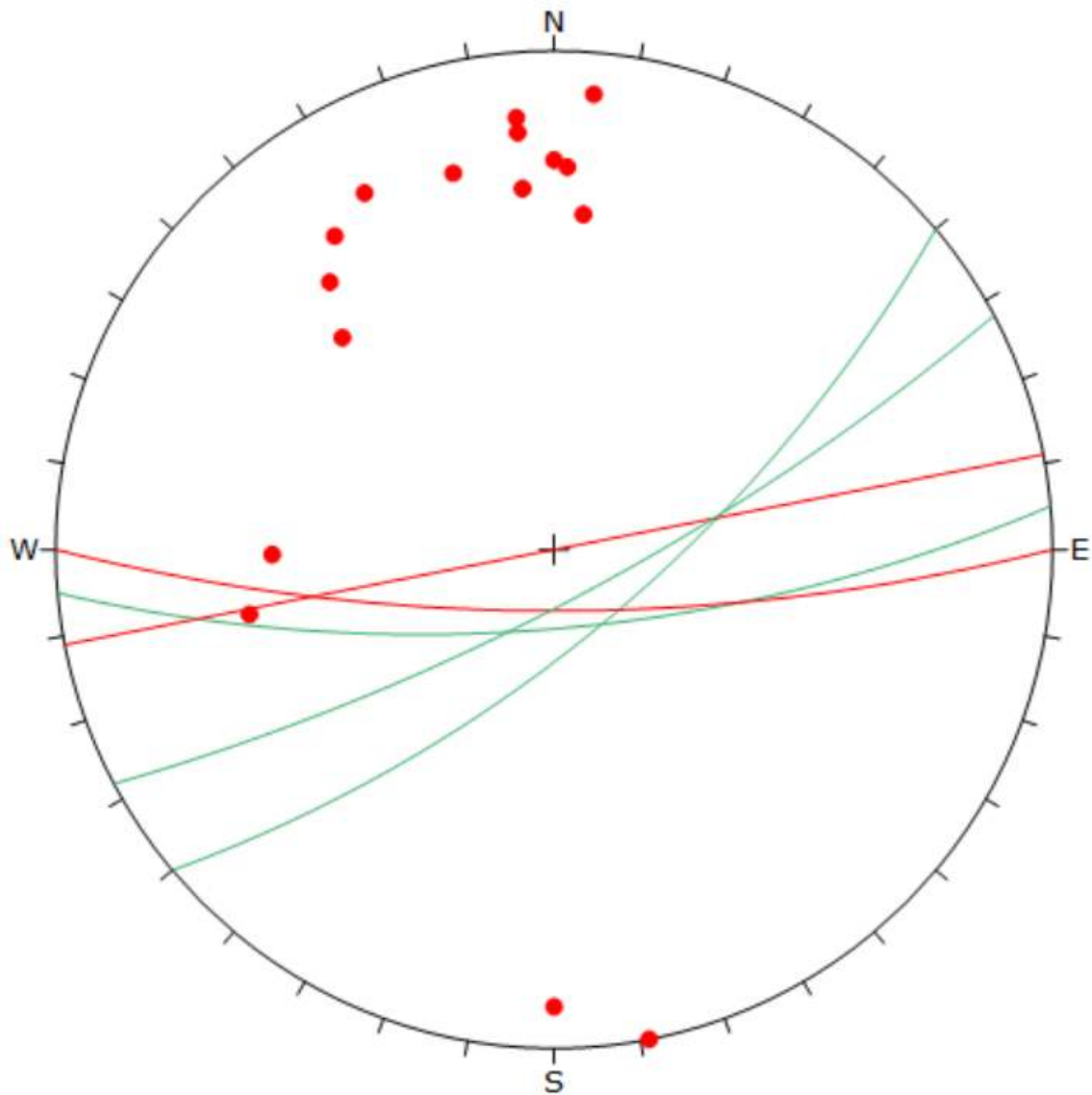


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Project No. 21C64003.00

Faults and Foliation



Figure 3



Legend

Equal Area, Lower Hemisphere Stereonet

- Previous fault measurement (pole)
- Planes representing the northern fault of Gable (1968)
- Planes representing the southern fault of Gable (1968)
- No major shear zone/fault observed for the 2022 report



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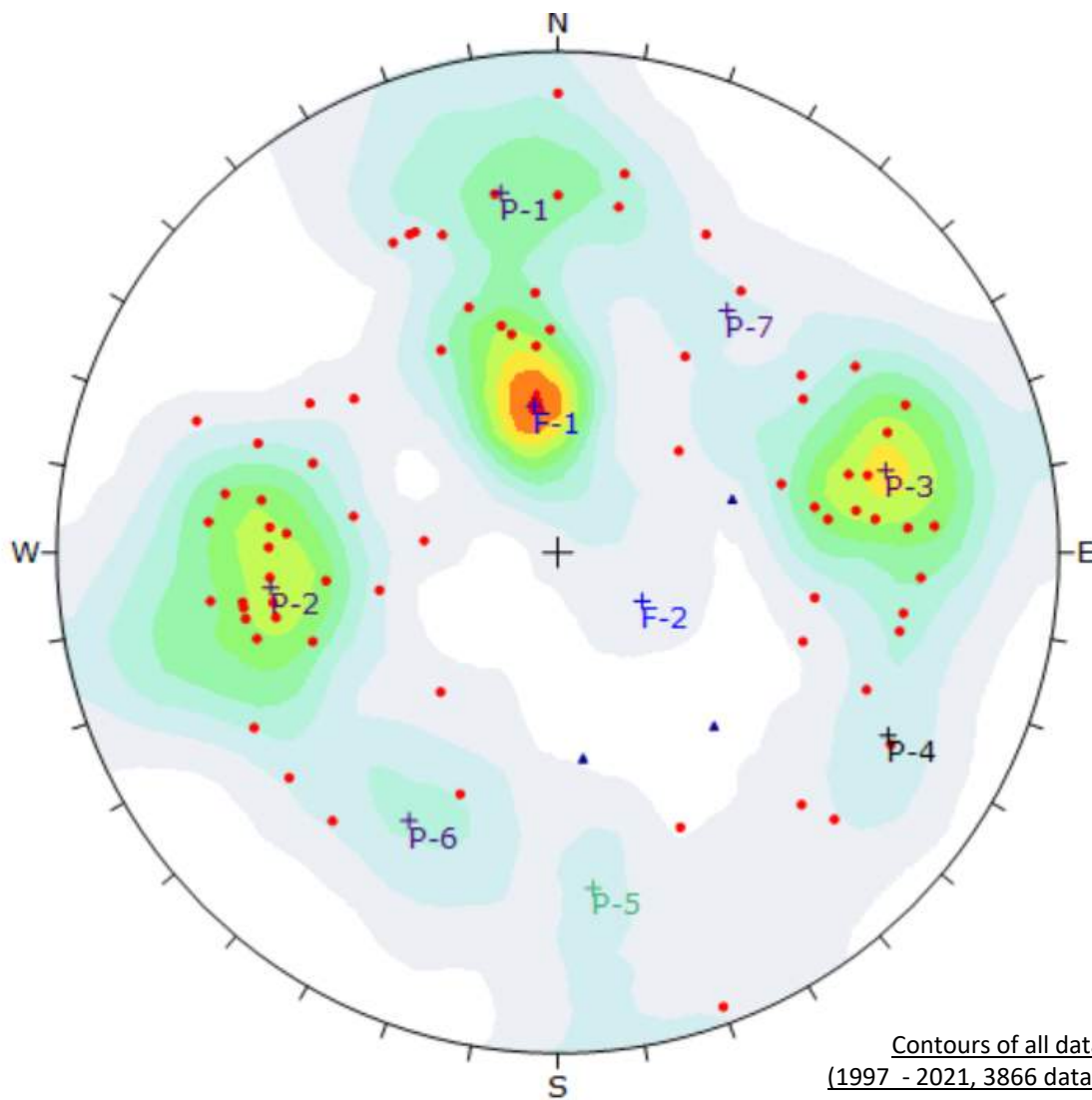
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Golden, Colorado
Project No. 21C64003.00

Fault Orientations



Martin
Marietta

Figure 4



Contours of all data
(1997 - 2021, 3866 data points)

Legend

Equal Area, Lower Hemisphere Stereonet

- ▲ Foliation measured in 2021 (06/2021 and 12/2021)
- Joint measured in 2021 (06/2021 and 12/2021)
- +P-1 Joints analyzed in Previous 2021 Annual Report
- +F-2 Foliations analyzed in Previous 2021 Annual Report

Color	Density Concentrations
	0.00 - 0.45
	0.45 - 0.90
	0.90 - 1.35
	1.35 - 1.80
	1.80 - 2.25
	2.25 - 2.70
	2.70 - 3.15
	3.15 - 3.60
	3.60 - 4.05
	4.05 - 4.50
Contour Data	
Maximum Density	4.17%
Contour Distribution	Fisher
Counting Circle Size	1.0%
Pole Vectors	

Explanation: This stereonet plot shows discontinuity measurements collected during this study as a symbolic plot overlain on a contour plot representing all discontinuity orientation data. Current discontinuity data is differentiated by discontinuity type (i.e. joints and foliations). The orientations of average joints and foliations analyzed in the previous year (2021 report which is based on 2020 data) are shown for comparison.

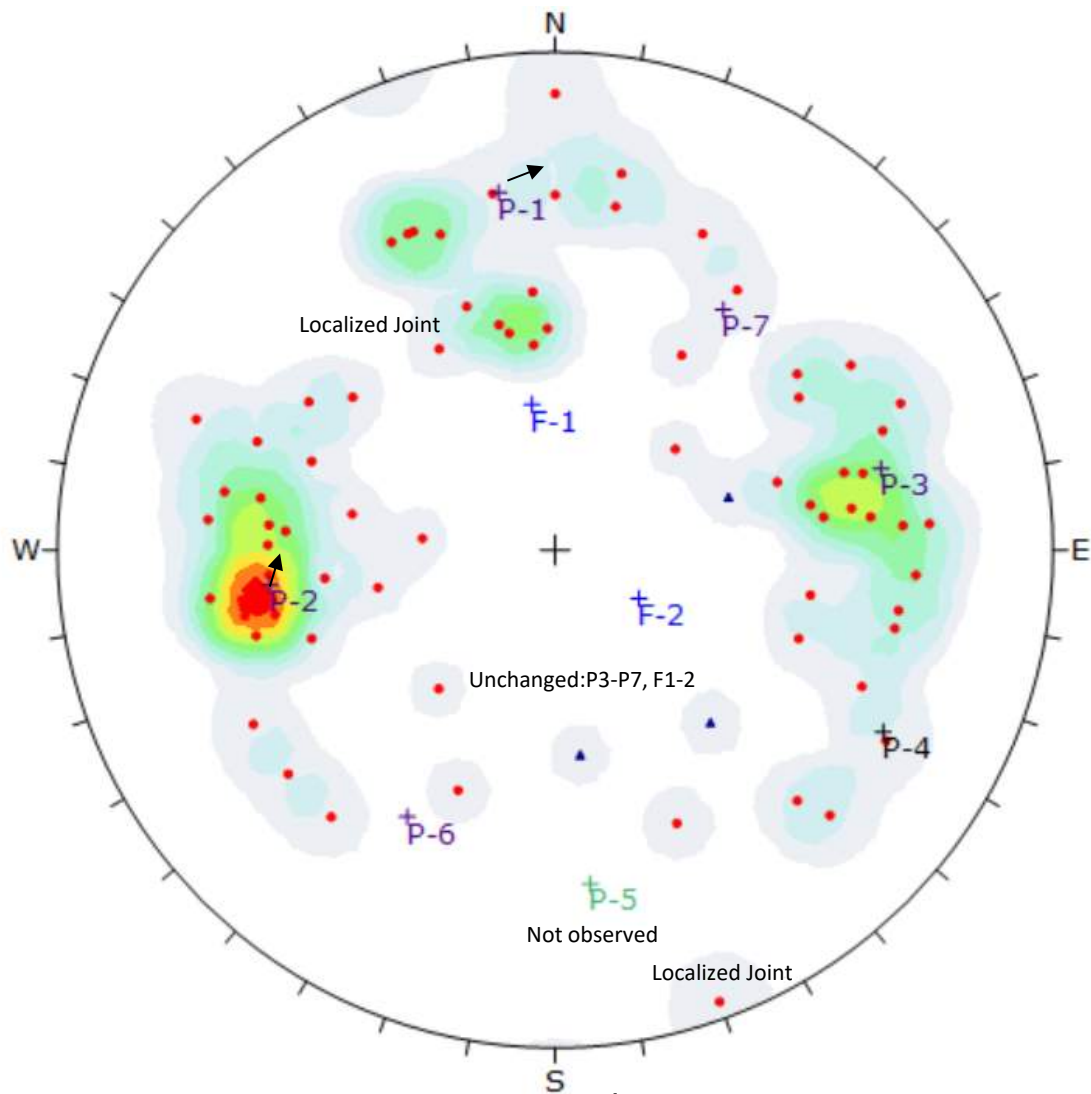


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Golden, Colorado
Project No. 21C64003.00

Contour Overlay
Plot



Figure 5



Equal Area, Lower Hemisphere Stereonet

- ▲ Foliation measured in 2021 (6/2021 and 12/2021)
 ● Joint measured in 2021 (6/2021 and 12/2021)
 P-1 Joints analyzed in Previous 2021 Annual Report
 F-2 Foliations analyzed in Previous 2021 Annual Report
 ↗ Arrow indicating relative shift in orientations based on 2021 data

Legend

Contours of current data
(77 data points)

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
Contour Data	
Maximum Density	
Contour Distribution	
Counting Circle Size	
Pole Vectors	
8.98%	
Fisher	
1.0%	

Explanation: This stereonet plot shows discontinuity measurements collected during this study. The measurements have been contoured to help visualize clustering of data. The orientations of joints and foliations analyzed in the previous year (2021 report) are shown together with arrows showing the shift in orientation of these average planes based on the current data (may not be shifted when compare with the entire dataset).



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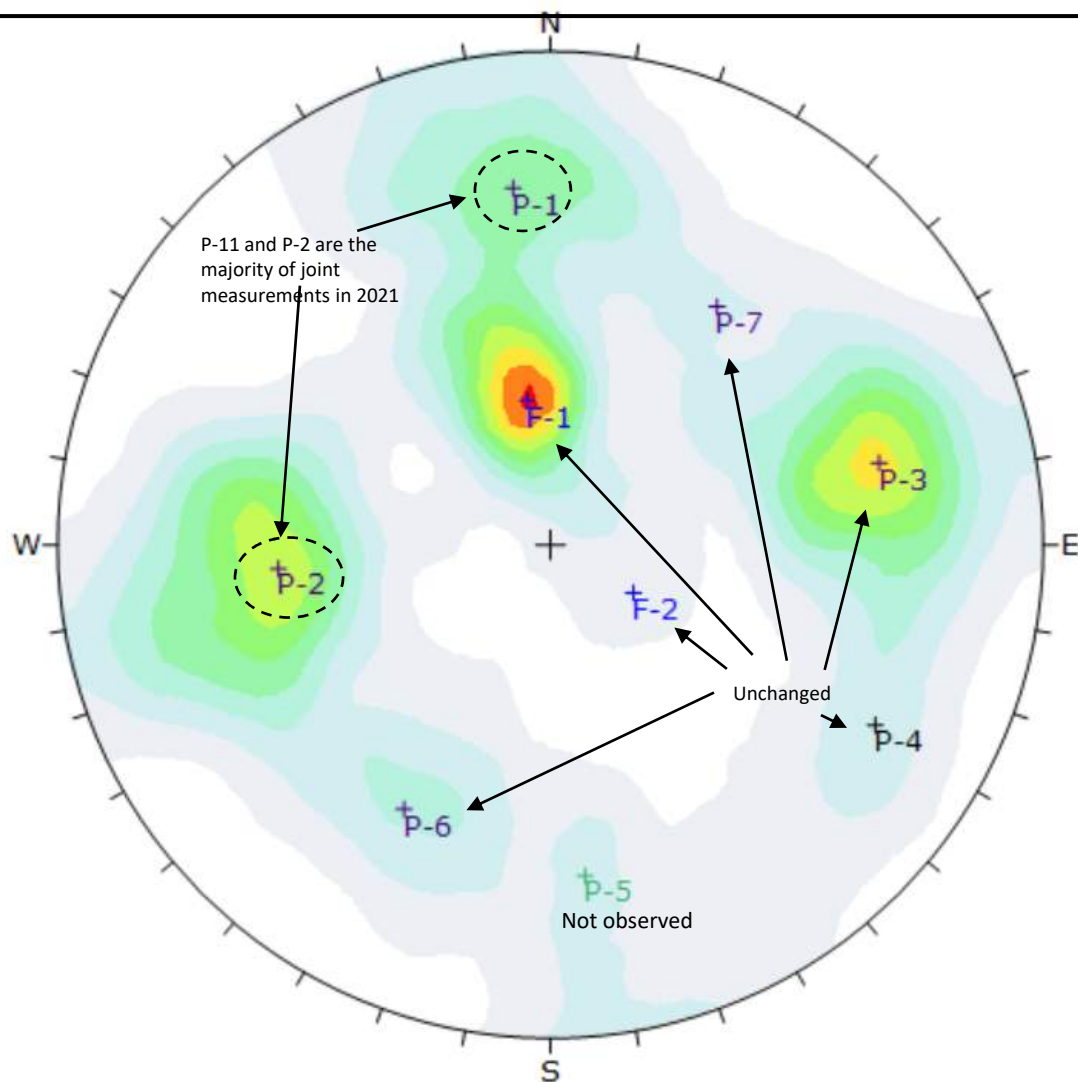
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Golden, Colorado
Project No. 21C164003.00

Contour Plot of
Current Data



Figure 6



Equal Area, Lower Hemisphere Stereonet

Legend

- P-1 Joints analyzed in Current Report
 F-2 Foliations analyzed in Current Report

Discontinuity	Dip/Dip Direction
F-1	33°/171° (unchanged)
F-2	22°/300° (unchanged)
P-1	72°/174°
P-2	58°/085°
P-3	68°/256° (unchanged)
P-4	74°/299° (unchanged)
P-5	Not Observed
P-6	63°/029° (unchanged)
P-7	61°/215° (unchanged)



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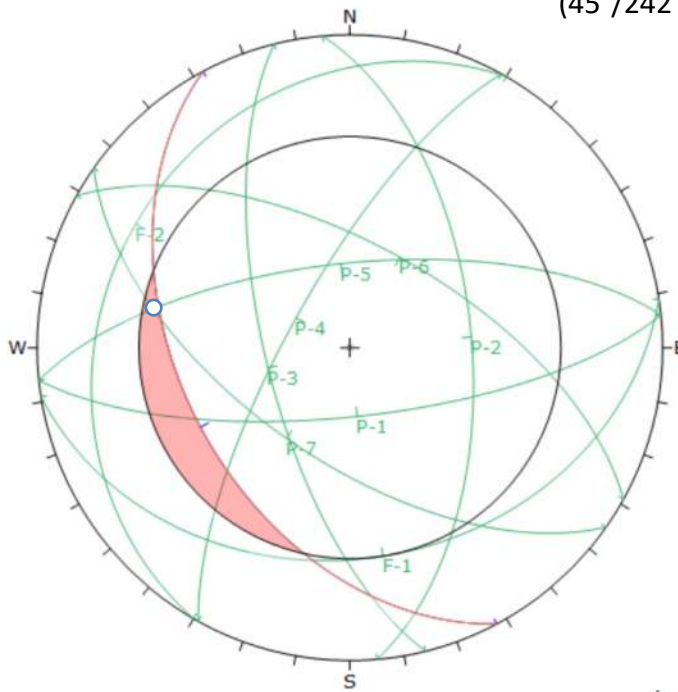
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Golden, Colorado
Project No. 21C64003.00

Average Discontinuity
Orientations (2022
Annual Report)

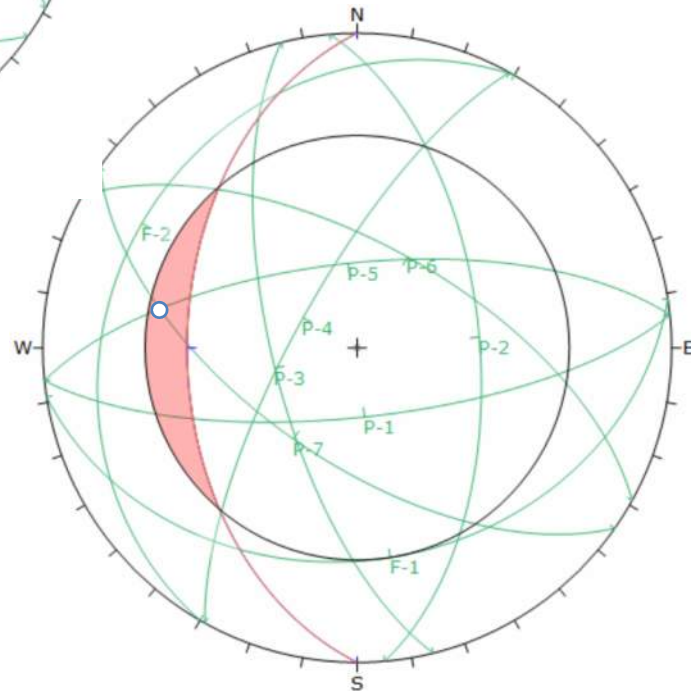


Figure 7

East Wall 1
(45°/242°)



East Wall 2
(45°/270°)



Legend

Equal Area, Lower Hemisphere Stereonet Plot

Friction Angle: 33°

— Wall Orientation

— Planes of Discontinuity Sets

■ Critical zone

○ Wedge intersection within the critical zone

○ Plane dip vector within the critical zone

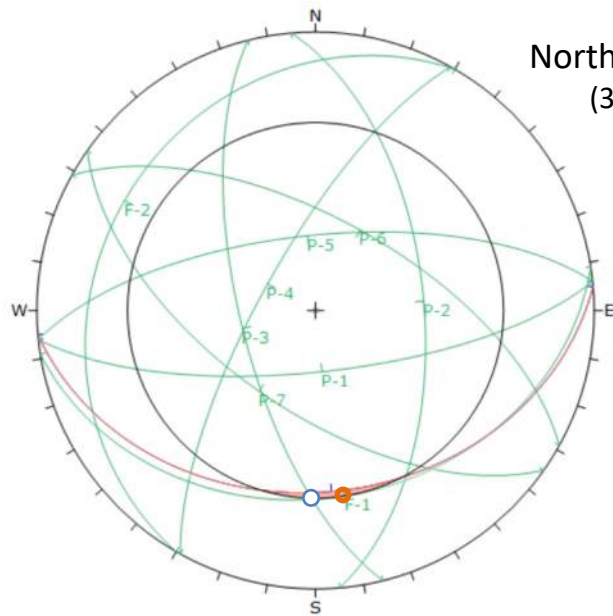


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Golden, Colorado
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Kinematic Analysis:
East Walls 1 and 2

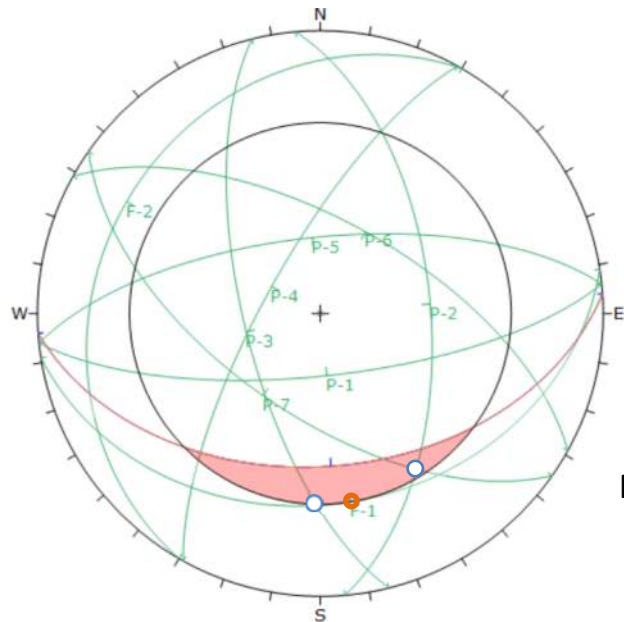
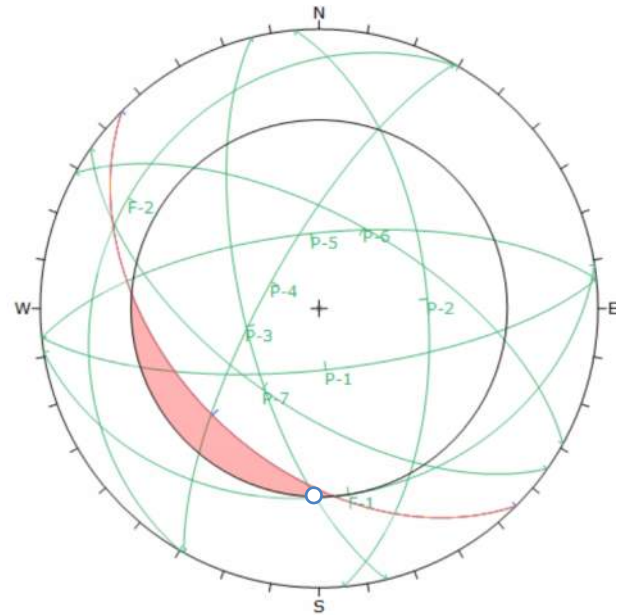


Figure 8



Northeast Wall 1
(35°/175°)

Northeast Wall 2
(45°/225°)



Northeast Wall 3
(45°/176°)

Legend

Equal Area, Lower Hemisphere Stereonet Plot

Friction Angle: 33°

— Wall Orientation

— Planes of Discontinuity Sets

■ Critical zone

○ Wedge intersection within the critical zone

● Plane dip vector within the critical zone

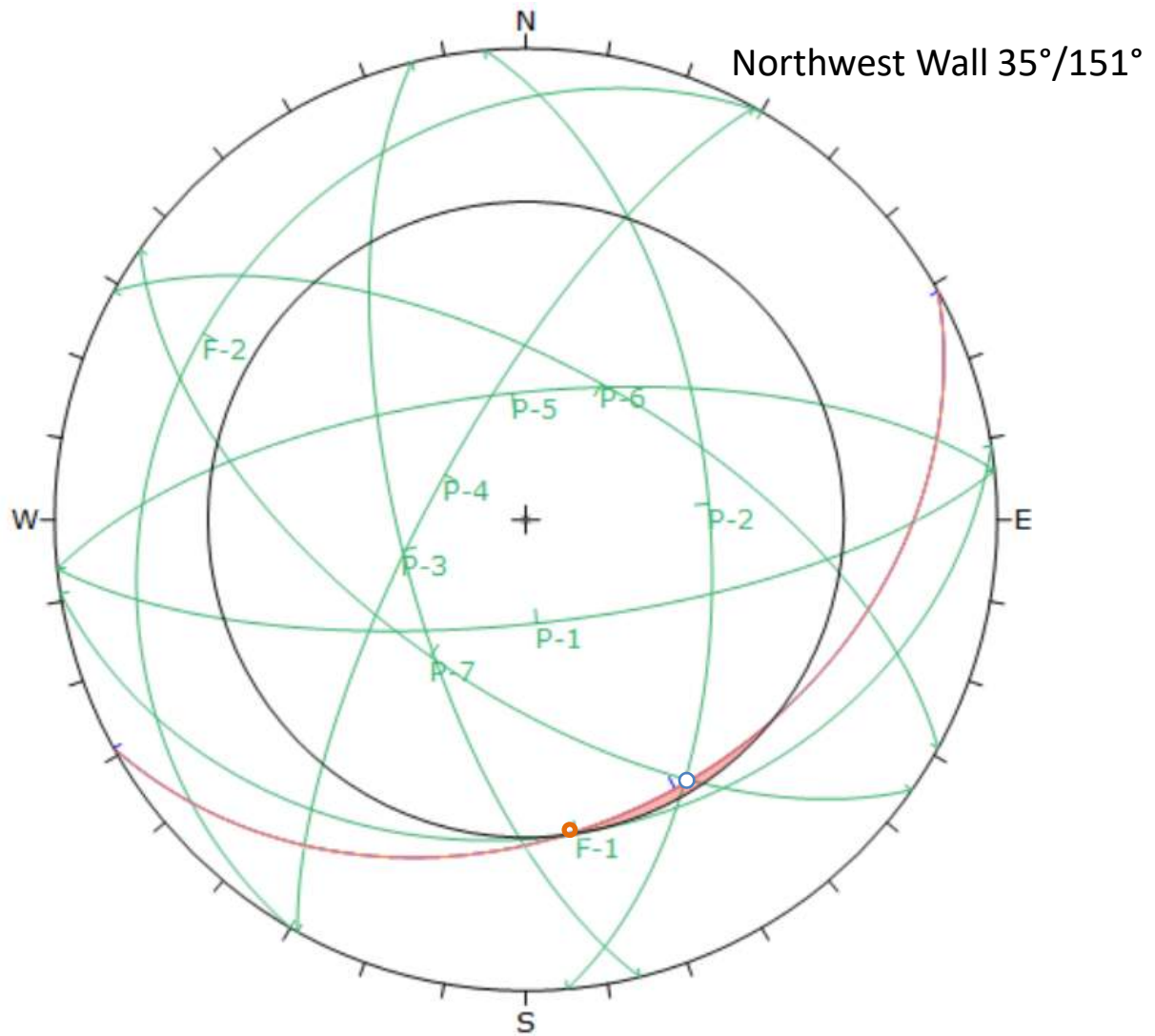


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Golden, Colorado
Project No. 21C64003.00

Kinematic Analysis:
Northeast Walls 1, 2 and 3



Figure 9



Legend

Equal Area, Lower Hemisphere Stereonet Plot

Friction Angle: 33°

— Wall Orientation

— Planes of Discontinuity Sets

■ Critical zone

○ Wedge intersection within the critical zone

○ Plane dip vector within the critical zone



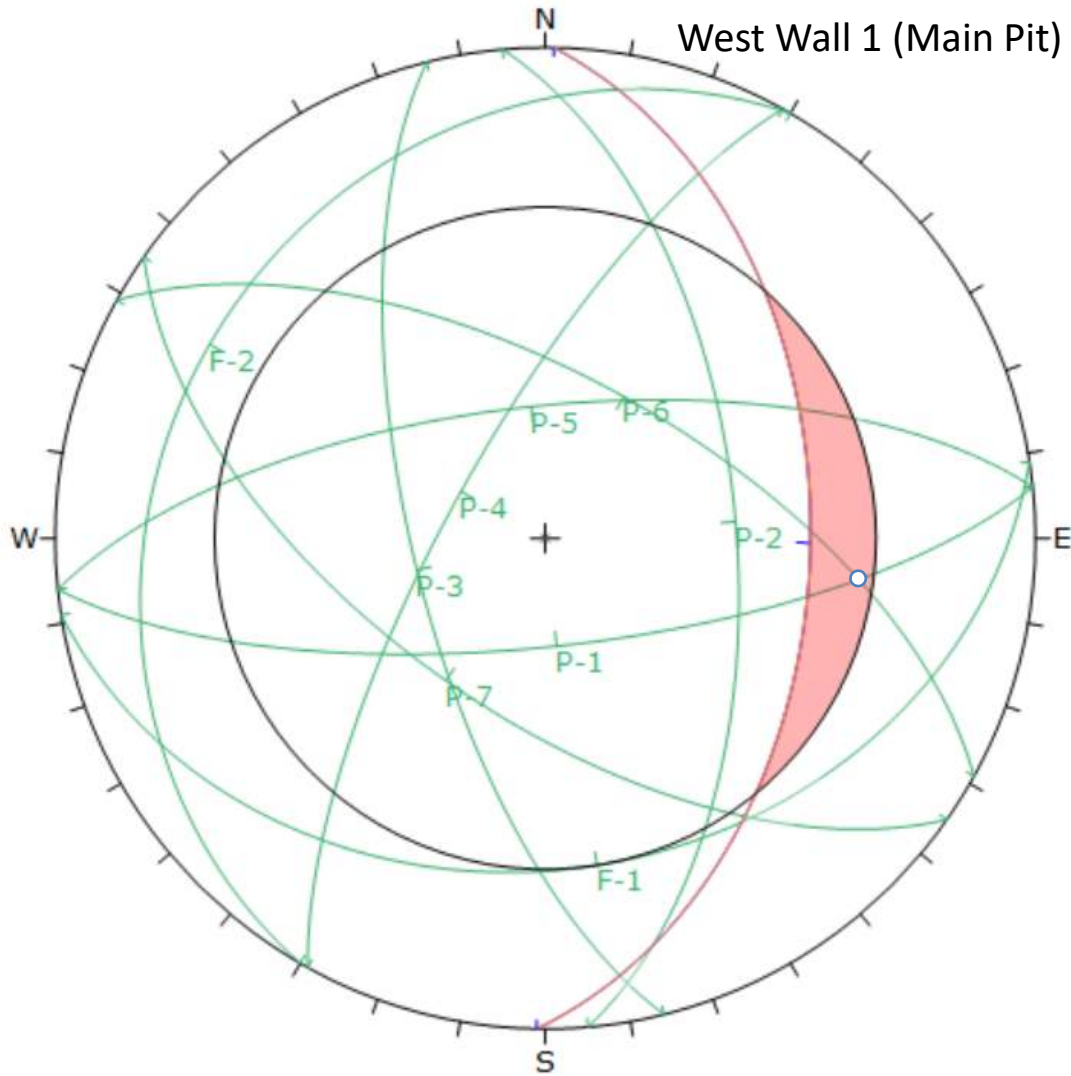
Spec-Agg Quarry
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Project No. 21C64003.00

Kinematic Analysis:
Northwest Wall



Figure 10

West Wall 1 (Main Pit) 45°/091°



Legend

Equal Area, Lower Hemisphere Stereonet Plot

Friction Angle: 33°

- Wall Orientation
- Planes of Discontinuity Sets
- Critical zone
- Wedge intersection within the critical zone
- Plane dip vector within the critical zone

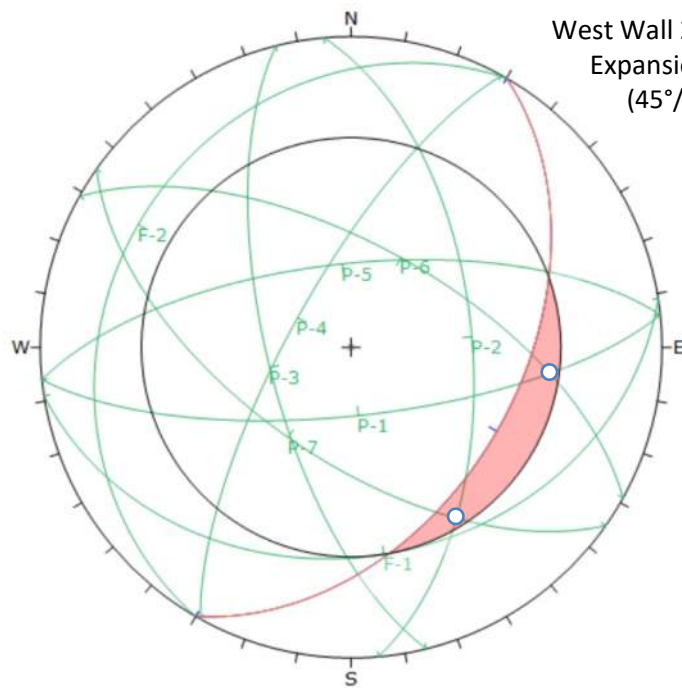


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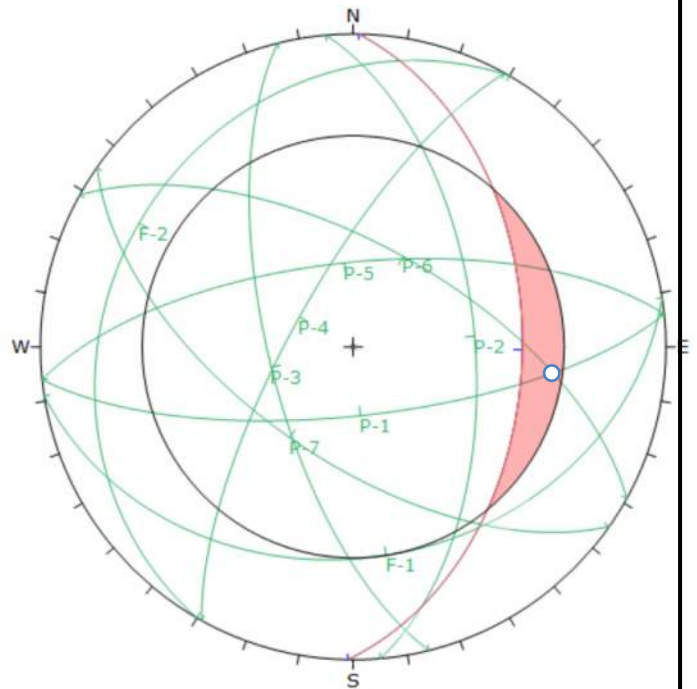
Kinematic Analysis:
West Wall 1 (Main Pit)



Figure 11



West Wall 3 (Southern Expansion Area)
(45°/091°)



Legend

Equal Area, Lower Hemisphere Stereonet Plot

Friction Angle: 33°

- Wall Orientation
- Planes of Discontinuity Sets
- Critical zone
- Wedge intersection within the critical zone
- Plane dip vector within the critical zone

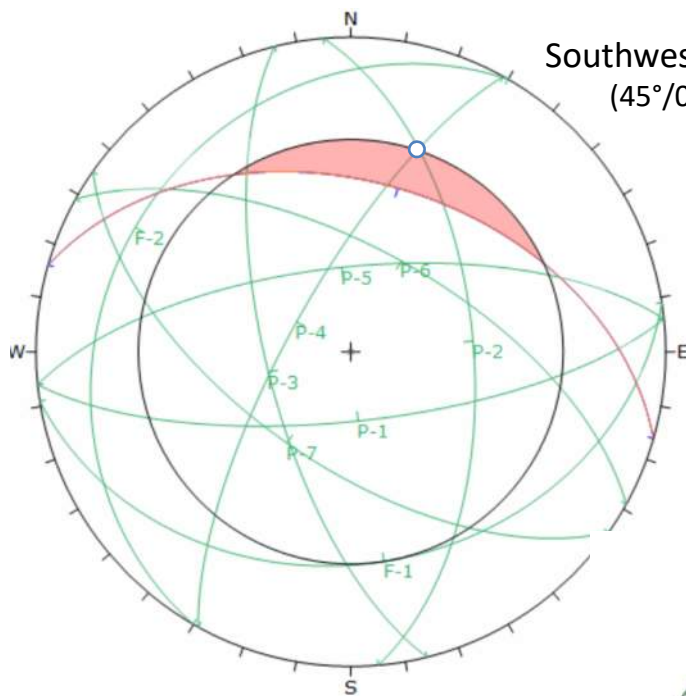


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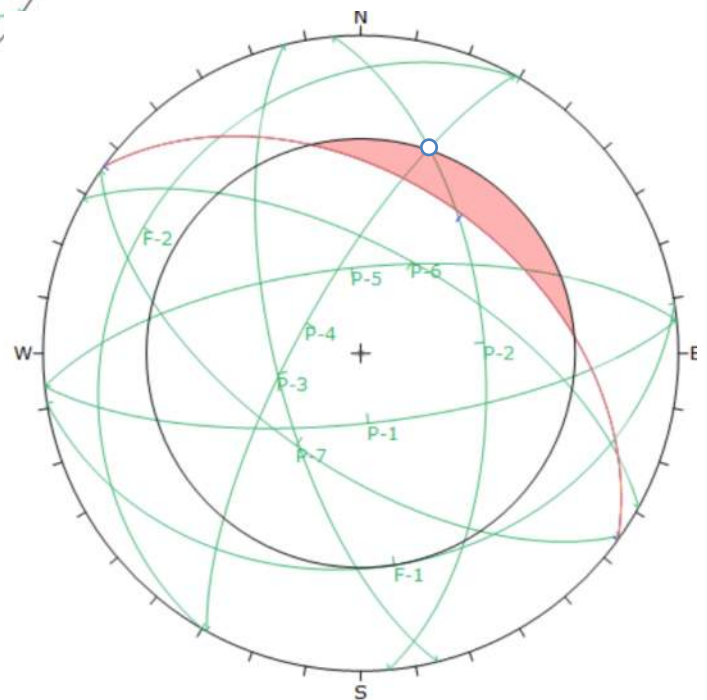
Kinematic Analysis:
West Walls 2 and 3
(Southern Expansion)



Figure 12



Southwest Wall 2
(45°/036°)



Legend

Equal Area, Lower Hemisphere Stereonet Plot

Friction Angle: 33°

- Wall Orientation
- Planes of Discontinuity Sets
- Critical zone
- Wedge intersection within the critical zone
- Plane dip vector within the critical zone

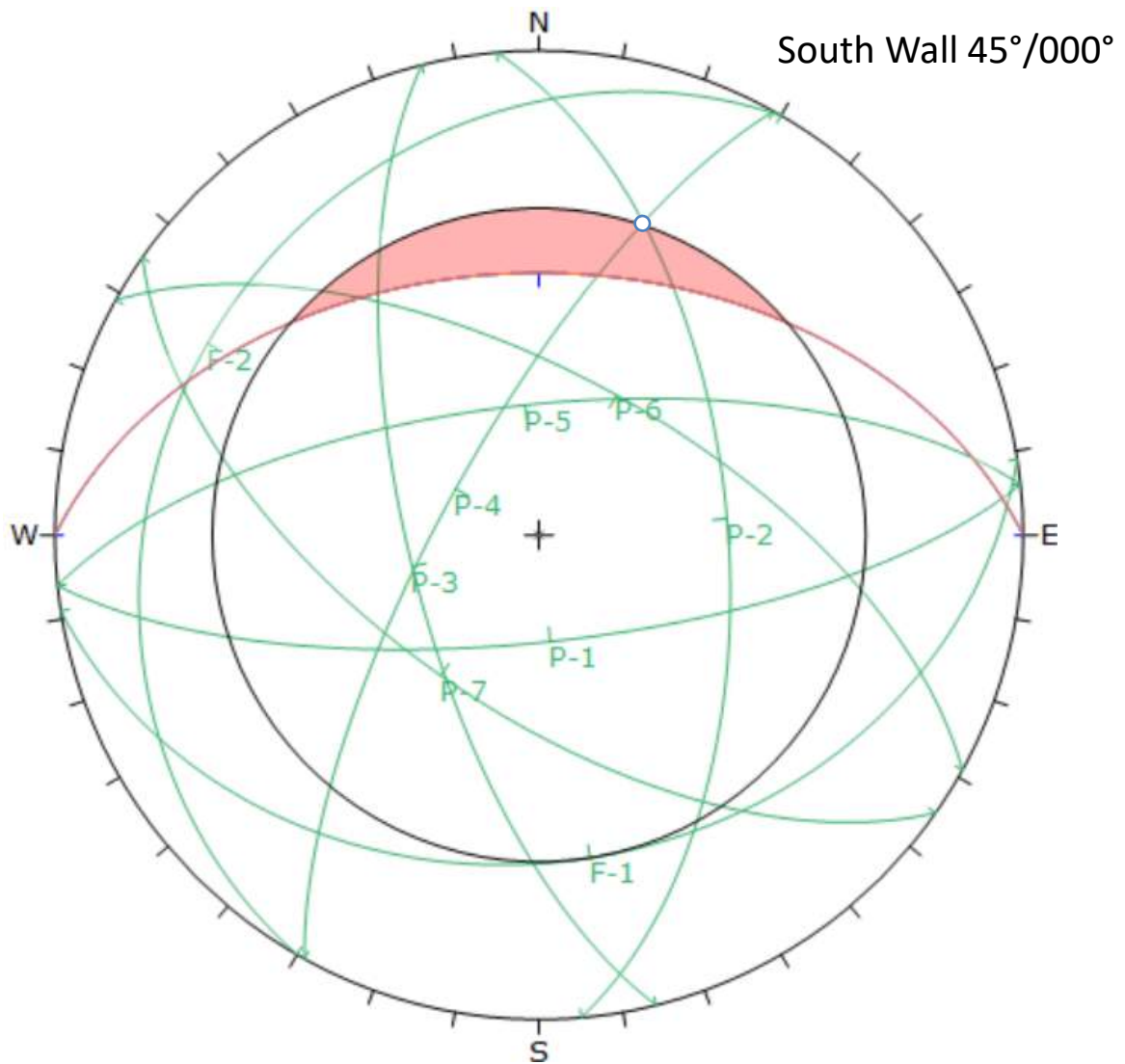


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Project No. 21C64003.00

Kinematic Analysis:
Southwest Walls
(Southern Expansion)



Figure 13



Legend

Equal Area, Lower Hemisphere Stereonet Plot

Friction Angle: 33°

- Wall Orientation
- Planes of Discontinuity Sets
- Critical zone
- Wedge intersection within the critical zone
- Plane dip vector within the critical zone



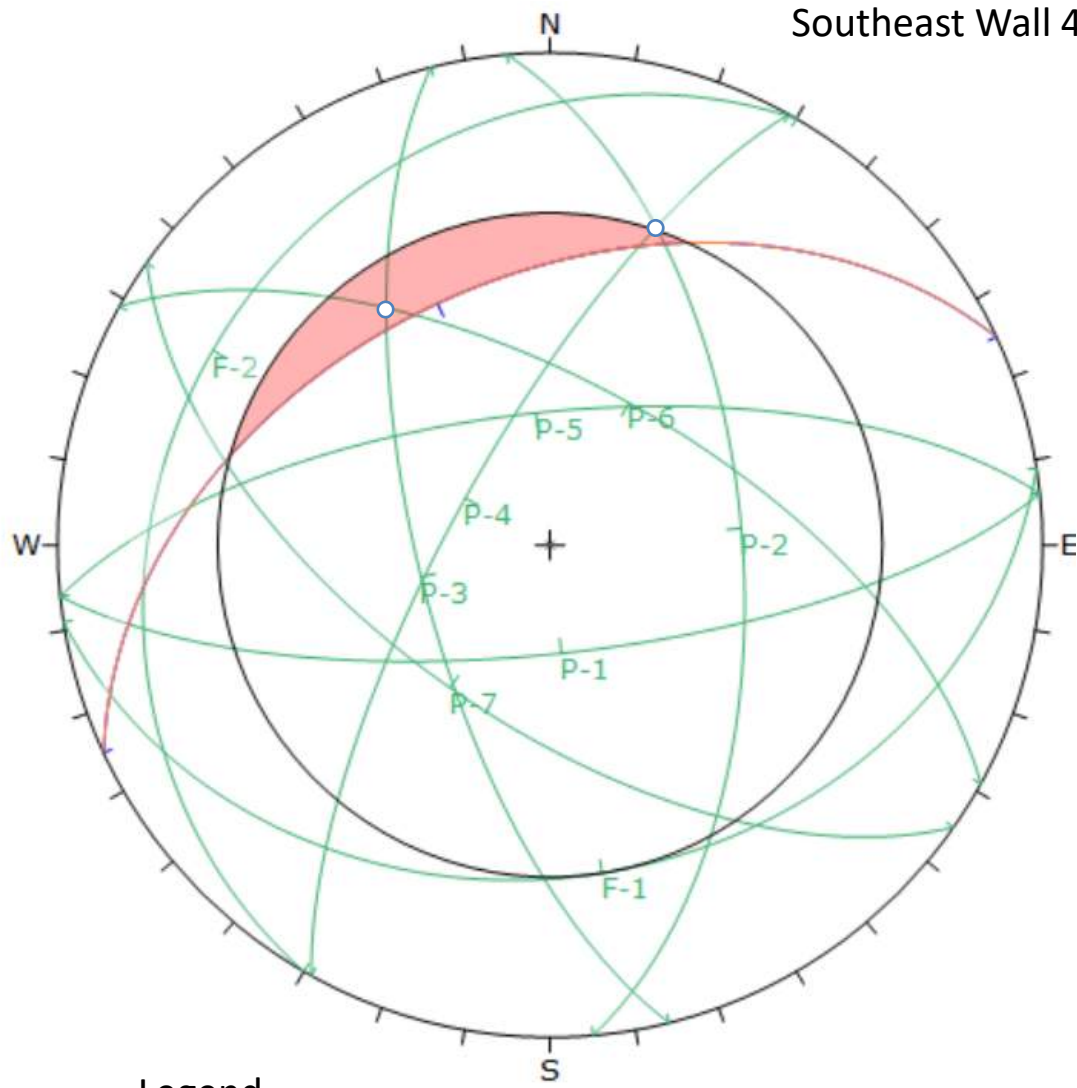
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Kinematic Analysis:
South Wall




Figure 14

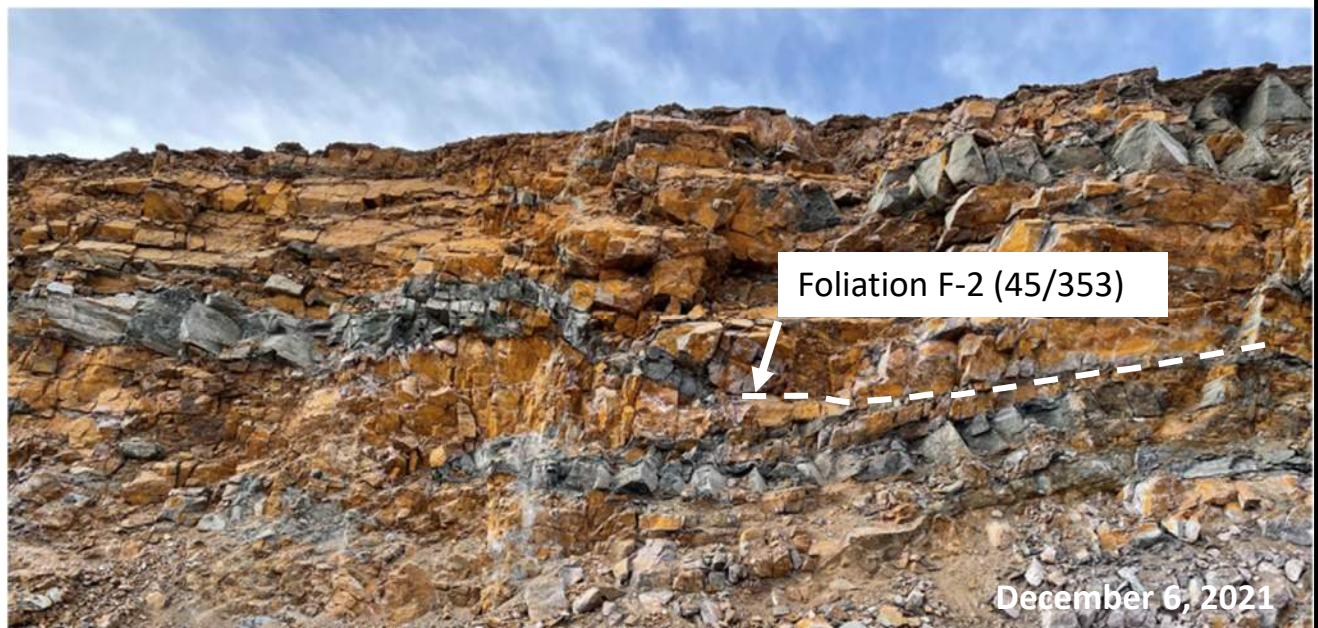
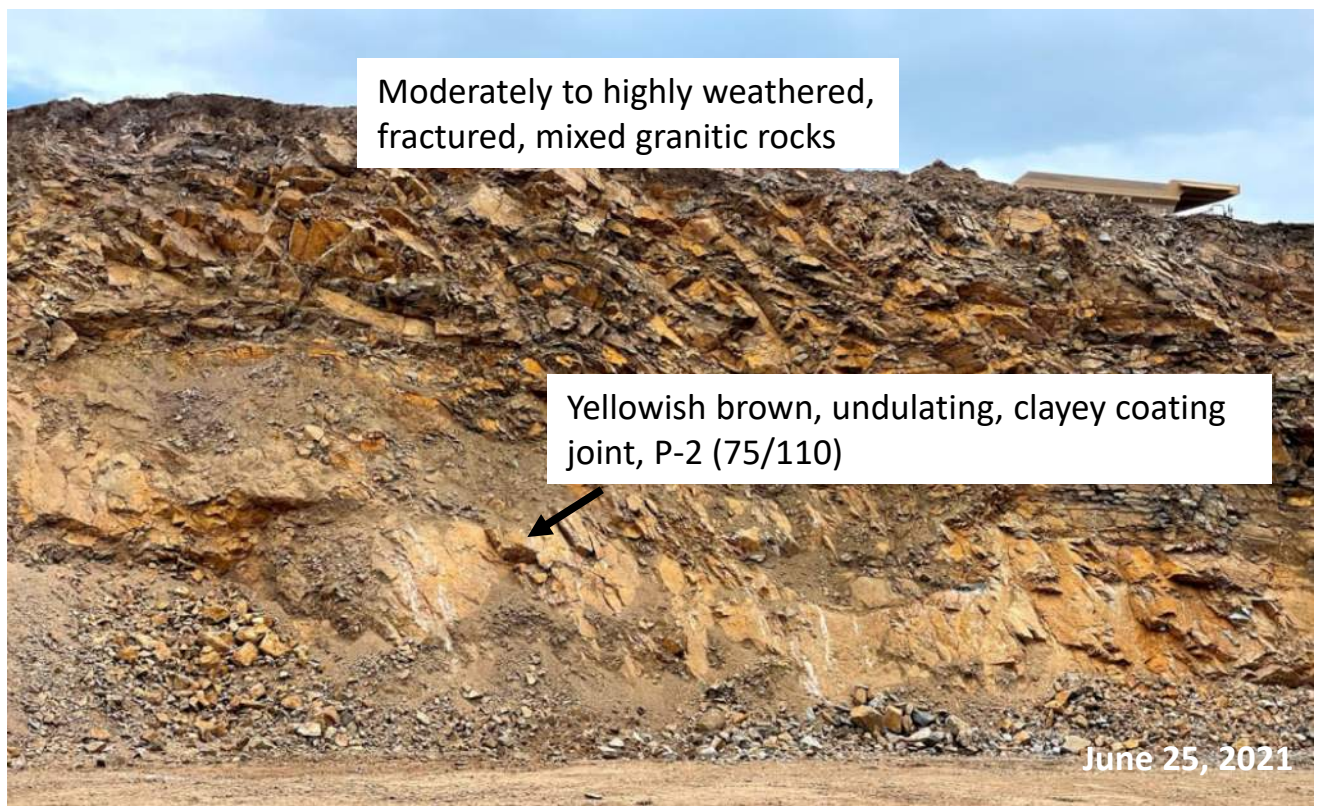
Southeast Wall 45°/335°



Legend

- Equal Area, Lower Hemisphere Stereonet Plot
- Friction Angle: 33°
- Wall Orientation
- Planes of Discontinuity Sets
- Critical zone
- Wedge intersection within the critical zone
- Plane dip vector within the critical zone

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Spec-Agg Quarry Golden, Colorado Project No. 21C64003.00	Kinematic Analysis: Southeast Wall
	Figure 15



Looking North in an newly active mine area (middle bench, ~Elevation 6510 msl) of the Southern Expansion Area near Station 22-05 (Figure 2).

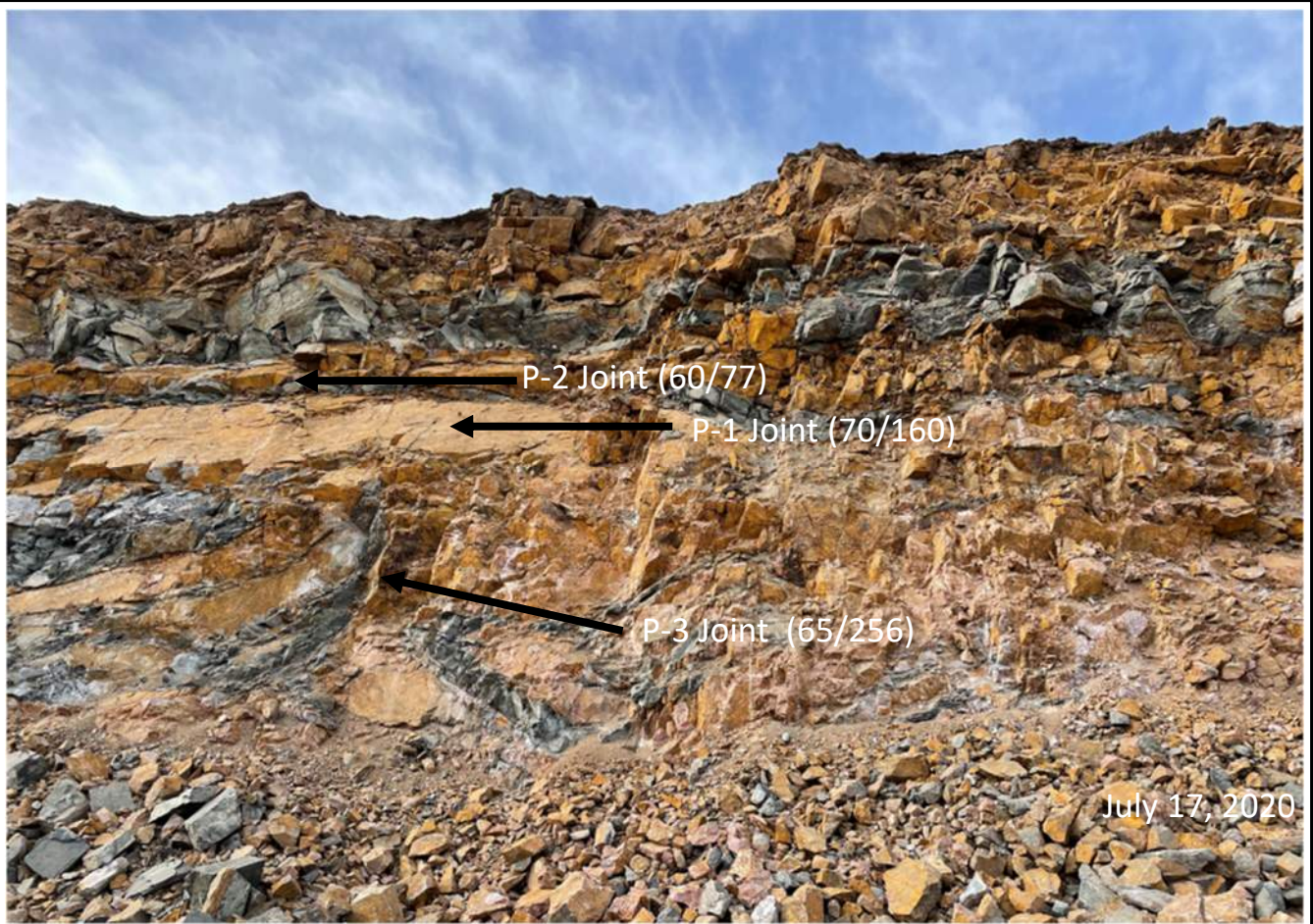


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Active Mining in Southern
Expansion Area



Photo 1



Looking North - P-1, P-3 and P-3 joints are the dominant joint sets in the lower temporary working bench area the Southern Expansion area (~Elevation 6475 ft msl).



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Discontinuity Exposure in
Southern Expansion Area

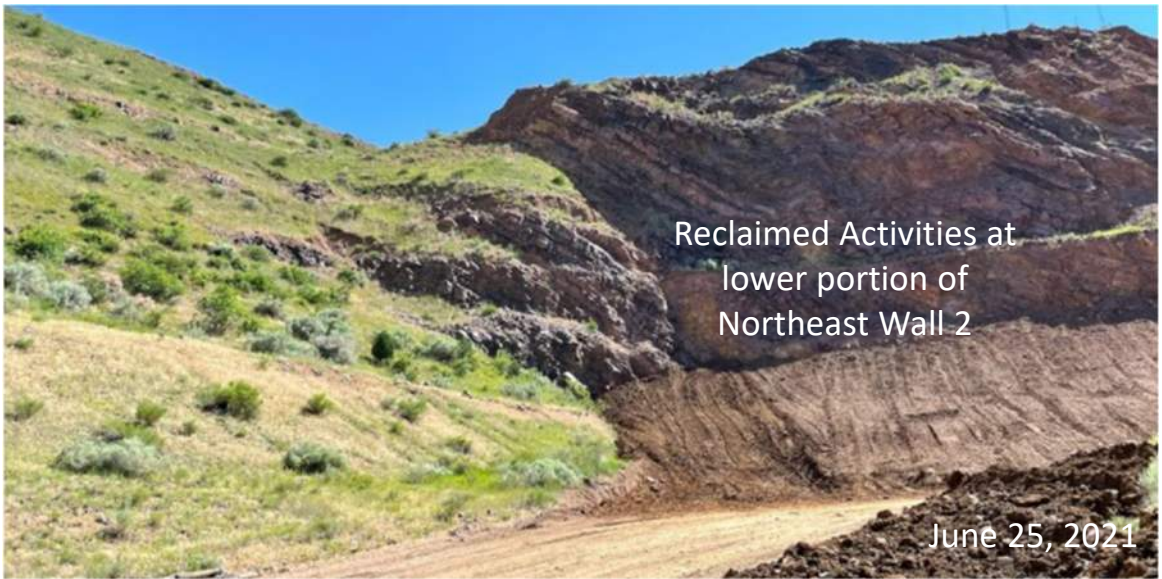


Photo 2



Looking Southwest near Station 22-06.
 No major shear zone was observed during this report year (in both June and December 2021 field activities).

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Spec-Agg Quarry Golden, Colorado Project No. 21C64003.00	Localized Shear Zone in Southern Expansion Area	
 Martin	Photo 3	



Looking East (Northeast Walls 1-2)



Looking East (access road temporary walls)

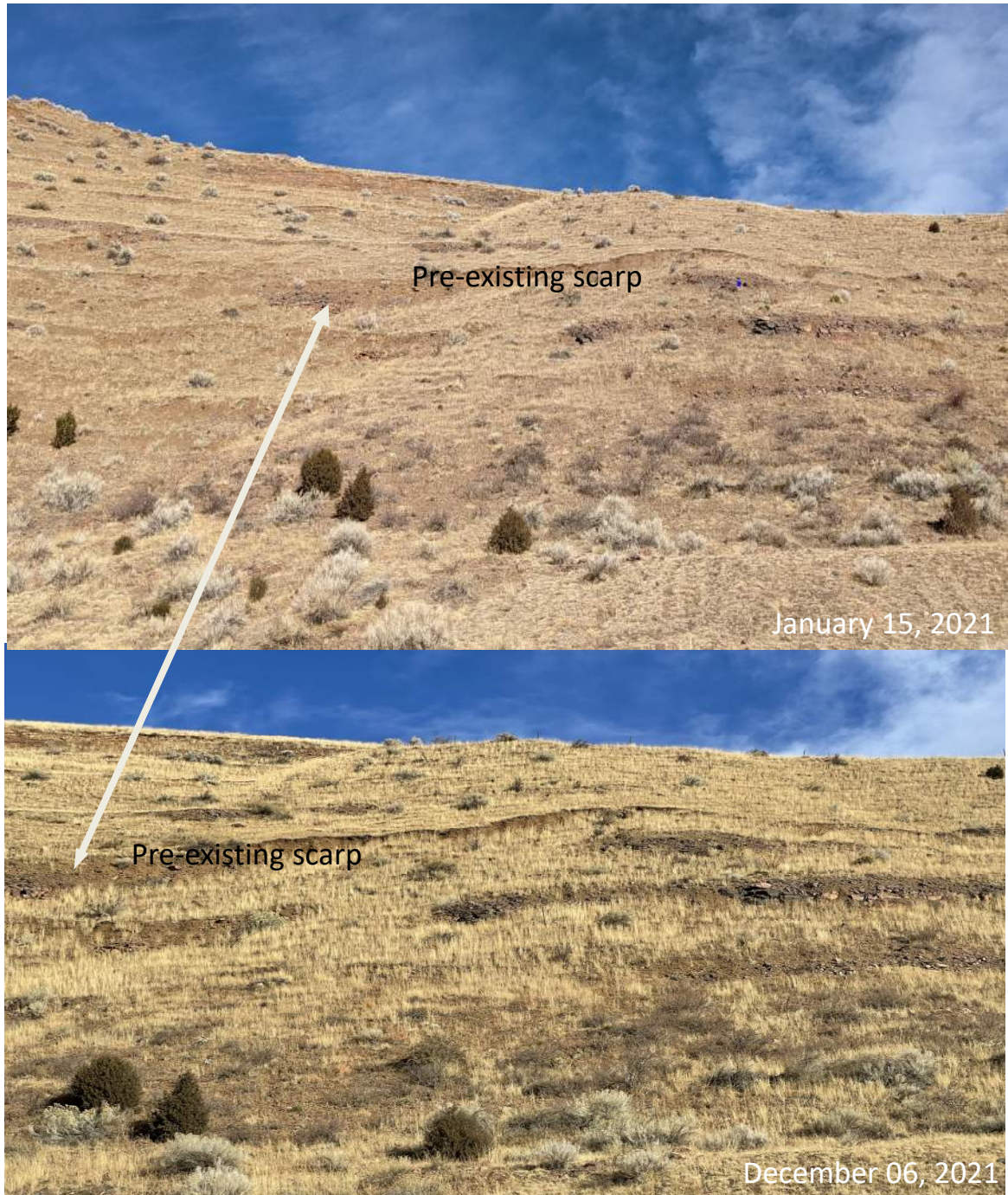


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Minimal Mining Activity
in Main Pit Area



Photo 4



Looking north from the Main Pit Area showing pre-existing scarp feature on the Northeast Wall 1. Area appears unchanged since January 2021.



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North Slope in Main Pit
Area



Photo 5