2019 ANNUAL REPORT
STRUCTURAL GEOLOGY EVALUATION
SPECIFICATIONS AGGREGATE QUARRY

Martin Marietta Materials
Golden, Colorado

18C64008.00
February 21, 2019

Lachel & Associates
A SCHNABEL ENGINEERING COMPANY

February 21, 2019

Ms. Julie Mikulas
Martin Marietta Materials, Inc.
1627 Cole Blvd, Suite 200
Lakewood, CO 80401

Subject: **Project 18C64008.00, 2019 Annual Report, Structural Geology Evaluation, Specification Aggregates Quarry, Golden, Colorado**

Dear Ms. Mikulas:

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 2018 and 2019 field mapping effort and structural geology evaluation. This study was performed in accordance with our proposal dated May 26, 2018.

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.

Matt Koziol
Senior Engineer

2/21/2019

Wen L. Lee, PhD
Senior Associate

Steve Brandon, PE
Senior Vice President

MKK:WLL:SHB

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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 2019 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 22 years (1997-2018/2019), 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 August 2018 and January 2019.

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.
- Compare the new rock structure data collected during site visits in 2018/2019 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 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. The area has been extensively modified and fresh exposures were covered by backfill material before measurements could be made.

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 western and southern margin of the Southern Expansion Area during previous and current year site visits. GPS measurements taken along the margin of the fault exposure (19-SHEAR) were registered in Google Earth to the existing fault map yielding a good match with the previously mapped trace (Figure 2 and Photo 3). The fresh exposed temporary highwall in the current lower bench (elevation approximately 6545 feet) show signs of diminishing fault exposure with much narrower width of the shear zone (3 to 5 feet).

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 the previous 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 is no mining activities in the main pit area.

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 our 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 August 2018 and January 2019 site visits (Photos 1 to 3). The mining is being accomplished with four 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 19-04 in Figure 2). The next bench to the east is in the vicinity of Stations 19-01 and 19-05 (Figure 2) and the next near Stations 19-02 and 19-06 (Figure 2). The final, lowest bench is in the vicinity of Stations 19-03 and 19-07 (Figure 2) and is at approximately EL 6,545 ft, based on GPS measurement and concrete monuments spray-painted with elevation markings. 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 the topographic configuration shown in Figure 2, with an approximate final mine floor elevation of EL 6,200 ft. 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 2018 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 August 2018 and January 2019.

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 112 discontinuity measurements were collected in 2018/2019 at eight (8) 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, 2004-2018) and with borehole geophysical data collected during the 2003 geotechnical investigation, a total of 3,655 discontinuity orientation measurements have been obtained over the past 22 years. Figure 5 shows the 112 discontinuity orientation measurements collected for this annual report overlain on a contour stereonet plot of the entire Spec-Agg structural dataset.

During our 2018/2019 site visits, we observed only one fault exposure along the temporary excavation wall in the Southern Expansion Area at station 19-SHEAR (Figure 2, and Photo 3). The fault is oriented approximately east-west, with apparent dip/dip direction of 85/185 and was exposed in the north to northwest facing temporary wall of the expansion area. The fault zone consists of orange-reddish weathered, broken and blocky pegamatite rock, with parallel fracturing with local clayey gouge. The location of this fault is, in general, a good match with the previously mapped trace. The apparent width of the fault zone varies from 3 to 5 feet. The fault orientation measurements for this annual report are presented with previous fault measurements and differentiated by the fault feature they represent 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 2018/2019 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 during the past year.

After planar failure along foliation planes in 1998 and 1999, the overall effective angle of the last three benches of Northeast Wall 1 and the Northwest Wall were reduced to an 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 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 2018 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 7.014 (Rocscience, 2018). 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 August 2018 and January 2019 site visits over contours for the entire dataset (from all previous years), and alongside representative discontinuity orientations used for the previous 2018 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 with a few emerging trends and exceptions. Joint set P-5 has emerged over more recent years, however, no points were observed this year. A foliation set F3 was identified in previous years (prior to 2013), but has not been observed in the past six years. Joint set P-7 was identified in the 2013 report, and was again observed some this year. A few localized joint data points identified in the 2017 and 2018 reports 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 this joint trend 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). Joint set P-7 has emerged over more recent years. Arrows shown in Figure 6 indicate the shifts in representative orientations of the observed discontinuity sets based on our evaluation of the new data.

Ultimately, a total of nine (9) discontinuity sets (two foliation sets and seven 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)		
	2017 Annual Report	2018 Annual Report	2019 Annual Report
F-1 (Foliation)	33°/171°	33°/171° (unchanged)	33°/171° (unchanged)
F-2 (Foliation)	22°/276°	19°/282°	22°/300°
F-3 (Foliation)	Not observed	Not observed	Not observed
P-1 (Joint)	74°/171°	73°/176°	72°/175°
P-2 (Joint)	59°/090°	60°/085°	55°/085°
P-3 (Joint)	68°/256°	68°/256° (unchanged)	68°/256° (unchanged)
P-4 (Joint)	74°/299°	74°/299° (unchanged)	74°/299°(unchanged)
P-5 (Joint)	68°/354°	68°/354° (unchanged)	68°/354° (unchanged)
P-6 (Joint)	59°/025°	61°/025°	61°/025° (unchanged)
P-7 (Joint)	65°/212°	59°/213°	61°/215°

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 7.014 (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 2018/2019 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), 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 stereonets, 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 30 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 stereonets, 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).

6.4.2 *East Walls*

For the 2019 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 2013-2018 annual reports (Figure 2). There is currently minimal or no mining activity 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 (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 2019 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 2013-2018 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. As 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. 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).

The stereonet plot for the Northwest Wall shows 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. Planar failure is not indicated in the stereonet plot for the Northwest Wall (Figure 10). However, even a slight variation of the foliation F-1 would create the potential for planar sliding.

For the 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 in the previous section, 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 the recent site visits (2013). Due 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 2019 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 2013-2018 annual reports (Figure 2). There is currently no mining activity in the west walls area except near West Wall 3.

The stereonet plot for West Wall 1 (Figure 11), adjacent to the Main Pit area, does not show indications of potential wedge failure modes. However, even a slight variability in the orientations of the joint sets P-1 and P-6 will have potential to form wedges within the critical zone for this wall. 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 one 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 include 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). Planar failure is not indicated in the stereonet plot for West Wall 2 (Figure 12).

The stereonet plot for West Wall 3 does not show indications of potential wedge failure modes (Figure 12). However, even a slight variability of the joint sets P-1 and P-6 would create the potential to form wedges within the critical zone for this wall. 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 2019 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 2013-2018 annual reports (Figure 2). Current mining activities are mainly in the southern walls area. The current temporary benches are being advanced to approximately EL 6,545 ft (Figure 2, Stations 19-3 and 19-07).

The stereonet plots for the Southwest Wall 1, Southwest Wall 2, and South Wall do not show indications of potential wedge failure modes. However, even a slight variability in the orientations of the joint sets P-2 and P-4 will have potential to form wedges within the critical zone for this wall. (Figures 13 and 14). The signatures of P-4 appear to be relatively weak in the Southern Expansion Area (Figure 6). Planar failure is not indicated in the stereonet plots for the Southwest Wall 1, Southwest Wall 2, and South Wall (Figures 13 and 14).

The stereonet plot for the Southeast Wall shows one discontinuity intersections that falls 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-3 and P-6. Also, even a slight variability in the orientations of the joint sets P-2 and P-4 will have potential to form wedges within the critical zone for this wall. Based on the current as well as previous year's data set, joint set P-4 has weak signatures represented by relatively few measured orientations representing these features (Figure 6). Planar failure is not indicated in the stereonet plot for the Southeast Wall (Figure 15).

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 2019 Annual Report, kinematic analyses are based on discontinuity measurements derived principally from data collected from the historic dataset supplemented with data collected during the August 2018 and January 2019 site visits. The 2019 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 2018/2019 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 2019 Annual Report.

The kinematic analysis for East Walls 1 and 2; Northeast Walls 1, 2 and 3; West Wall 2; and Southeast Wall each indicate the possibility for wedge failures to occur. Additionally, the analysis for Northeast Walls 1 and 3 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 is 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 should be relayed to Lachel for an evaluation of the effects on the slopes’ stability.

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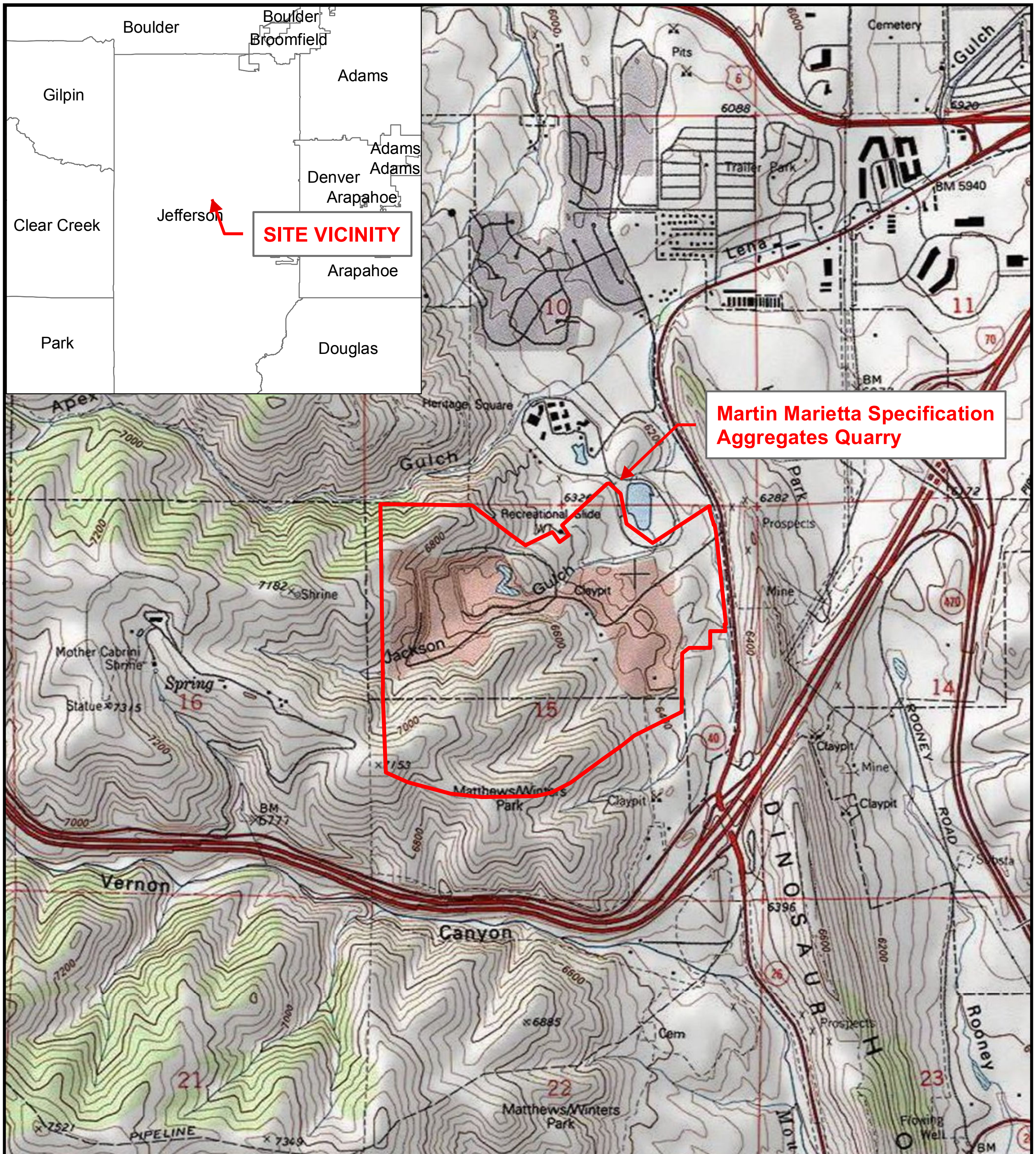
FIGURES



Basemap:Copyright:© 2013 National Geographic Society, i-cubed

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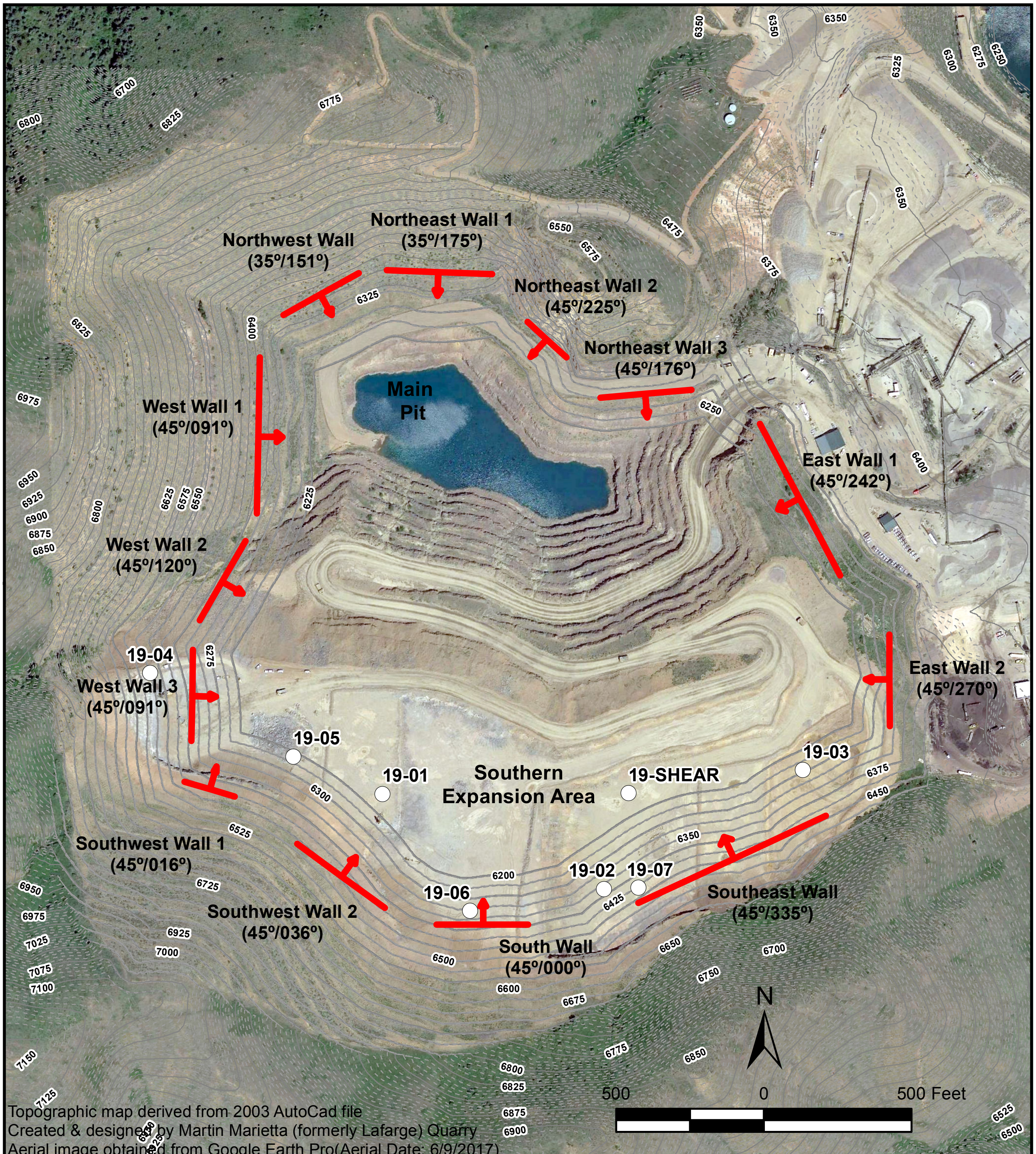
Spec-Agg Quarry Golden, Colorado Project No. 18C64008.00	Site Vicinity Map
Martin Marietta Materials	Figure 1



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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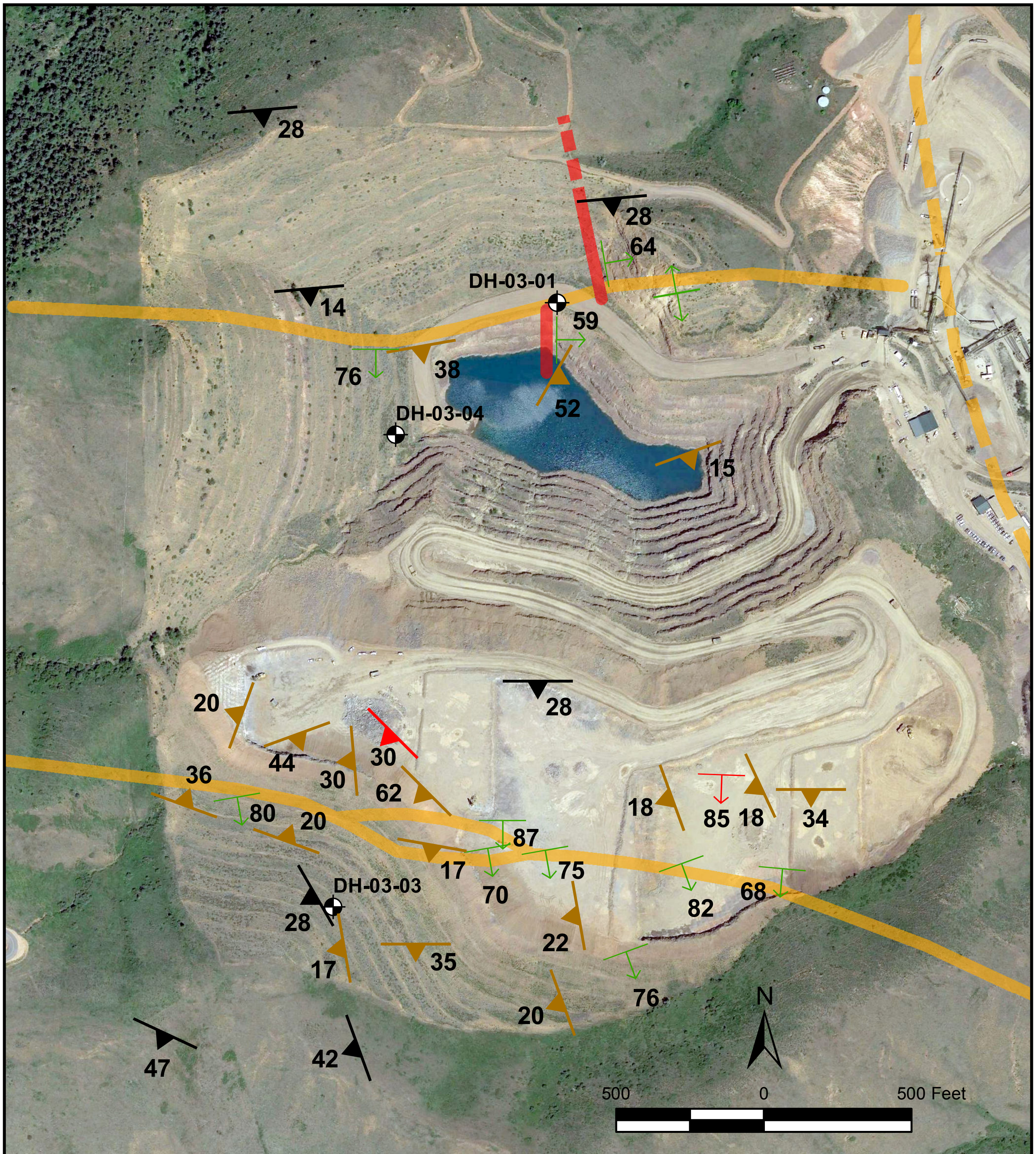
Spec-Agg Quarry
Golden, Colorado
Project No. 18C64008.00

Mining Plan and 2018/2019 Mapping Locations

Martin Marietta Materials

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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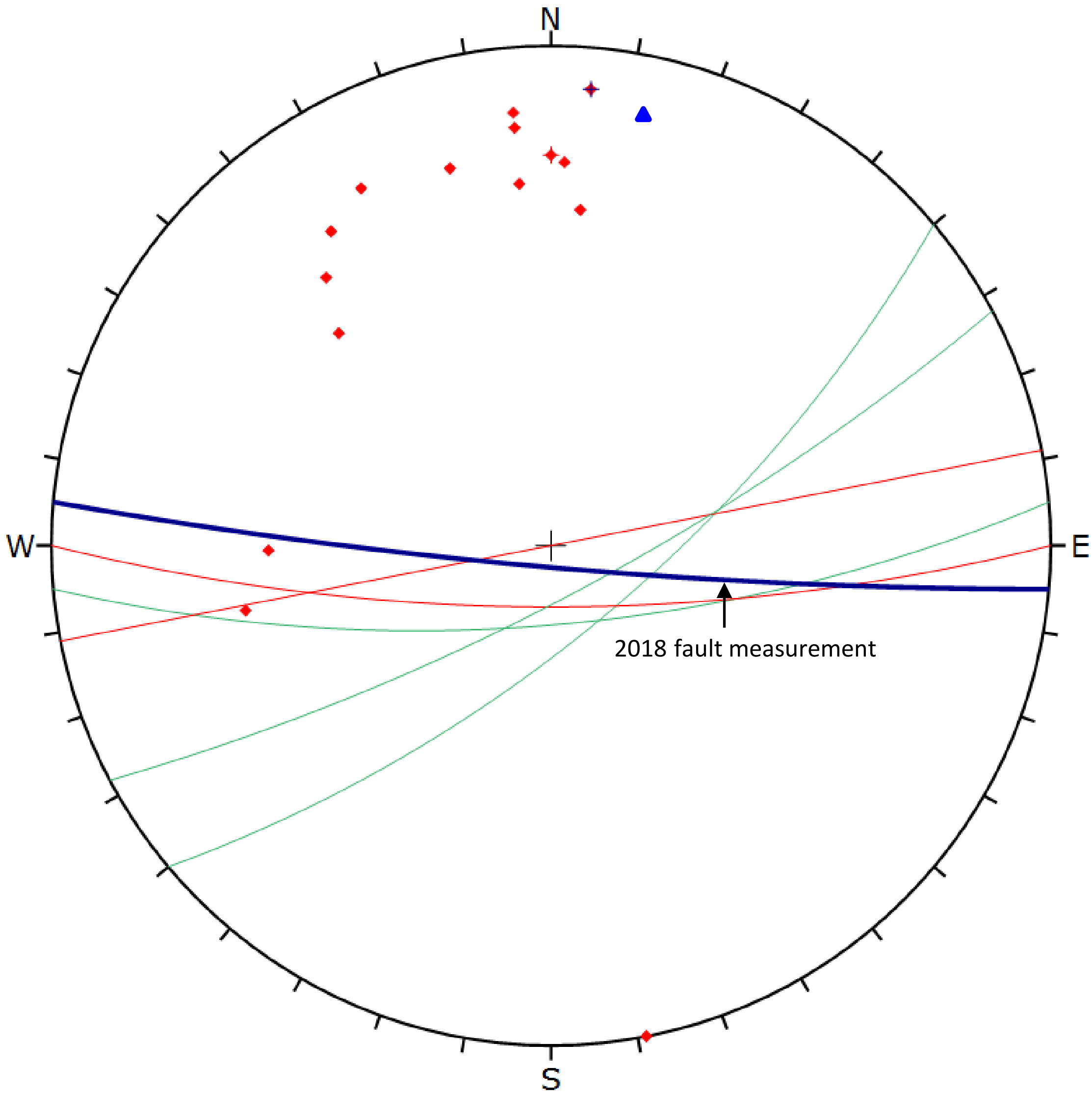
Spec-Agg Quarry
Golden, Colorado
Project No. 18C64008.00

Faults and Foliation

Martin Marietta Materials

Figure 3



Legend

Equal Area, Lower Hemisphere Stereonet

- 2018 fault measurement (pole)
- Previous fault measurement (pole)
- Planes representing the northern fault of Gable (1968)
- Planes representing the southern fault of Gable (1968)

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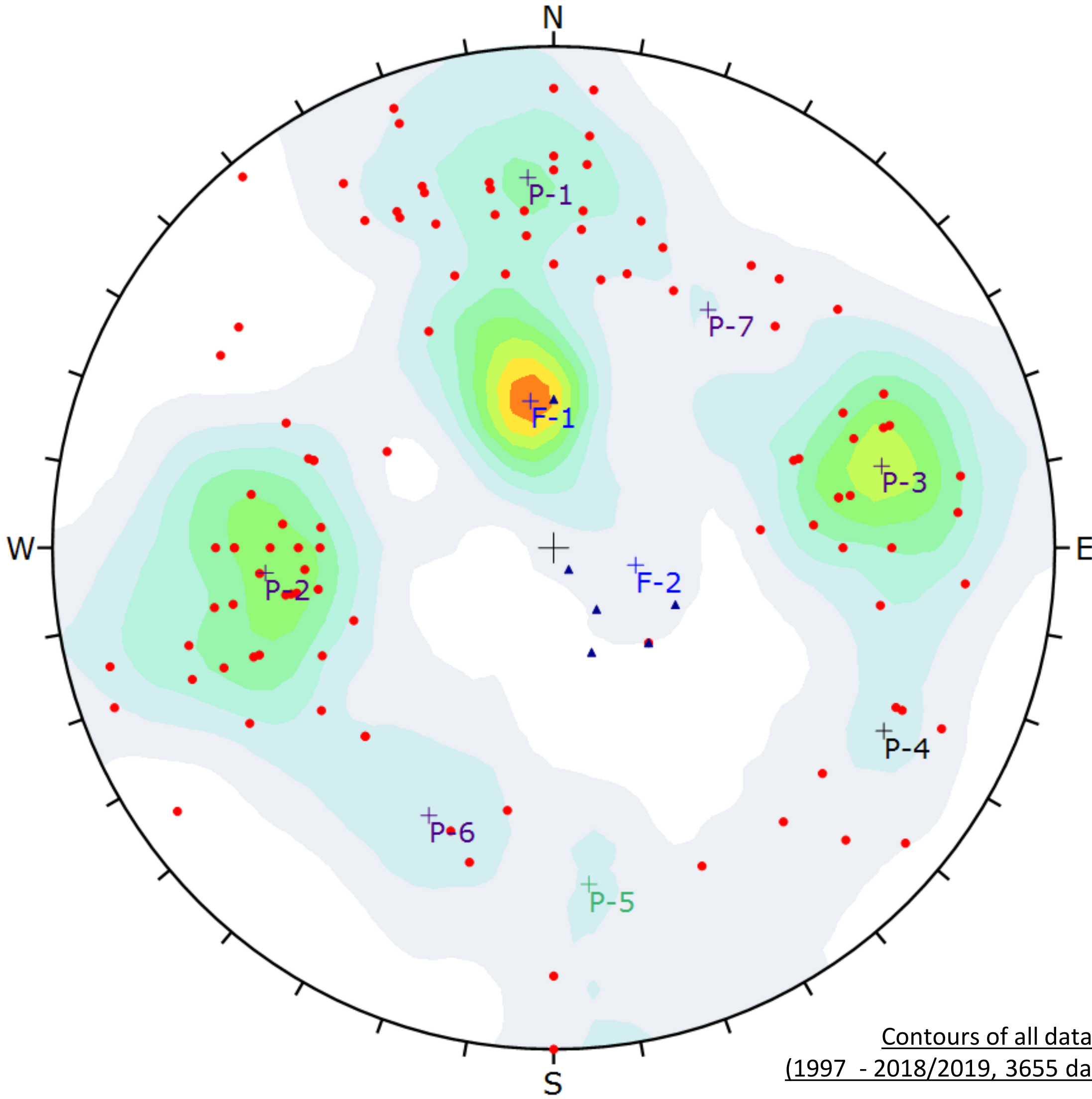
Spec-Agg Quarry Golden, Colorado Project No. 18C64008.00	Fault Orientations
Martin Marietta Materials	Figure 4



Contours of all data
(1997 - 2018/2019, 3655 data points)

Legend

Equal Area, Lower Hemisphere Stereonet

- ▲ Foliation measured in 2018/2019 (08/2018 and 01/2019)
- ● Joint measured in 2018/2019 (08/2018 and 01/2019)
- +P-1 Joints analyzed in Previous 2018 Annual Report
- +F-2 Foliations analyzed in Previous 2018 Annual Report

Color	Density Concentrations
	0.00 - 0.50
	0.50 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	2.00 - 2.50
	2.50 - 3.00
	3.00 - 3.50
	3.50 - 4.00
	4.00 - 4.50
	4.50 - 5.00
Contour Data	Pole Vectors
Maximum Density	4.41%
Contour Distribution	Fisher
Counting Circle Size	1.0%

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 (2018 report which is based on 2017 data) are shown for comparison.

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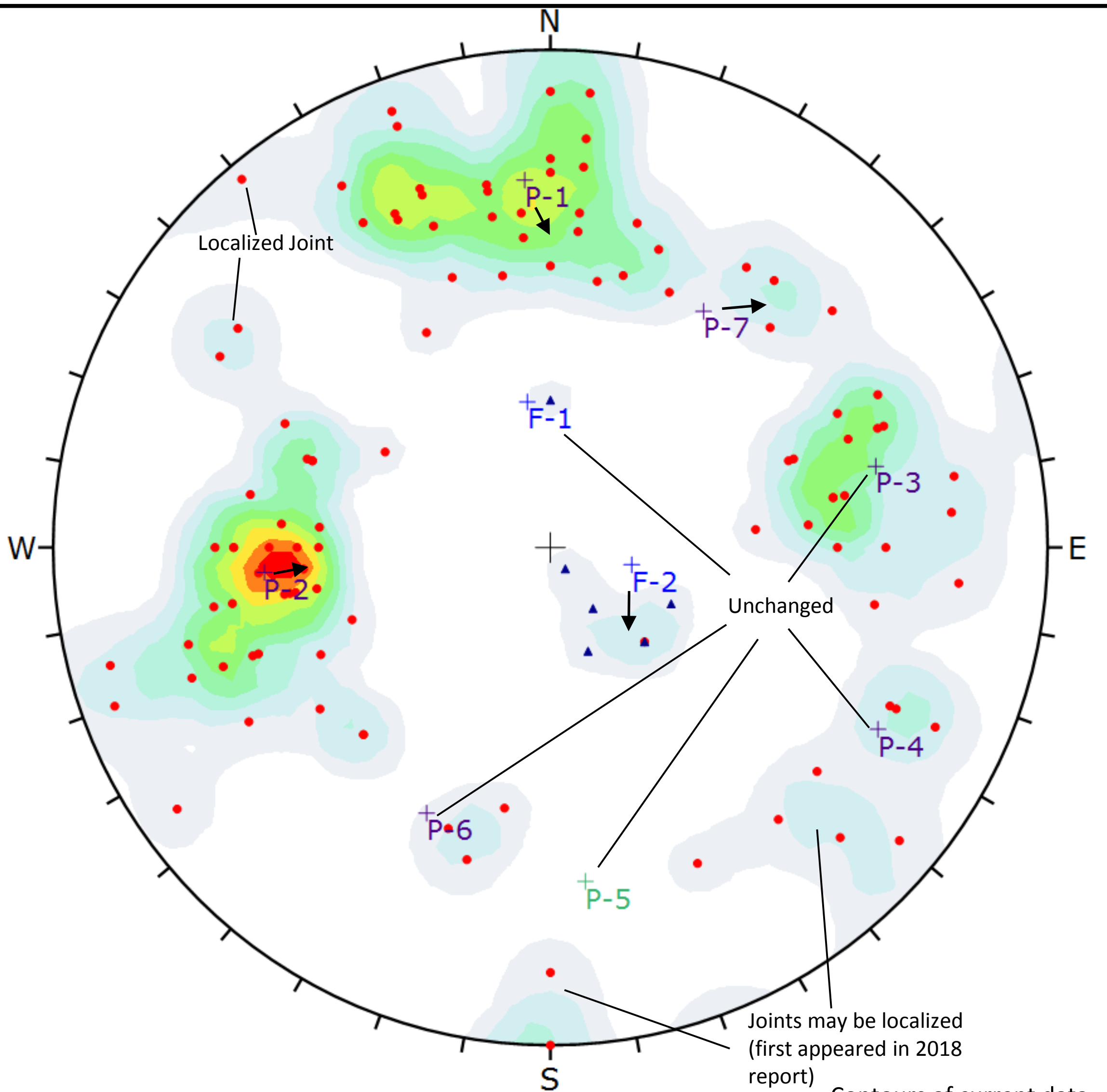
Spec-Agg Quarry
Golden, Colorado
Project No. 18C64008.00

Contour Overlay Plot

Martin Marietta Materials

Figure 5



Legend

Equal Area, Lower Hemisphere Stereonet

- ▲ Foliation measured in 2018 (8/2018 and 1/2019)
- ● Joint measured in 2018 (8/2018 and 1/2019)
- +P-1 Joints analyzed in Previous 2018 Annual Report
- +F-2 Foliations analyzed in Previous 2018 Annual Report
- +P-7 New Joint Set Observed in 2012 - 2013
- ↙ Arrow indicating relative shift in orientations based on 2018 data

Contours of current data (2018/2019, 112 data points)

Color	Density Concentrations
	0.00 - 0.80
	0.80 - 1.60
	1.60 - 2.40
	2.40 - 3.20
	3.20 - 4.00
	4.00 - 4.80
	4.80 - 5.60
	5.60 - 6.40
	6.40 - 7.20
	7.20 - 8.00
Contour Data	Pole Vectors
Maximum Density	7.93%
Contour Distribution	Fisher
Counting Circle Size	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 (2017 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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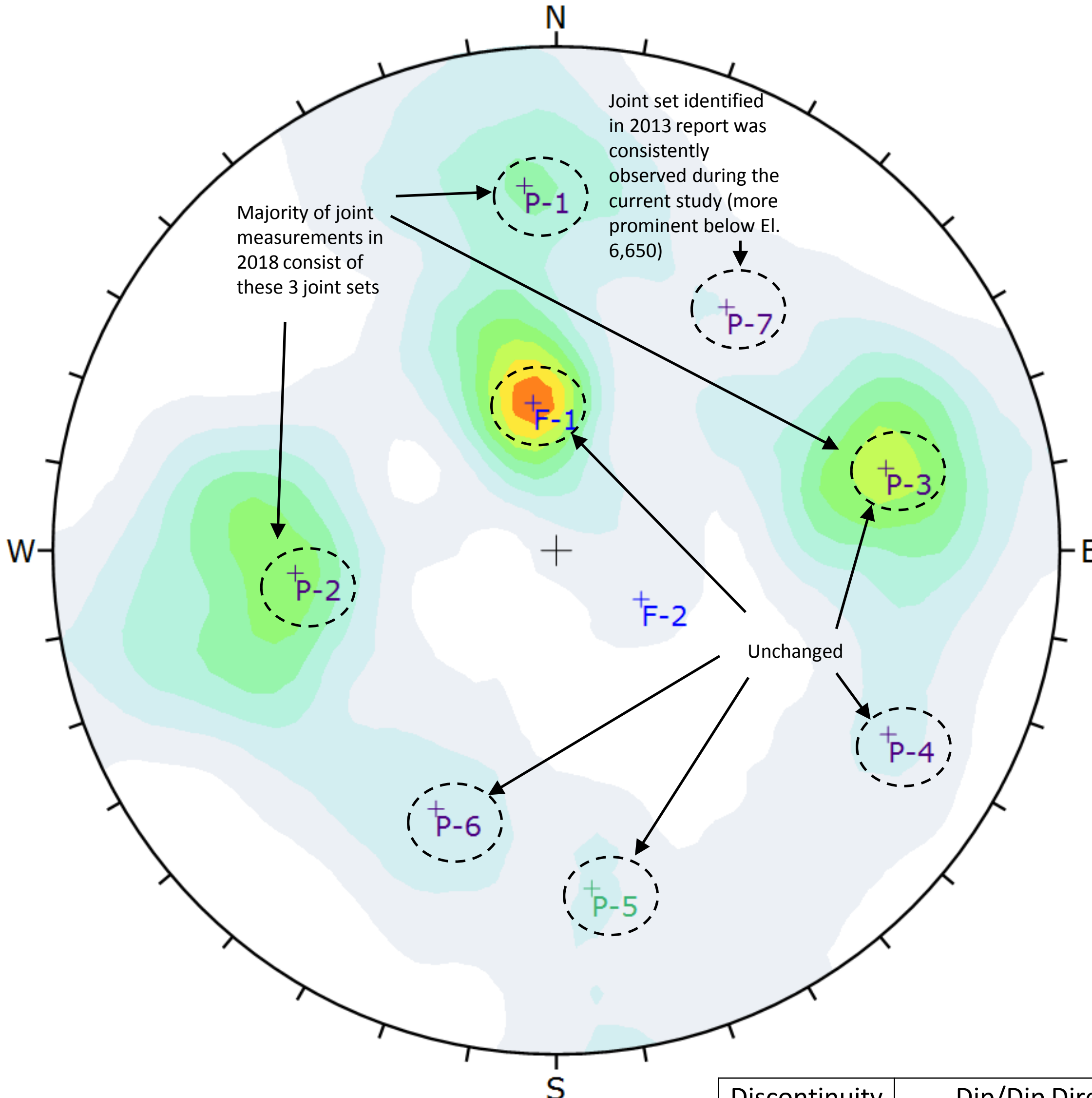
Spec-Agg Quarry
Golden, Colorado
Project No. 18C64008.00

Contour Plot of Current Data

Martin Marietta Materials

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°
F-2	22°/300°
P-1	72°/175°
P-2	55°/085°
P-3	68°/256°
P-4	74°/299°
P-5	68°/354°
P-6	61°/025°
P-7	61°/215°

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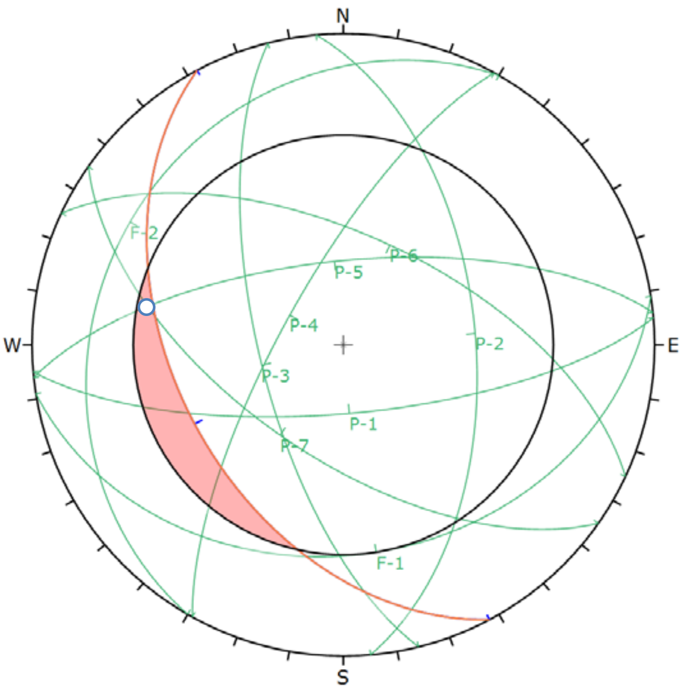
Spec-Agg Quarry
Golden, Colorado
Project No. 18C64008.00

Average Discontinuity Orientations (2019 Annual Report)

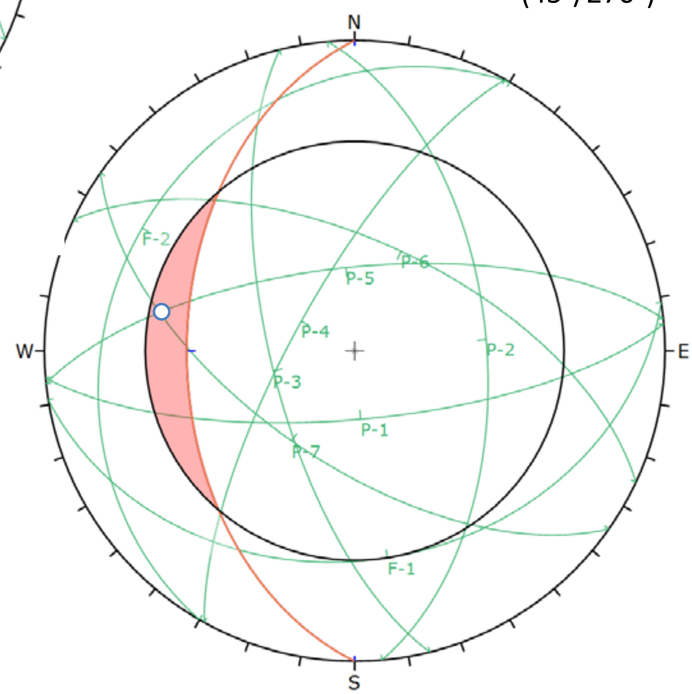
Martin Marietta Materials

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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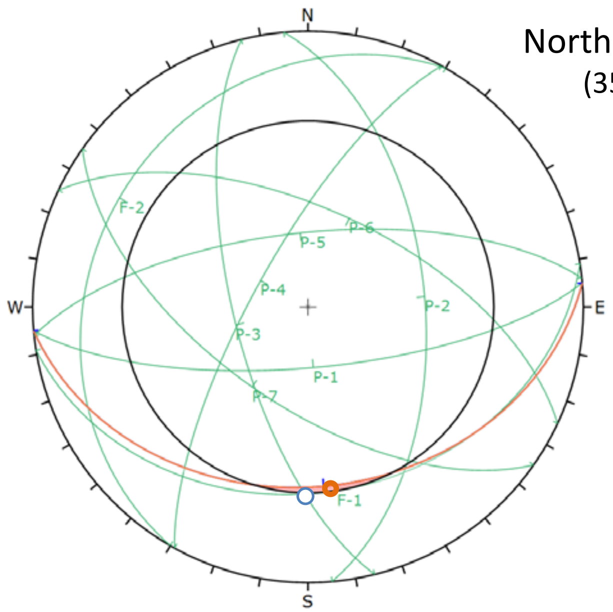
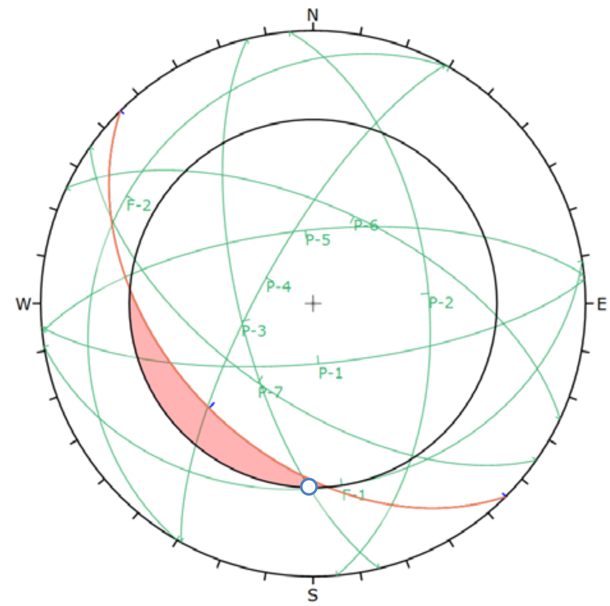
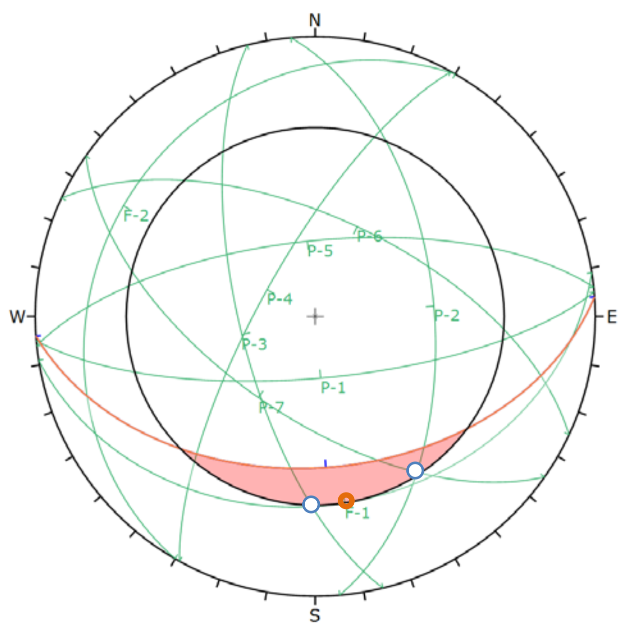
Spec-Agg Quarry Golden, Colorado Project No. 18C64008.00	Kinematic Analysis: East Walls 1 and 2
Martin Marietta Materials	Figure 8



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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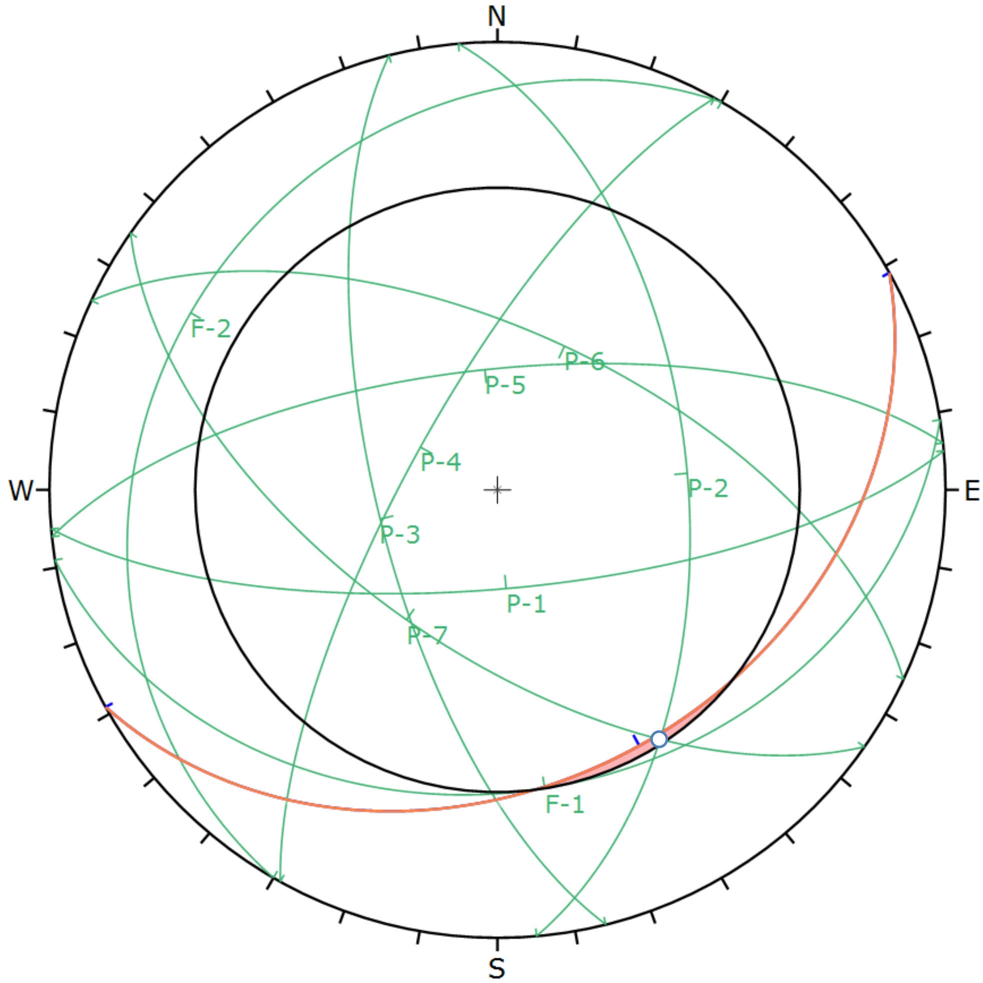
Spec-Agg Quarry Golden, Colorado Project No. 18C64008.00	Kinematic Analysis: Northeast Walls 1, 2 and 3
Martin Marietta Materials	Figure 9

Northwest Wall 35°/151°



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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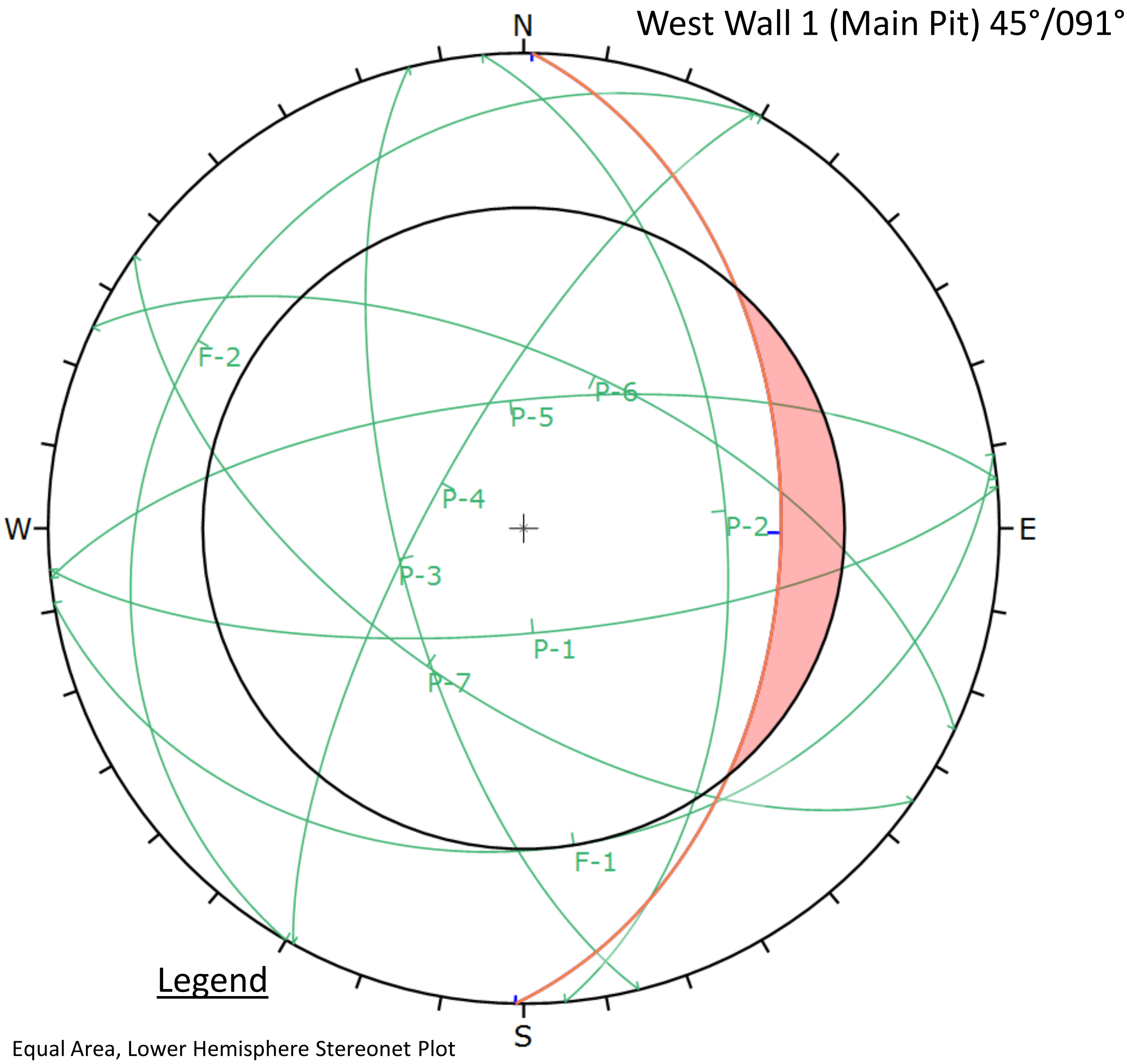
Spec-Agg Quarry Golden, Colorado Project No. 18C64008.00	Kinematic Analysis: Northwest Wall
Martin Marietta Materials	Figure 10



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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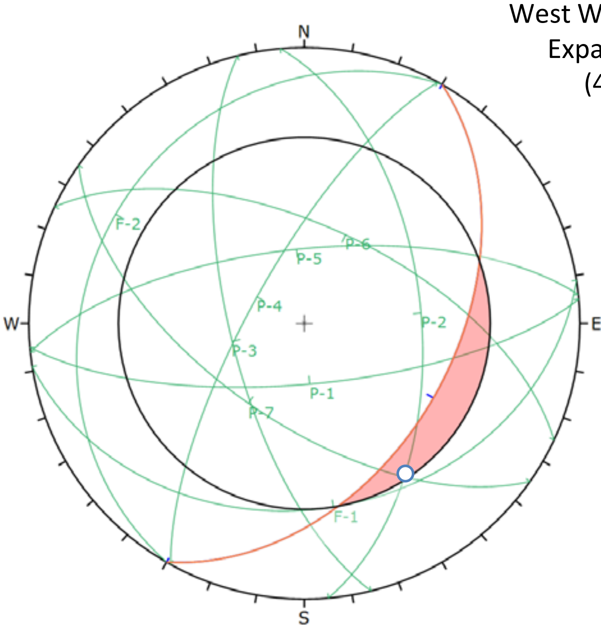
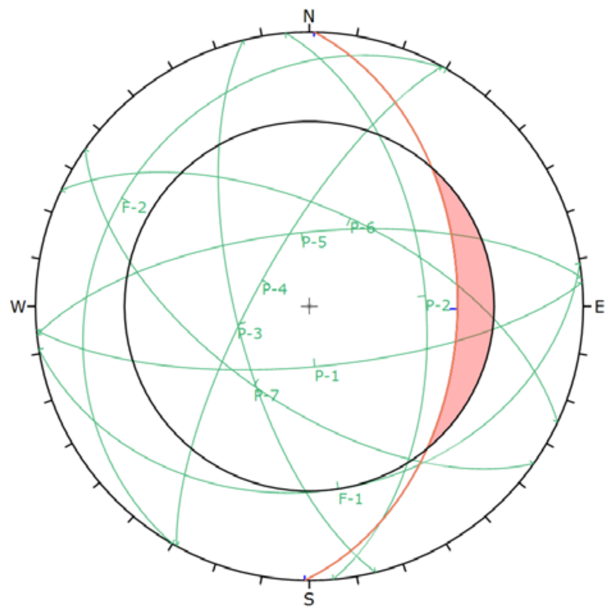
Spec-Agg Quarry Golden, Colorado Project No. 18C64008.00	Kinematic Analysis: West Wall 1 (Main Pit)
Martin Marietta Materials	Figure 11

West Wall 2 (Southern Expansion Area) (45°/120°)



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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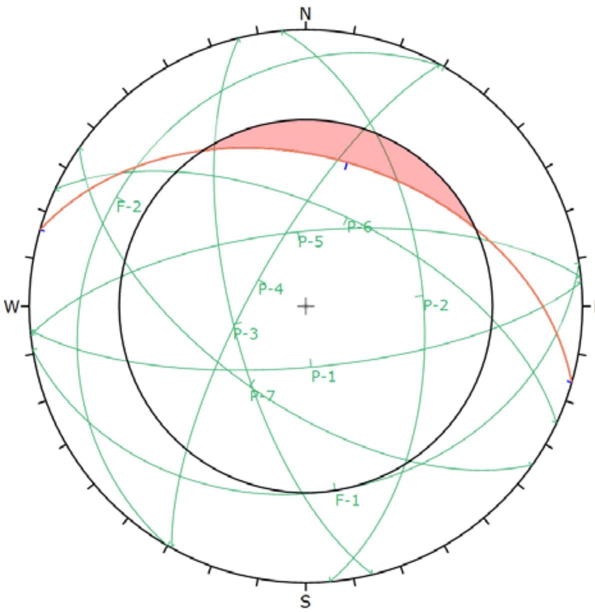
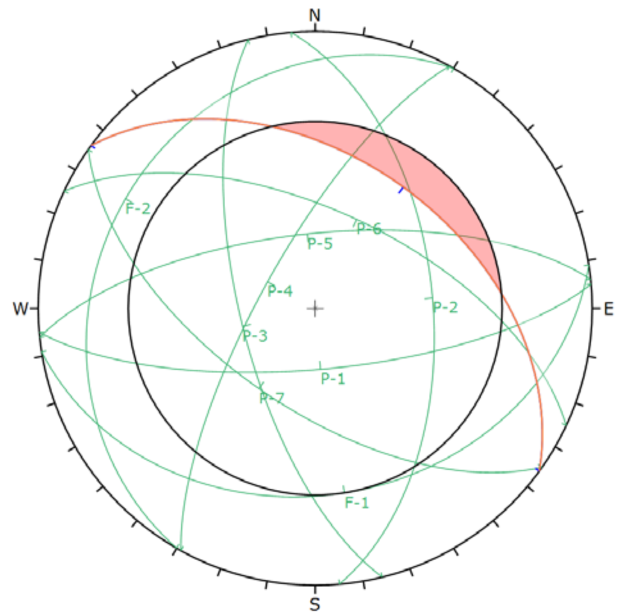
Spec-Agg Quarry Golden, Colorado Project No. 18C64008.00	Kinematic Analysis: West Walls 2 and 3 (Southern Expansion)
Martin Marietta Materials	Figure 12

Southwest Wall 1
(45°/016°)



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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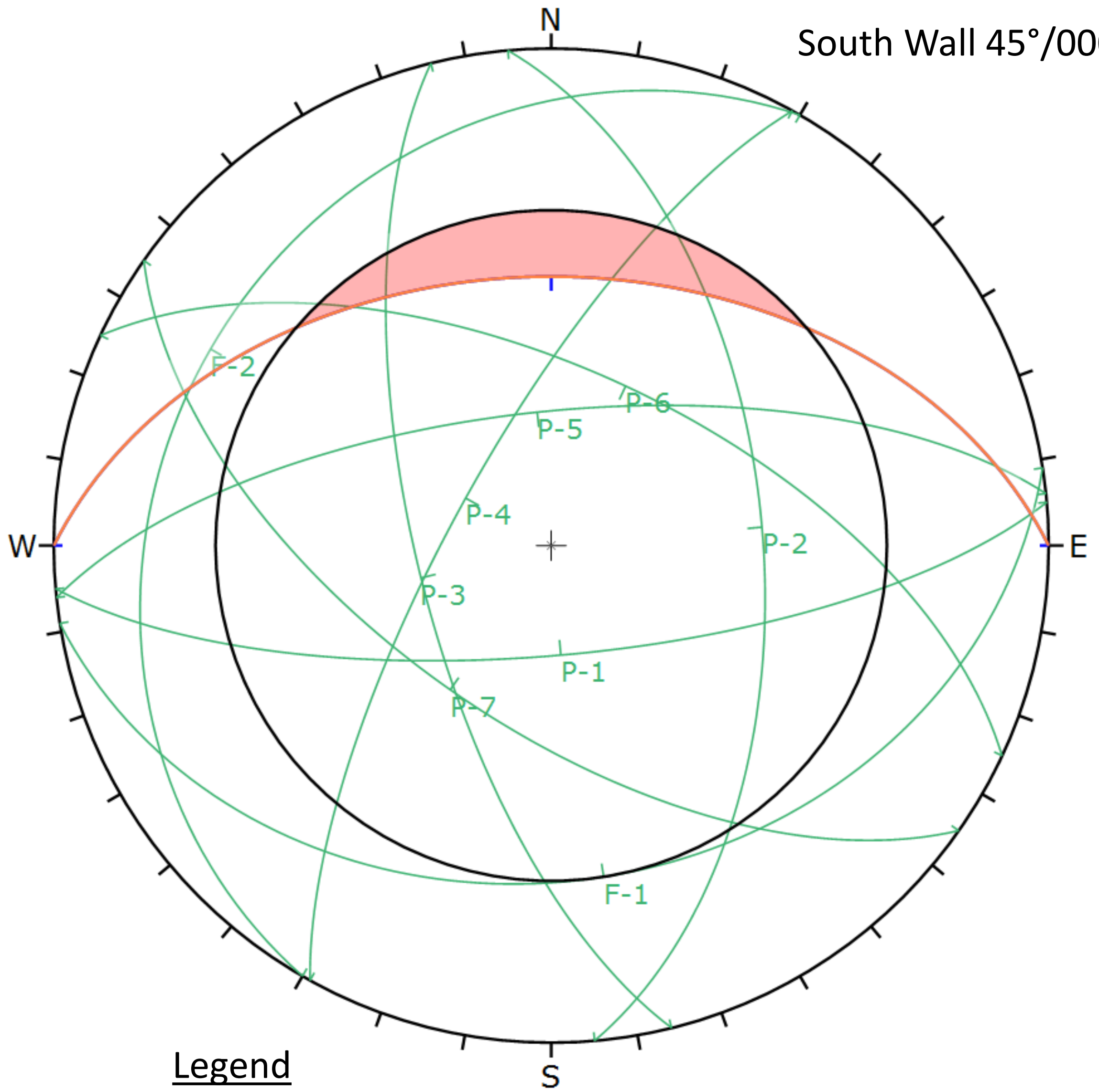
Spec-Agg Quarry Golden, Colorado Project No. 18C64008.00	Kinematic Analysis: Southwest Walls (Southern Expansion)
Martin Marietta Materials	Figure 13

South Wall 45°/000°



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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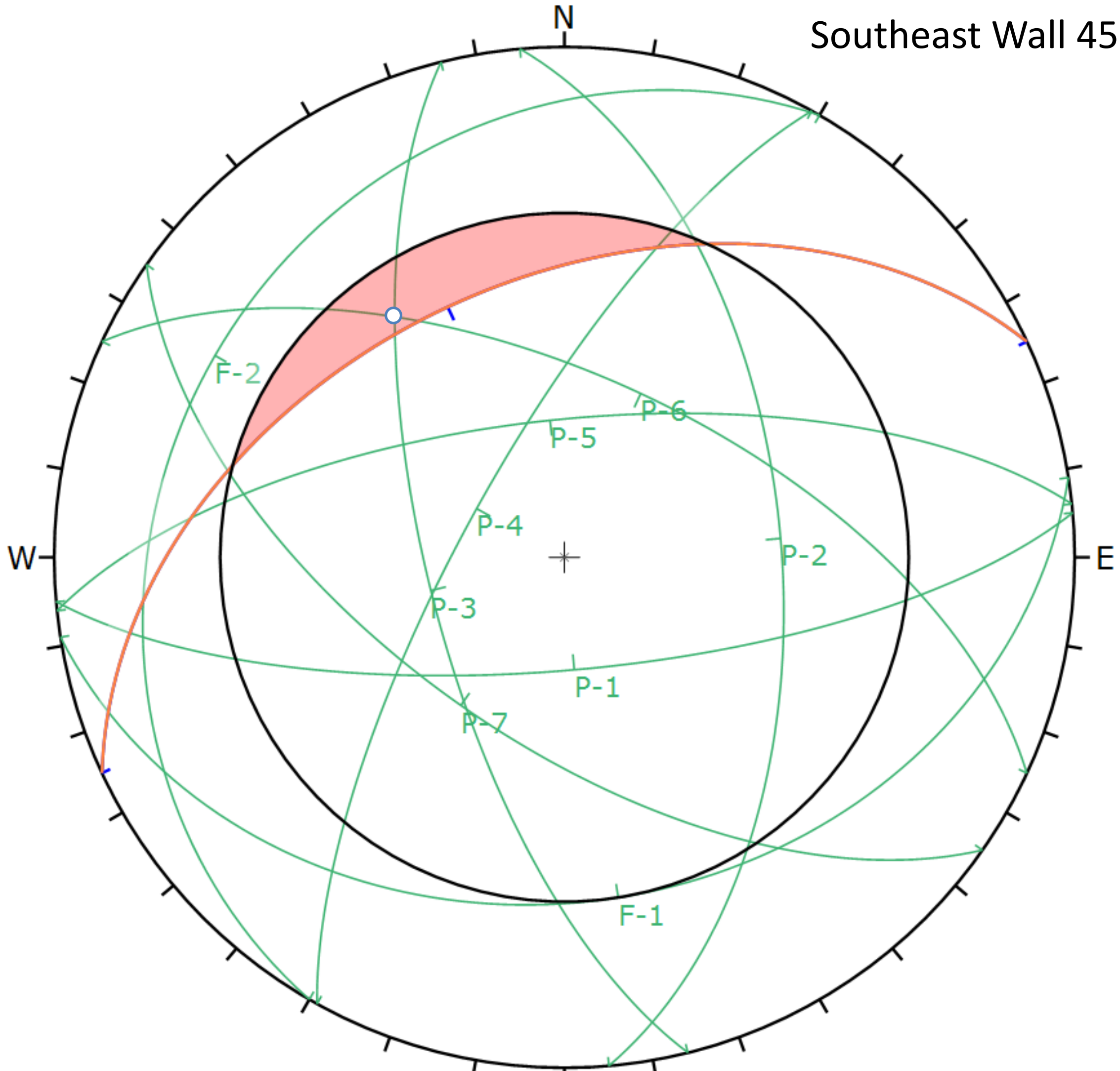
Spec-Agg Quarry Golden, Colorado Project No. 18C64008.00	Kinematic Analysis: South Wall
Martin Marietta Materials	Figure 14

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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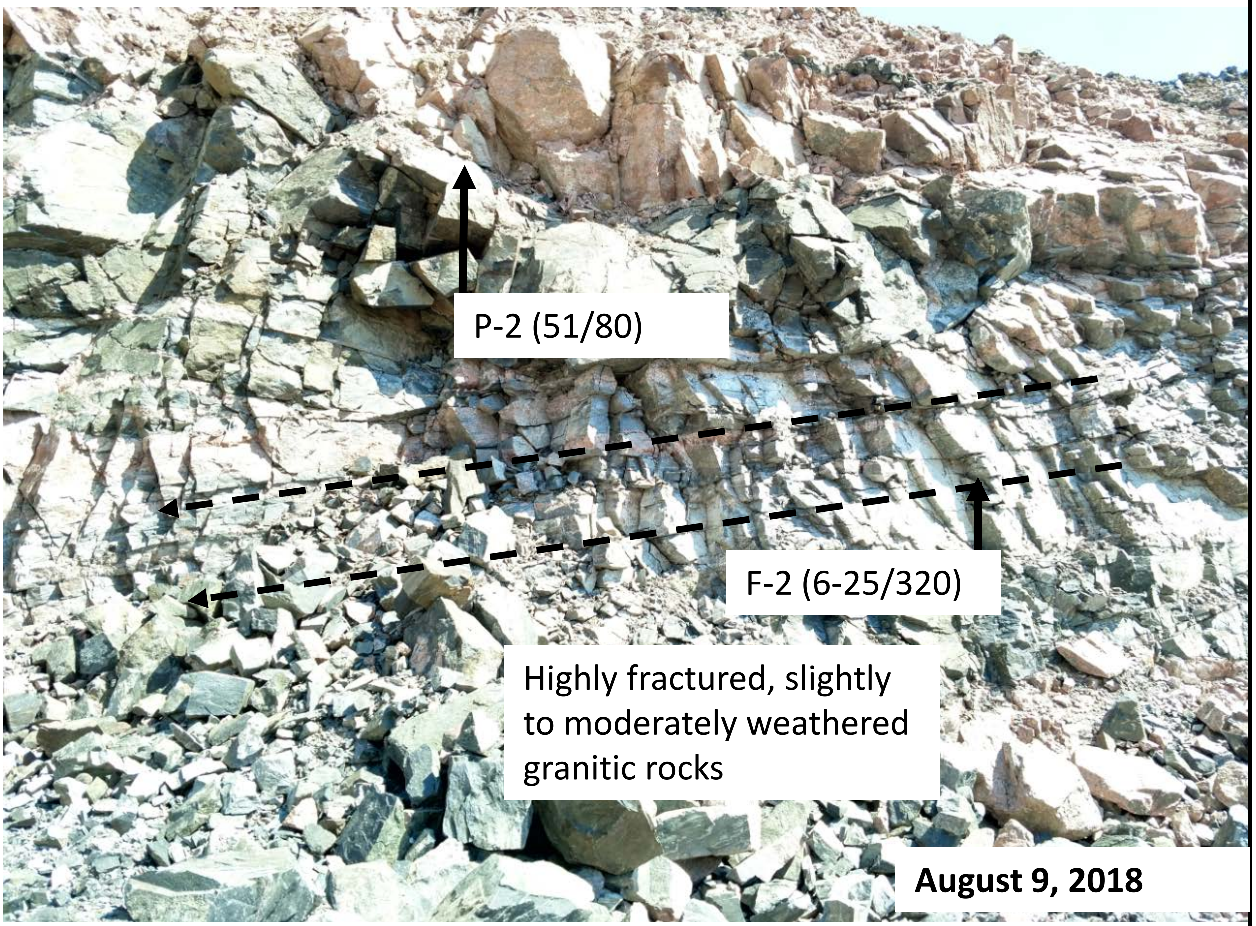
Spec-Agg Quarry Golden, Colorado Project No. 18C64008.00	Kinematic Analysis: Southeast Wall
Martin Marietta Materials	Figure 15



Looking southwest (Southwest Wall 2) in an actively-mined area (upper bench, ~EL 6615 ft) of the Southern Expansion Area near Station 19-01 (Figure 2).

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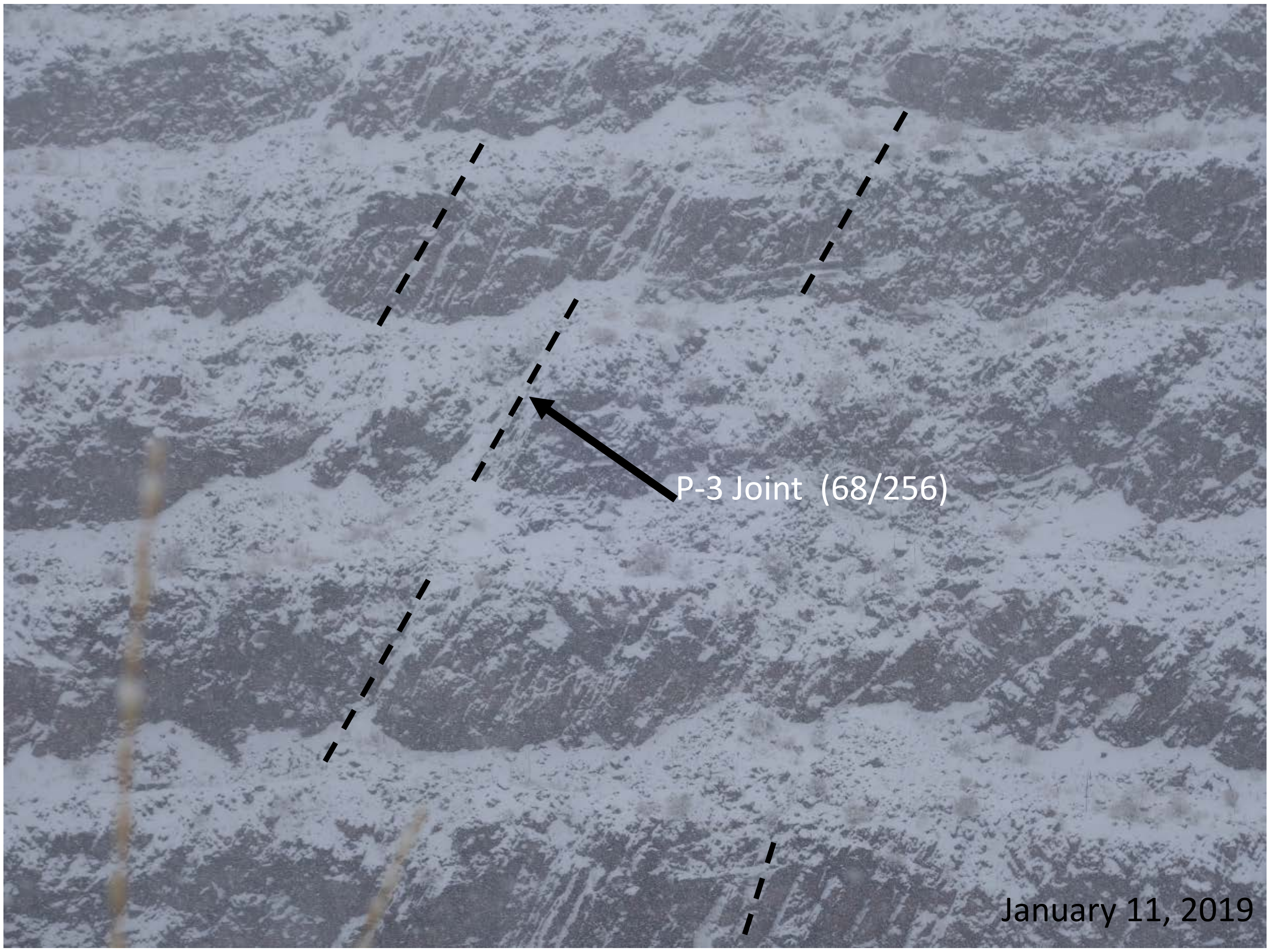
Spec-Agg Quarry Golden, Colorado Project No. 18C64008.00	Active Mining in Southern Expansion Area
Martin Marietta Materials	Photo 1



Exposed joint set P-3 highlighted by snow accumulation on temporary north facing wall of the Main Pit Area. Rock is slightly to moderately weathered.

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Spec-Agg Quarry Golden, Colorado Project No. 18C64008.00	Discontinuity Exposure in Main Pit Area
Martin Marietta Materials	Photo 2

Looking from Station 19-Shear (Figure 2) at near vertical east-west trending fault (3 to 5 feet wide) observed in an actively-mined portion of the Southern Expansion Area at ~EL 6545 ft.

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Spec-Agg Quarry Golden, Colorado Project No. 18C64008.00	Fault Exposure in Southern Expansion Area
Martin Marietta Materials	Photo 3

Main Pit area showing temporary walls and impounded water.
Top Photo: Looking east (2017)
Bottom Photo: looking south (2019)

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Spec-Agg Quarry Golden, Colorado Project No. 18C64008.00	Minimal mining activity in Main Pit Area
Martin Marietta Materials	Photo 4

Pre-existing scarp

Looking north from the Main Pit Area at pre-existing scarp feature on the north slope. It appears unchanged since December 2017.

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Spec-Agg Quarry Golden, Colorado Project No. 18C64008.00	North Slope in Main Pit Area
Martin Marietta Materials	Photo 5