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Subsidence Analysis Report

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FINAL REPORT ON

EAGLE PROJECT ADDITIONAL GEOTECHNICAL SCOPE

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February 8, 2006



05-1193-011

EXECUTIVE SUMMARY

Golder Associates Ltd. (Golder) completed phase 1 of a geotechnical study of the Eagle deposit and issued a report in April 2005 (Golder Geotechnical Study). Additional geotechnical scope was completed in phase 2 and is contained in this report issued in February 2006. The objectives of the additional geotechnical scope were to refine the geologic characterization, to evaluate the effectiveness of the backfilling program and predict potential elastic and plastic deformation of the crown pillar. Phase 3 of a geotechnical study will be completed with information obtained during operations.

An updated version of the 2004 drillhole core logging database was received on September 23, 2005. This version of the database included additional borehole information entered since January 2005, as well as results from subsequent drilling completed at the Eagle site. This version of the database contained a total of approximately 66 boreholes representing approximately 17,300 m of core. This database contained additional information from approximately 17 boreholes representing 6,100 m of core. The updated data were used to refine the geologic characterization and geotechnical model as presented in Sections 2 and 3.

New information was received to update the geometry of the crown pillar. The updated top of bedrock elevation was considered to be at 415 m based on data received from KEMC (i.e., borehole intercepts and modelled bedrock topography). An updated mine plan was also received from McIntosh Engineering that considered the top of mining at the 357.5 m elevation (353 m sill elevation). The revised crown pillar geometry was used to update the two stability assessments: CPillar and Scaled Span. The CPillar results predicted that the crown pillar would be stable for rock mass classification values of 70 (modelled to be the typical value in the crown pillar) as well as 60 (modelled to be on the lower end of values to be expected in the crown pillar). The Scaled Span assessment predicted that the crown pillar would be stable for rock mass classification values of 70, but was potentially unstable with a value of 60. The conclusion of the stability assessment was that the crown pillar is predicted to be stable with typical rock mass classification values and that potentially lower values would be identified during operations by KEMC prior to establishing the crown pillar.

The KEMC mine design will start mining at the lower levels and progress upwards. Additional drill information will be collected as the mining front approaches the crown pillar area, which will allow a better characterization of the rock mass quality of the crown pillar and the top of bedrock elevation. As more information becomes available, a further refinement of this crown pillar assessment can be completed before commencing development in the upper levels of the mine. Based on this additional information, it may be possible to mine above the current proposed top of mining elevation. Several alternatives will be available to KEMC, should the rock mass classification values be lower than 70. These options will include: increasing the

thickness of the crown pillar by decreasing the top of mining elevation, decreasing the number of stopes mined in the upper level to reduce the footprint of the crown pillar, and mining the stopes in the upper level in stages and maximizing the tightness of backfill employed (i.e., minimizing the vertical void beneath the crown pillar). Details of the crown pillar stability assessment are presented in Section 4.

MAP3D and PHASE² were used to model the vertical displacement of the crown pillar as a result of the current mine design. The vertical displacement results from the models predict the potential deflection at the top of bedrock (i.e., the interface between the bedrock and overburden). A wide range of models were created with differing geometries and input parameters as presented in Section 5. Typically, the modelling results predicted vertical displacements of up to 2 cm and typical horizontal extents of the vertical displacement occur over an area between coordinates 431405 to 431550 Easting and 5177480 to 5177620 Northing. Given that this is the vertical displacement predicted at the top of bedrock, and that the bedrock is covered by overburden (approx. 17 m), it would be expected that this displacement of the crown pillar would be imperceptible at surface.

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1.0 INTRODUCTION

Golder Associates Ltd. (Golder) completed a geotechnical study of the Eagle deposit and issued a report in April 2005 (Golder Geotechnical Study). The additional geotechnical scope contained in this report is supplemental to the April 2005 report. The objectives of the additional geotechnical scope were to refine the geologic characterization, to evaluate the effectiveness of the backfilling program and predict potential elastic and plastic deformation of the crown pillar.

For the purpose of this report, ground surface subsidence has been defined as the deflection of bedrock surface due to mining activity. To evaluate elastic deflection, Map3D software was used to predict the surface deflections for both non-backfilled and backfilled cases. To evaluate plastic deflection, a level of backfill was considered. This backfill level is commonly referred to as the 'tightness' of the fill and was evaluated based on the average vertical distance of the backfill from the top of the mined excavation. The extent to which the crown pillar can unravel is controlled by this vertical void and the extent to which the rock bulks as it unravels. Once the available vertical void is filled by the bulking rock, the unraveling of the crown pillar will arrest. The new geometry created by the unraveling was also assessed for deflection with the same software listed above. This evaluated both the effectiveness of the backfilling program and the predicted elastic and plastic deformation in the crown pillar.

An assessment of the potential displacements in the crown pillar was also completed. Furthermore, the dimensions and geometry of the crown pillar over which these displacements are predicted were defined in the assessment. Although these numbers would allow average strain ($\Delta L/L$) to be calculated, these parameters should be considered as basic inputs for the evaluation of strain in the crown pillar. A key consideration in evaluating the strain and the response of the rock mass to the strain (i.e., the potential changes to the rock fracturing network) is the geologic characterization of the rock mass. The goal of this characterization will be to further define the lithologic zones, rock fabric, material properties and major structure to the extent possible, given the available data. Completing these items is pre-requisite to making an evaluation of strain and potential changes to the rock fracturing network. This report includes: predicted crown pillar displacements, crown geometries, and geologic characterization.

2.0 UPDATED GEOTECHNICAL DATA

The Golder Geotechnical Study (dated April 28, 2005) was based on information contained in the KEMC geotechnical logging database dated January 3, 2005. This version of the Microsoft Access database contained a total of approximately 92 boreholes. The pre-2004 data is comprised of 43 NQ-sized boreholes representing just over 8,700 m of core, of which less than 50% is orientated. The 2004 data is comprised of 49 boreholes representing over 11,200 m of core, of which more than 75% is orientated.

An updated version of the 2004 database was received on September 23, 2005. This version of the database includes additional borehole information entered since January 2005, as well as results from subsequent drilling completed at the Eagle site. This version of the database contained a total of approximately 109 boreholes representing approximately 17,300 m of core. This is an increase of approximately 17 boreholes representing 6,100 m of core. In the review of the database, it was identified that the geotechnical logs of borehole 05EA110 were not present in the new drillhole database (but were present in the csv file with the collar coordinates). This omission is noted for completeness but does not affect the characterization of the crown pillar, as the location of this borehole is approximately 350 m east of the decline.

A QA/QC check of the data was completed. The database was then used to update the GoCAD geotechnical model. A review of the spatial distribution of the borehole data in GoCAD (Figure 1) indicated the following:

- Area 1 – 38 boreholes are collared at surface in the north side of the crown pillar. The boreholes are fan drilled between 45° and 90° toward the south with a 30 m spacing between borehole set-ups. These boreholes provided coverage of the hangingwall side of the crown, centre of the orebody and the footwall at depth. The southern portion of the crown pillar could not be drilled from surface due to collar access restrictions. Collar locations could not be within 100 ft of a creek passing over the southern portion of the crown pillar;
- Area 2 – 12 boreholes are collared at surface in the footwall of the deposit. The boreholes are fan drilled between 45° and 70° toward the north with a 30 m spacing between borehole set-ups. These holes provided coverage in the footwall, hangingwall and centre of the deposit;
- Area 3 – 10 boreholes are collared at surface, north of the hangingwall. The boreholes are fan drilled between 50° and 60° toward the south with a 50 m to 250 m spacing between borehole set-ups. These holes provided coverage for the hangingwall at depth and the centre of the deposit;
- Area 4 – 20 boreholes are collared at surface along the east side of the deposit. The boreholes are fan drilled toward the south with a varying spacing between borehole set-ups. These holes provide coverage along the eastern end of the deposit; and
- Area 5 – 1 borehole in the database which is drilled near the portal area.

The remaining boreholes are located outside the five areas above.

The updated database included 8 additional boreholes in the crown pillar area (i.e., Area 1). Based on the drill coverage currently in the database, there is limited data for the south portion of the crown pillar. In the updated database, more holes have been added to the east side of the crown pillar but due to surface restrictions, all the additional holes were collared north of the ore zone with dips of 45° or more. This results in limited geotechnical information in the southern portion of the crown pillar. Additional information in the southern portion of the crown pillar and along the length of the decline will be collected during development and operations.

It should be noted that soil and rock formations are variable to a greater or lesser extent. The data from individual borehole logs in the database indicate approximate subsurface conditions only at the individual borehole locations. Boundaries between zones on the logs are often not distinct, but rather are transitional and have been interpreted. Subsurface conditions between boreholes are inferred and may vary significantly from conditions encountered at the boreholes.

3.0 GEOTECHNICAL MODEL

The geotechnical model created for the Eagle Project was the base for the majority of the work conducted as part of the Golder Geotechnical Study (dated April 28, 2005). The data used in the geotechnical model was based primarily on the data provided by KEMC from their two Microsoft Access databases which contain the exploration drill core information, the proposed mine geometry (provided by McIntosh) and the lithological block model data provided by KEMC.

The geotechnical model was created using GoCAD software. This model was updated using the updated geotechnical data (as described above) and used to create RQD and Rock Mass Rating (RMR) sections for the Eagle deposit as was done in the original study. Updated values for the crown pillar area were also created.

3.1 GoCAD Model

The rock mass rating portion of the geotechnical model has been completed using the GoCAD software based on the updated Microsoft Access database (September 2005). The model contains two fields, Rock Quality Designation (RQD) and Rock Mass Rating (RMR), which can be queried to produce contoured sections in GoCAD. Eighteen sections were contoured in GoCAD for RQD and RMR and are illustrated on Figures 2 to 19.

A simple algorithm to calculate RQD (on a 3 m interval) for each borehole has been written. The structure of the two databases (pre-2004 and 2005) is the same for the fields required to calculate RQD. The majority of the data (pre-2004 and 2005) contained sufficient data to calculate RQD.

A series of algorithms have been created to calculate four of the five parameters summed to give an RMR rating. RMR has been calculated on a 3 m interval for each hole. The majority of the data in the 2005 database was found to adequately calculate RMR. Of the pre-2004 data, roughly half of the data is lacking all or some of the data required to calculate RMR. Table 1 lists the boreholes that were used in the GoCAD model in order to define the RMR for the Eagle deposit.

TABLE 1
BOREHOLES USED IN GOCAD MODEL

RMR Calculated for Entire Hole	RMR Calculated for Part of Hole	Insufficient Data to Calculate RMR	Database
03EA029 to 03EA043, YD02-24 to YD02-28, YD02-06	YD02-02, YD02-04, YD02-09, YD02-11, YD02-13, YD02-14, YD02-16, YD02-17, YD02-20	YD02-01, YD02-03, YD02-05, YD02-08, YD02-10, YD02-12, YD02-15, YD02-18, YD02-19, YD02-21, YD02-22, YD02-23	Pre-2004
04EA044 to 05EA109, YD02-07	-	-	2005

Eighteen RQD and RMR contour plots have been created in GoCAD to indicate the rock mass quality for the various rock types in the ore, hangingwall and footwall of the deposit. Ten of the plots are horizontal planes created at specific elevations: 173 m, 188 m, 203 m, 233 m, 263 m, 293 m, 323 m, 353 m, 383 m, and 405 m. Three east-west vertical sections were created along the 5177500, 5177560 and 5177620 Northing and five north-south plots were created along the 431585, 431545, 431500, 431457 and 431420 Easting.

3.2 RQD Summary

In the Golder Geotechnical Study (dated April 28, 2005), summaries were defined by mining method (i.e., Transverse Stopping from approximately 160 m to 280 m, Longitudinal Stopping from approximately 100 m to 160 m and decline and access to the east of the deposit). In order to maintain consistency with the Golder Geotechnical Study, RQD values were assessed for the same elevation intervals. RQD values are summarized below:

TABLE 2
EAGLE PROJECT RQD

Elevation	RQD Minimum	RQD Typical
100 m – 160 m Ore	80	90
100 m – 160 m F/W	80	90
100 m – 160 m H/W	80	90
160 m – 280 m Ore	60	90
160 m – 280 m F/W	65	90
160 m – 280 m H/W	40	90

TABLE 2 (CONTINUED)
EAGLE PROJECT RQD

Elevation	RQD Minimum	RQD Typical
280 m – 355 m Ore	70	95
280 m – 355 m F/W	75	95
280 m – 355 m H/W	80	95
355 m – 385 m Ore	70	95
355 m – 385 m F/W	75	90
355 m – 385 m H/W	50	85

3.3 RMR Summary

Eighteen RMR contour plots have been generated in GoCAD as illustrated on Figures 2 to 19. As stated in the above section, minimum RMR, typical RMR values and their Q_{equiv} values have been summarized by elevation, which match the RMR summary table in the Golder Geotechnical Study (dated April 28, 2005). Rock mass classification values are summarized below:

TABLE 3
EAGLE PROJECT RMR (Q_{EQUIV})

Elevation	RMR Minimum	RMR Typical	Q_{Equiv} Minimum	Q_{Equiv} Maximum
100 m – 160 m Ore	70	75	18.0	31.3
100 m – 160 m F/W	65	70	10.3	31.3
100 m – 160 m H/W	70	75	17.0	31.3
160 m – 280 m Ore	65	75	10.3	31.3
160 m – 280 m F/W	60	75	5.9	31.3
160 m – 280 m H/W	65	70	10.3	18.0
280 m – 355 m Ore	65	75	10.3	31.3
280 m – 355 m F/W	65	80	10.3	54.6
280 m – 355 m H/W	65	75	10.3	31.3
355 m – 385 m Ore	60	70	5.9	18.0
355 m – 385 m F/W	65	75	10.3	31.3
355 m – 385 m H/W	60	75	5.9	31.3
385 m – 405 m (above Ore)	60	75	5.9	31.3

This summary of rock mass classification compares well with the one presented in the Golder Geotechnical Study (dated April 28, 2005). Rock mass classification has been calculated at specific data locations (at individual drills runs) and all information between data locations has been interpreted. The interpretation between data locations has been contoured in plans and sections in GoCAD using kriging as the interpretation method.

3.4 Crown Pillar Geologic Characterization

A review of the crown pillar geologic characteristics has been conducted in order to better define the rock mass in the crown pillar. The following items have been completed in order to meet this objective:

- Query the geotechnical database in order to identify drillholes located in the crown pillar;
- Complete a discontinuity assessment based on the information from the drillholes in the crown pillar;
- Sort the discontinuity assessment based on lithology and discontinuity type;
- Review major structure section of the geotechnical database and identify if information exists on specific structural zones that may impact the crown pillar; and
- Review the GoCAD modelled estimates of RMR defining the crown pillar.

3.4.1 Crown Pillar Geotechnical Database Query

A query of the geotechnical database was conducted in GoCAD to identify boreholes located within the crown pillar area. The horizontal extent of the search radius was a 30 m wide perimeter around the footprint of the crown pillar (as defined by the upper extent of mining in the geometry provided by McIntosh). The vertical extent of the search included a 30 m height above and below the 383 m elevation.

Twenty-six holes intersected the search volume and consisted of the following geotechnical drillholes:

- 04EA045 to 04EA046;
- 04EA053 to 04EA057;
- 04EA060, 04EA062;
- 04EA064 to 04EA067;
- 04EA069;
- 04EA081 to 04EA084;
- 04EA099 to 04EA102; and
- 04EA104 to 04EA107.

The dominant lithologies (rock types) identified in the above drillholes is illustrated on Figure 20 (upper diagram). The isometric view of the crown pillar area (Figure 20) illustrates that the dominant rock types above and directly below the crown are semi-massive (SMSU), massive sulphides (MSU), feldspathic peridotite and peridotite (FPER and PER). The bedrock surrounding the perimeter of the crown is a combination of peridotite, silt stone (SLST) and sandstone (SDST), with the bedrock adjacent the north side of the crown dominated by siltstone and sandstone and the bedrock adjacent the south side of the crown dominated by feldspathic peridotite and peridotite (FPER and PER).

3.4.2 Crown Pillar Major Structural Assessment

A query of the geotechnical database for major structures was completed and compared to the drillholes that intersect the crown pillar area. All of the major structures in the 2005 geotechnical database are listed in a table labelled “tblMajorStructures”. The query of this table indicates that 40 individual major structural zones (a total 183 were recorded) were identified in 22 of the 26 drillholes intersecting the crown pillar area. A major structural zone in this table was identified as either a “gouge”, “sheared” or “broken” zone with a depth down the hole, length of zone and comment. The majority of the zones (20) were classified as broken with lengths varying between 0.1 m and 55 m in core length. Ten zones were identified with lengths 1 m or greater from the original major structural table (i.e., “tblMajorStructures”) and these have been listed in Table 4.

TABLE 4
MAJOR STRUCTURES CROWN PILLAR AREA

Hole ID	Depth (m)	Length (m)	Zone	Comment
04EA055	105.48	1.1	sheared	Intensely serpentinized zone of calcite cemented breccia
04EA055	110.75	6.75	broken	Core rubblized with minor slickensides and gouge
04EA060	27.96	1.3	broken	Slickensided, broken core
04EA062	47.1	55.0	broken	Core is in varying states of rubble, brecciated and stockworks
04EA064	46.95	1.48	broken	Quartz and calcite cemented breccia at contact
04EA067	34.29	3.51	broken	None
04EA067	71.85	2.8	sheared	None
04EA069	93.35	1.25	broken	None
04EA099	57.75	2.75	broken	None
04EA101	106.53	1.67	broken	Highly broken and shattered with some gouge and calcite veinlets

Note: The major structures were defined based on the geologic description.

The major structural zones in the boreholes intersecting the crown were loaded in a 3-D geological software package (Datamine Studio) to visualize the structural zone locations relative to the crown pillar area. An isometric view of the holes which intersect the crown pillar area is shown in Figure 20 (lower diagram).

The overall main structural zones indicate there is an increase in structural frequency toward the east and northeast areas of the crown pillar when compared to the central and west areas. This is also confirmed by the lower RMR values that were interpreted from the GoCAD model along the 405 m elevation on Figure 2. The RMR values in the east and northeast areas of the crown are between 60 and 70.

As described in the Golder Geotechnical Study (dated April 28, 2005), a discrete fault plane feature was indicated by the previous AMEC study. This fault plane has been included in the GoCAD models and is located approximately between the 431520 and 431560 Easting. The estimated strike of the fault plane is 010°/190° azimuth and the dip is sub-vertical.

Additional discrete structure may be present in the crown pillar which could have a significant effect on the behaviour of the crown. Current contours of RQD and RMR show low value zones (i.e., one such zone extends approximately east-west across the northern contact of the intrusion) that may indicate the location of discrete structure. The potential presence of such structure and the nature of these structures should be determined as part of the planned underground drilling program prior to establishing the upper levels of the mine and the crown pillar.

3.4.3 Crown Pillar Stereographic Structural Assessment

A review of the orientated discontinuity data for the crown pillar area has been completed using the DIPS (Rocscience, 2003) software which plots discontinuity data in two dimensional stereographic projection plots. Discontinuity sets were plotted using the 26 drillholes intersecting the crown pillar area based on the following rock types: feldspathic peridotite, peridotite, hornfels, semi-massive sulphide and combined siltstone and sandstone. Stereographic pole contour plots for the above rock types are illustrated on Figures 21 to 25 and listed in Table 5.

TABLE 5
MAJOR AND MINOR DISCONTINUITY SETS CROWN PILLAR AREA

Rock Type	Set No.	Dip (degrees)	Dip Direction (degrees)
Feldspathic Peridotite	1m	80	321
	2m	47	277
	3m	29	241
	4m	06	030
	5m	29	331
Peridotite	1m	08	081
	2m	36	344
	3m	78	159
Semi Massive Sulphides	1m	82	347
	2m	01	120
	3m	38	319
	4m	40	019
Siltstone & Sandstone	1m	03	009
	2m	35	054
	3m	42	345
	4m	46	252
Hornfels	1m	17	335
	2m	25	059
	3m	53	009
	4m	87	151

The discontinuity pole plots were scattered for the rock types reviewed. However, some dominant discontinuity sets (features in more than one rock type) were identified between the rock types reviewed and are summarized as follows:

- J1=03°-17°/335°-009° and 01°-08°/080°-120°, horizontal feature dipping from the northwest to the southeast;
- J2=80°-82°/321°-347° or 78°-87°/151°-159°, vertical feature dipping northwest to southeast;
- J3=29°-42°/319°-335°, 29° to 42°, feature dipping to the northwest;
- J4=29°-47°/241°-277°, 29° to 47°, feature dipping to the west-southwest; and
- J5=40°-53°/009°-019° or 25°-35°/054°-059°, 25° to 53°, feature dipping north-northeast.

4.0 CROWN PILLAR

4.1 Crown Pillar Geometry

The bedrock surface elevation has been considered to be located at 415 m. This elevation was based on two sources: 1) bedrock intercepts of drillholes found to penetrate the crown pillar and 2) from the current interpretation of bedrock topography. This data was supplied by KEMC in the form of Excel spreadsheets containing drillhole collar information and the current bedrock topographic contour.

Mine design was obtained from McIntosh (Dec. 5, 2005). In the previous mine design, the top of mining was located at the 387.5 m elevation. The new design has removed the upper level of stopes (Level 1) and now has the top of mining at Level 2 (357.5 m elevation). These design modifications resulted in a new crown pillar geometry.

4.2 Crown Pillar Stability Assessment

Previous crown pillar assessments have been completed for the Eagle Project using the Scaled Span Concept Method (empirical) and the CPillar (Rocscience, 2001) limit equilibrium program. AutoCAD drawings have been provided by McIntosh Engineering illustrating the updated mining geometries. The crown pillar configuration is as follows:

- Crown bottom elevation (back of last mining panel) = 357.5 m.;
- Crown pillar span (S) = 68 m;
- Crown pillar strike length (L) = 50 m;
- Bedrock surface elevation = 415 m; and
- Crown pillar thickness (t) = 57.5 m (415 m – 357.5 m).

The rock mass quality (i.e., RMR and Q_{equiv}) of the crown pillar has also been updated based on the 2005 GoCAD model. The RMR in the eastern and western areas of the crown pillar has been estimated to be between 60 and 70 and the RMR in the central area of the crown pillar between 80 and 90 based on the 415 m and 383 m elevation contours illustrated on Figures 2 and 3. The following rock mass quality values have been considered for the crown pillar assessment:

- Minimum RMR = 60 ($Q_{equiv}=5.9$); and
- Typical RMR = 70 ($Q_{equiv}=17.97$).

4.2.1 Eagle Crown Pillar Scaled Span C_s

The concept of a scaled span for defining crown pillar stability was originally proposed in Golder's report for a CANMET research project (Golder, 1990). The concept was formulated based on back-analysis of old failures and review of precedent experience.

For any given geometry and rock quality, the crown pillar stability is estimated empirically by plotting rock mass quality, using Q against a scaled crown pillar span index, C_s , calculated as follows:

$$C_s = S \left\{ \frac{\gamma}{t (1 + S_R) (1 - 0.4 \cos (\text{dip}))} \right\}^{0.5}$$

where: S = crown pillar span (m);

γ = density of the rock mass (t/m^3);

t = thickness of crown pillar (m);

S_R = span ratio = S / L (crown pillar span / crown pillar strike length); and

dip = dip of the orebody or foliation (degrees).

In this equation, all the parameters are related to the geometry of the crown pillar. The effects of groundwater and clamping stresses are included within the determination of the rock mass quality (Carter, 1992).

With the rock quality, Q , known, an estimate of the maximum stable span can be made by reference to the critical span (S_c) calculated as follows:

$$S_c = 3.3 \times Q^{0.43} \times \sinh^{0.0016}(Q)$$

where: S_c = critical span (m)

When $C_s < S_c$, the crown pillar is considered stable and when the $C_s > S_c$, the likelihood of failure is high, assuming the crown has not been artificially reinforced by bolting or fill. The ratio of $S_c/C_s = F_c$ can be considered to be an expression of the crown pillar stability Factor of Safety (FOS).

The crown pillar dimensions used in the Eagle project are listed in Section 4.2 and have been based on the current mine design provided by McIntosh Engineering.

The dip of the orebody in the upper level of the mine is vertical to sub-vertical. For this assessment, the worst case of vertical (-90°) was used. The rock mass quality of the crown pillar was based on the minimum (RMR=60 or $Q_{\text{equiv}} = 5.9$) and typical (RMR = 70 or $Q_{\text{equiv}} = 17.97$) estimates in Table 3. Summarized in Table 6 is the scaled span assessment based on the current crown pillar dimensions.

TABLE 6
SCALED SPAN CROWN PILLAR ASSESSMENT

Bottom of Crown Pillar	H/W Dip ($^\circ$)	t (m)	S (m)	L (m)	C_s	RMR	Q_{EQUIV}	Sc	Fc (FOS)
357.5 m	90	57.5	68.0	50.0	9.77	70.00	17.97	11.75	1.20
357.5 m	90	57.5	68.0	50.0	9.77	66.40	12.05	9.80	1.0
357.5 m	90	57.5	68.0	50.0	9.77	60.00	5.92	7.15	0.73

The crown pillar is predicted to be stable when considering the typical RMR value of 70 (FOS 1.20). The FOS for the crown pillar is above 1.0 for RMR values >66.4 ($Q_{\text{equiv}} = 12.05$). The crown pillar is predicted to be potentially unstable when considering the minimum RMR values of 60 (FOS = 0.73).

4.2.2 CPillar Analysis

The program CPillar (Rocscience, 2001) was used for checking the empirical scaled span procedure assessment of stability state. This program uses limit equilibrium techniques to compute an FOS and probability of failure (POF) against several modes of failure, including various cracking modes and vertical downward sliding of a rectangular, horizontal crown pillar (assuming a rigid block model). Input, in the form of geometry, rock mass strength, in situ stresses and groundwater conditions are entered (with the option to input standard deviations of controlling parameters, if known) and, based on these values, a mean FOS and POF is calculated.

A number of basic assumptions were made for the CPillar analyses performed to evaluate the stability of the Eagle Mine crown pillar. These assumptions are as summarized below:

- (i) To be conservative, the water levels were estimated to be coincident with the ground surface;
- (ii) The extent of the in situ horizontal stresses, which affect the crown pillar, have not been determined. The analyses were conducted with horizontal and vertical stress ratios $K = 1$;
- (iii) The dip of the orebody in the region of the crown pillar was estimated to be 90° ;
- (iv) To be conservative, all the stopes are assumed to not have the benefit of active pressure from backfill below;

- (v) For comparative purposes, a standard deviation of 10% of the mean value for most input parameters has been used;
- (vi) RMR values that were used for the analysis were the minimum and typical values from Table 3; and
- (vii) m values were determined using m (undisturbed) = $m_i \cdot \exp((\text{RMR}-100)/28)$ from Hoek and Brown, 1988 with m_i estimated = 25.

The same crown pillar geometries that were used in the Scaled Span assessment were used in the CPillar analysis. The water depth that was used in the analysis assumed the crown pillar was completely saturated with water and (crown pillar t + overburden depth – water depth from surface) was measured from the bottom of the crown pillar. The following parameters were used in the CPillar analysis:

- Bedrock Strength (Peridotite) = 120 MPa, standard deviation (SD) = 39 MPa;
- Overburden depth = 17 m; and
- m (RMR=60) = 6 or m (RMR=70) = 8.6.

Summarized in Table 7 are the results of the CPillar analysis based on the current crown pillar dimensions and rock mass quality.

TABLE 7
EAGLE CROWN PILLAR CPILLAR ANALYSIS

Bottom of Crown Elev (m)	x (m)	y (m)	t (m)	OB (m)	k	RMR	m	Fc (FOS)
357.5	68	50	57.5	12	1	60	6	3.65
357.5	68	50	57.5	12	1	70	8.6	6.40

Results from the CPillar analysis indicate that the factor of safety (FOS) for the crown pillar with RMR values of 60 and 70 are 3.65 and 6.40, respectively. CPillar predicts that the crown pillar will be stable with RMR values of 60 or 70.

4.3 Crown Pillar Discussion and Recommendations

The long-term stability of the crown pillar will be dependent on the following parameters:

- Rock mass quality of the crown pre-mining and post-mining;
- Crown pillar dimensions;
- Quality/quantity of backfill placed; and
- Void size beneath crown pillar.

The CPillar results predicted that the crown pillar would be stable for rock mass classification values of 70 (modelled to be the typical value in the crown pillar) as well as 60 (modelled to be on the lower end of values to be expected in the crown pillar). The Scaled Span assessment predicted that the crown pillar would be stable for rock mass classification values of 70 but was potentially unstable with a value of 60. The above two stability assessments were completed to consider different potential failure mechanisms for the crown pillar. The Scaled Span assessment is considered the industry accepted method of assessing overall crown pillar stability. The conclusion of the stability assessment was that the crown pillar is predicted to be stable with typical rock mass classification values and that potentially lower values (i.e., <70) would be identified by KEMC prior to establishing the crown pillar.

The KEMC mine design will start mining at the lower levels and progress upwards. Additional drill information will be collected as the mining front approaches the crown pillar area which will allow a better characterization of the rock mass quality of the crown pillar and the top of bedrock elevation. As more information becomes available, a further refinement of this crown pillar assessment can be completed before commencing development in the upper levels of the mine. Based on this additional information, it may be possible to mine above the current proposed top of mining elevation. Several alternatives will be available to KEMC, should the rock mass classification values be lower than 70. These options will include: adjusting the thickness of the crown pillar, decreasing the number of stopes mined in the upper level to reduce the footprint of the crown pillar, and mining the stopes in the upper level in stages and maximizing the tightness of backfill employed (i.e., minimizing the vertical void beneath the crown pillar).

5.0 MODELLING OF CROWN PILLAR DEFLECTION

MAP3D and PHASE² were used to model the deflection of the crown pillar. The vertical displacement results from the models predict the movement at the top of bedrock. The top of bedrock is the interface between the bedrock and overburden. The top of mining based on the mine design is at the 357.5 m elevation and the top of bedrock has been estimated approximately at the 415 m elevation and surface at the 432 m elevation. This results in approximate minimum crown pillar and overburden thicknesses of 57.5 m and 17 m, respectively. The following sections detail the modelling of the crown pillar.

A base model was constructed using the revised mining plan geometries created by McIntosh. Material properties for the host rock and the ore were based on the Eagle deposit data and backfill properties were based on typical industry standards. Stress regime data for the Eagle deposit was based on published values for the regional stresses in the Canadian Shield.

Models were created in both MAP3D and PHASE² to simulate a variety of mining conditions and worst case scenarios. Both the MAP3D and PHASE² analysis results displayed similar vertical displacements validating the modelling results.

5.1 Model Geometry

The model geometries were based on the revised mining plan received from McIntosh. The primary model created had all of the stopes mined and backfilled with high strength rockfill.

5.2 Modelling Material Parameters and Stress Regime

The material parameters and stress regime used for the models were the same as those used in the models for the Golder Geotechnical Study (dated April 28, 2005). It should be noted that the stress regime data for the Eagle deposit is unknown. An estimate of the stress regime was based on the regional stresses in the Canadian Shield from Herget (1988). Details on the material properties and estimated stress regime can be found in the Golder Geotechnical Study.

As part of the data collection program to be conducted during the initial development of the mine, it is recommended that the stress regime be assessed. This assessment will allow a more accurate estimate of the stress regime to be used in the refined crown pillar assessment that KEMC intends to complete prior to developing under the crown pillar.

5.3 Effect of Backfill and Plastic Displacement Assessment

The effectiveness of backfill was assessed for varying degrees of tightness to the bottom of the crown pillar. Deflection of the crown pillar was then considered for the reduced crown pillar thicknesses resulting from sloughage (i.e., plastic deformation) associated with the different degrees of backfill tightness. This was done by considering unraveling and bulking of the crown pillar for different void/arrest heights.

MAP3D and PHASE² were used to model elastic displacements and stress changes in the crown pillar based on the unravelled/arrested geometry. Plastic deformations that propagate to surface were not considered, as these will not be possible with the proposed backfill program that KEMC intends to employ.

In any jointed, blocky rock mass, the potential for an unravelling failure exists. This failure is typically progressive in nature, initiated by blocks falling out of the back due to gravity and low confining stresses. Unravelling failure may progress to surface, depending on the void space and the thickness of the crown pillar. As rock fails, it swells in volume due to the introduction of voids in the broken mass. The swelling or bulking factor is generally considered to be at least 30%.

The unravelling assessment used in this report assumes that the rock mass will fail with vertical walls until the void chokes itself or reaches surface. This is a conservative assumption and generally a rare case. More common is the formation of a draw cone (typical of very broken up ground or overburden) or of a failure dome (typical of hard rock). In the case of a draw cone, there is a substantial increase in the volume of ground mobilized and available to bulk and choke the void. In the case of the failure dome, the horizontal stresses provide sufficient confinement to the rock mass and the void stabilizes itself before reaching surface.

The results of the unravelling assessment for the Eagle Project are presented in Table 8. Bedrock surface and the original stope back are considered to be at the 415 m and 357.5 m elevations, respectively. The assessment has been completed for various backfill levels.

TABLE 8
CROWN PILLAR GEOMETRIC UNRAVELLING POTENTIAL

Backfill Elevation (Distance from backfill to stope back)	H_r (m)	H_v (m)	H_f (m)	Potential Unravelling Failure to Surface
357.5 m (backfill tight to stope back)	57.5	0	0	No
356.9 m (backfill 0.6 m from stope back)	57.5	0.6	2	No
356.3 m (backfill 1.2 m from stope back)	57.5	1.2	4	No
355.9 m (backfill 1.8 m from stope back)	57.5	1.8	6	No

Notes: H_v = Height of available void below crown pillar.
H_r = Height of rock (thickness of crown pillar excluding overburden).
H_f = Height of potential failure above stope before chokes off, assuming bulking factor of 30%.

KEMC intends to fully backfill all of the stopes in the mining areas under the crown pillar. The tightness of the backfill in these stopes is dependent on many factors including the type of backfill used, the method of placing the backfill and the geometry of the stopes. This unravelling assessment shows the correlation between the tightness of the backfill (i.e., the initial vertical void left between the top of backfill and the back of the stope) and the potential height of unravelling. The top of bedrock is the interface between the bedrock and overburden. The approximate depth of overburden above the crown pillar is 17 m (i.e., surface at approximately 432 m elevation).

These results were used to assess the plastic deflection of the crown pillar as related to backfill height. Each backfill height (i.e., vertical voids of 0.6 m, 1.2 m, and 1.8 m) was used to create a reduced crown pillar geometry in MAP3D and PHASE² models. This allowed the combined backfill tightness, unravelled geometry and calculated deflection to be determined for each scenario.

5.4 Modelling Results

Several scenarios were analyzed in MAP3D. A wide range of models were created with differing geometries and input parameters. Typically, the modelling results predicted that vertical displacements of up to 2 cm could be expected and the typical horizontal extent of the vertical displacement could occur over an area between coordinates 431360 to 431550 Easting and 5177480 to 5177620 Northing.

Additional models were analyzed in PHASE² to verify the predicted displacements identified in the MAP3D model. The PHASE² models displayed similar results, with a maximum vertical displacement of approximately 2 cm.

GOLDER ASSOCIATES LTD.



FOR Paul Palmer, P.Eng.

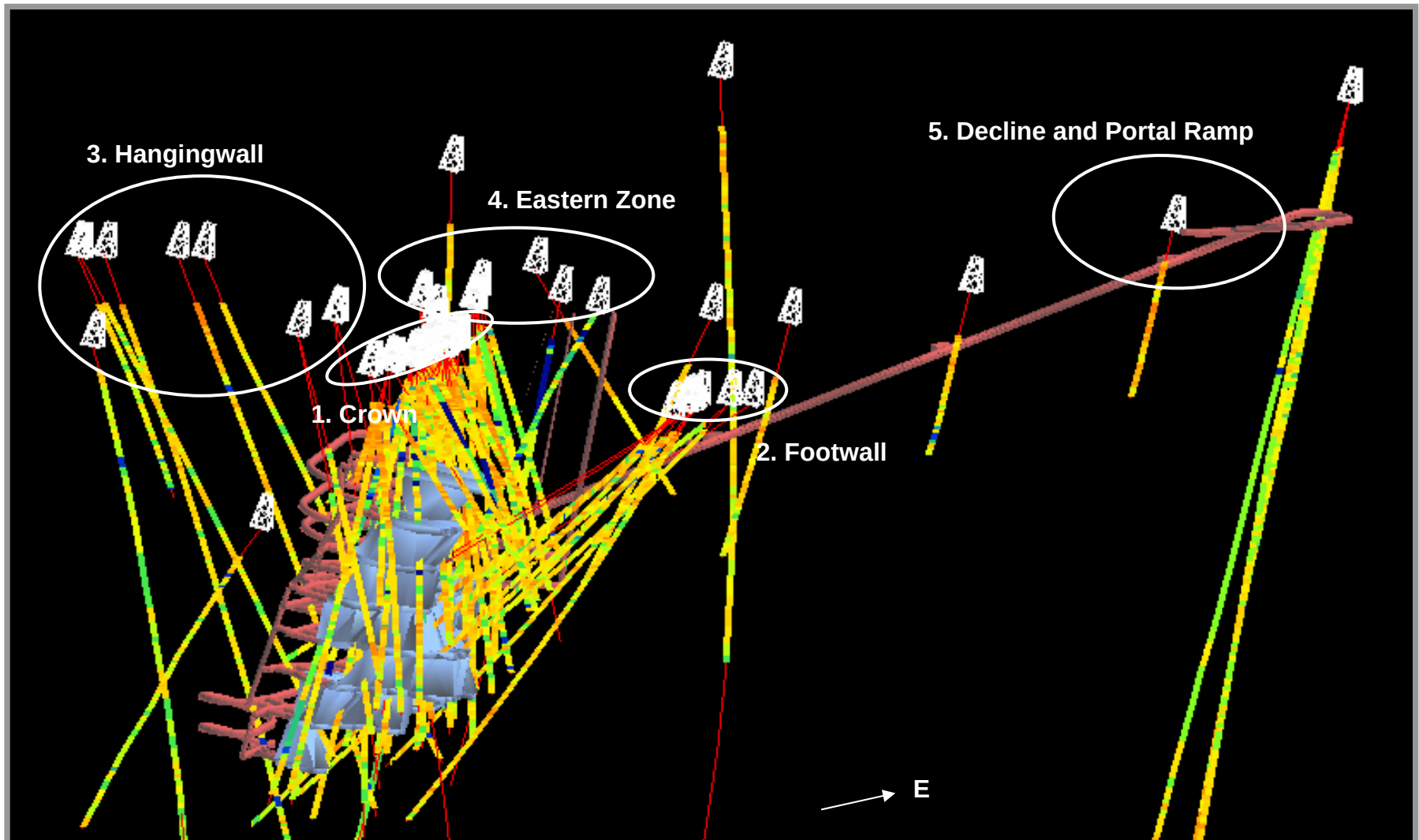
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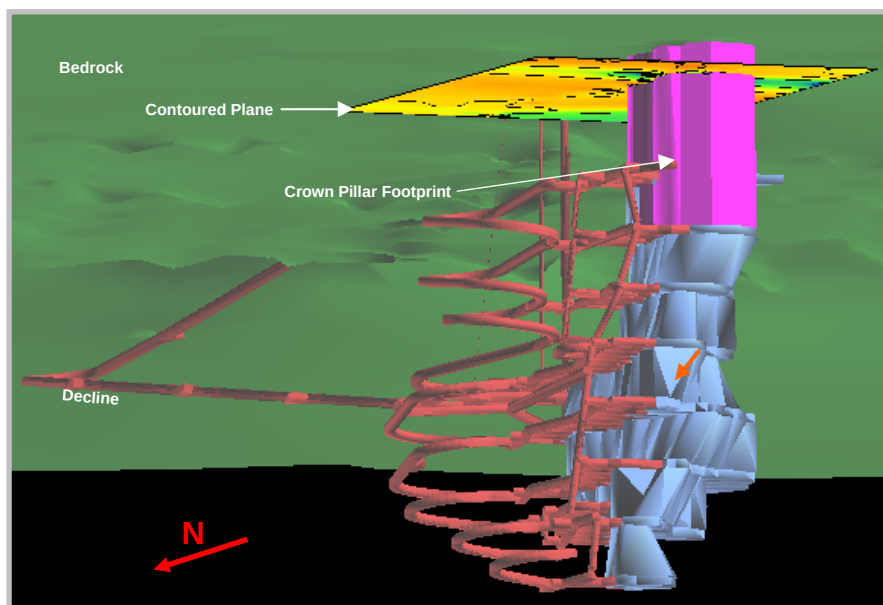
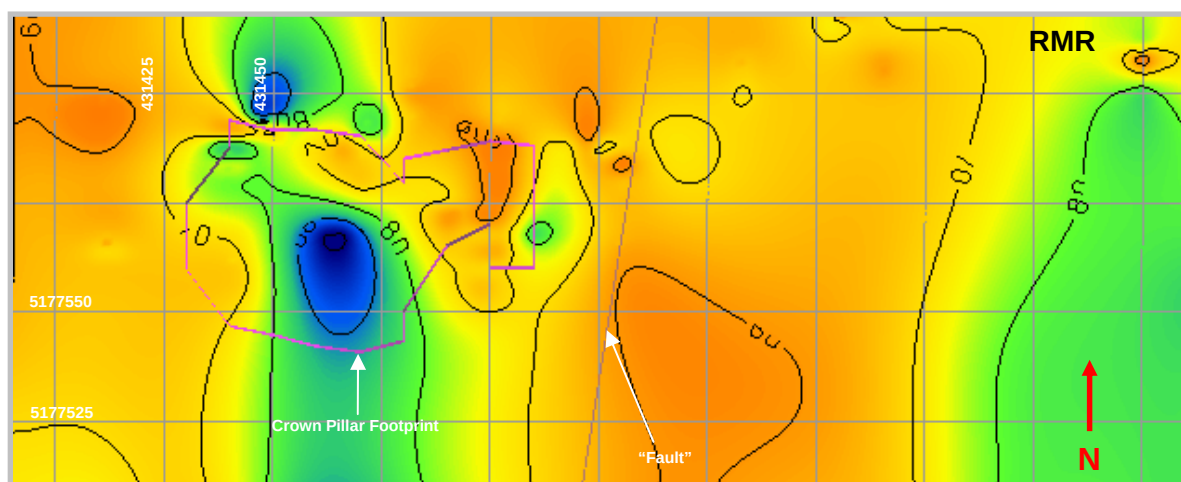
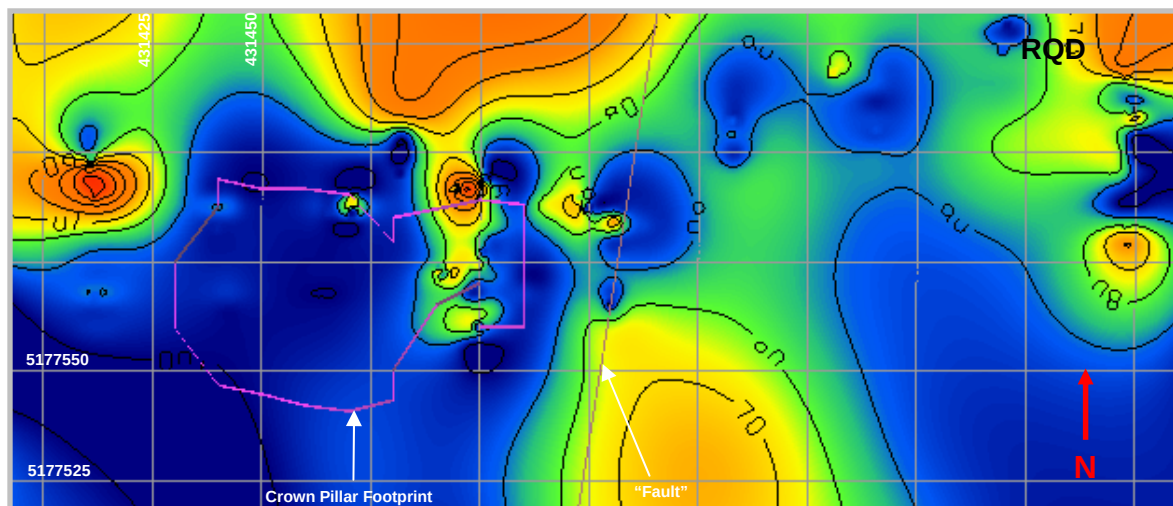


K.J. Beauchamp, P.Eng.

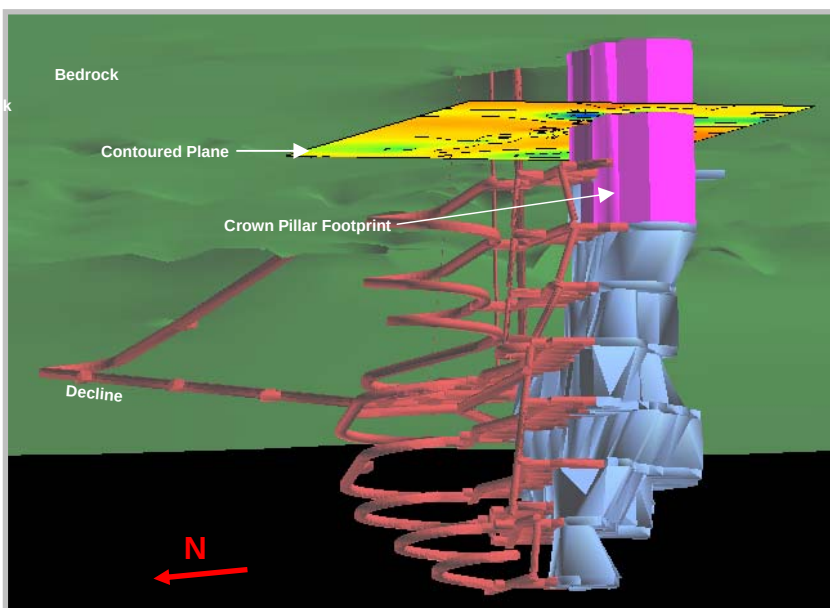
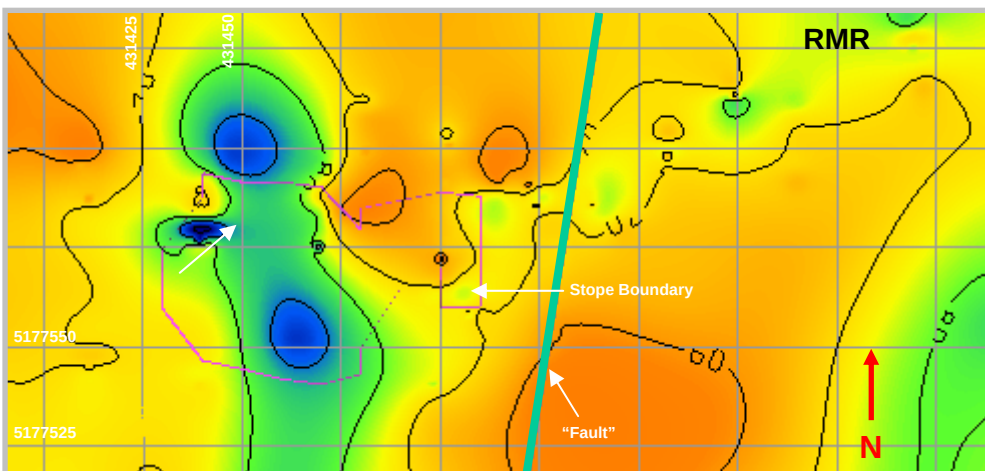
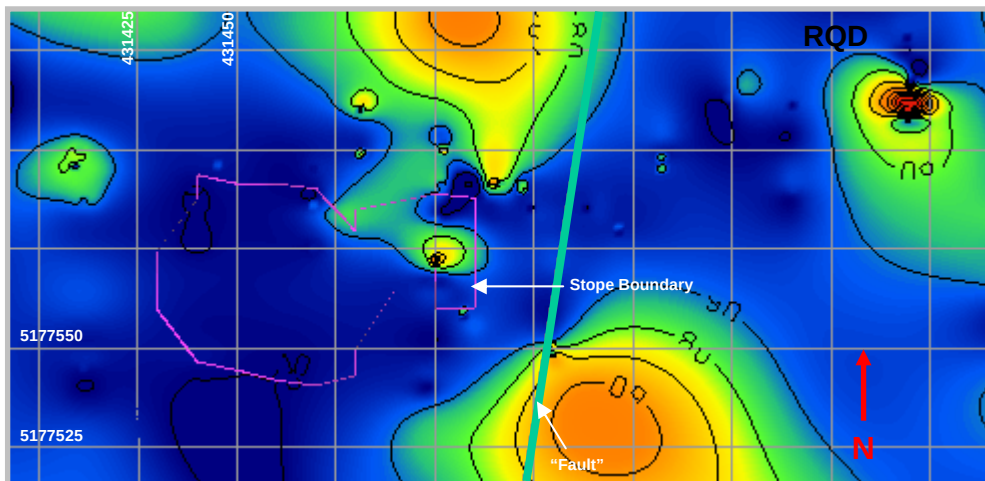
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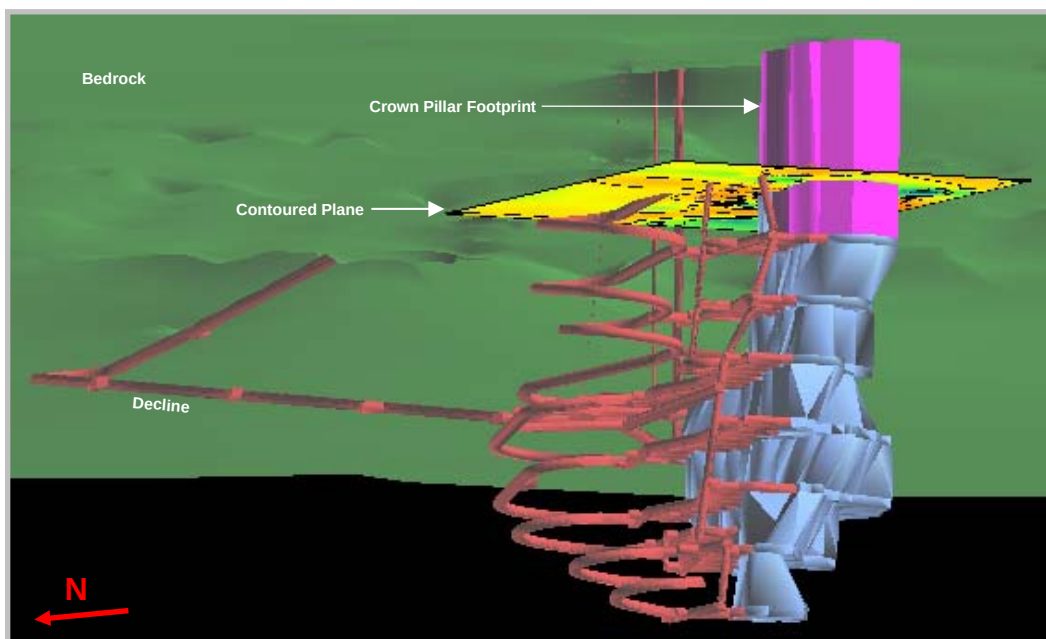
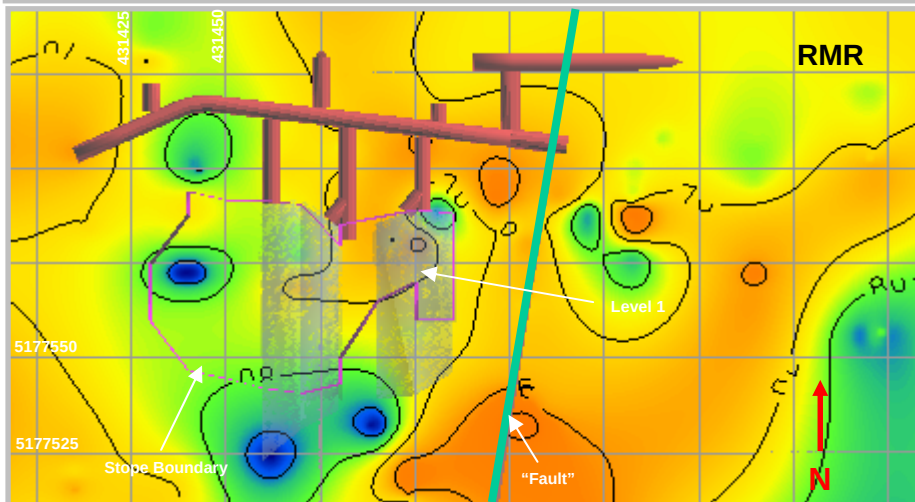
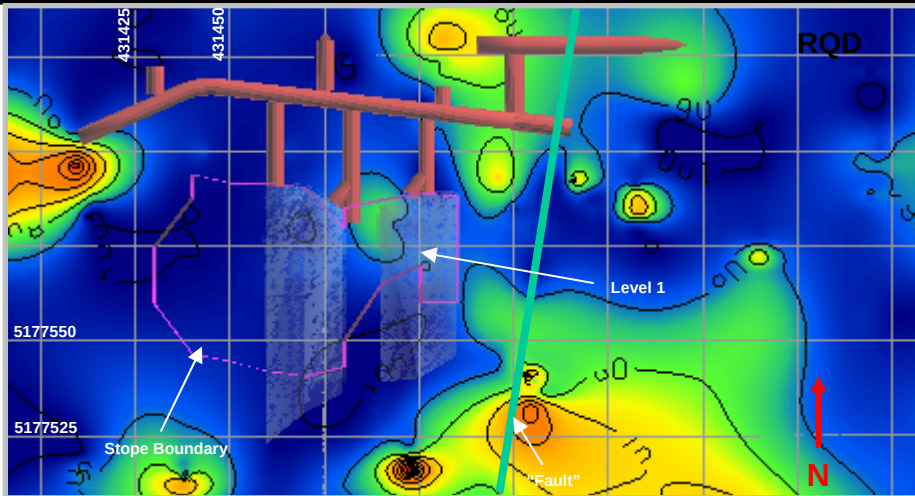




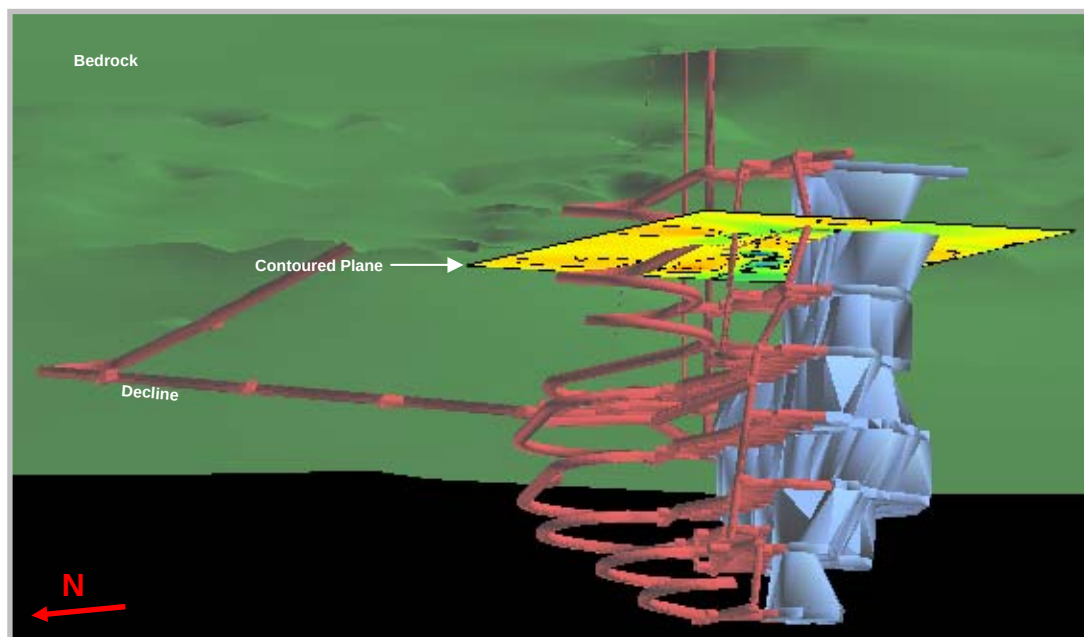
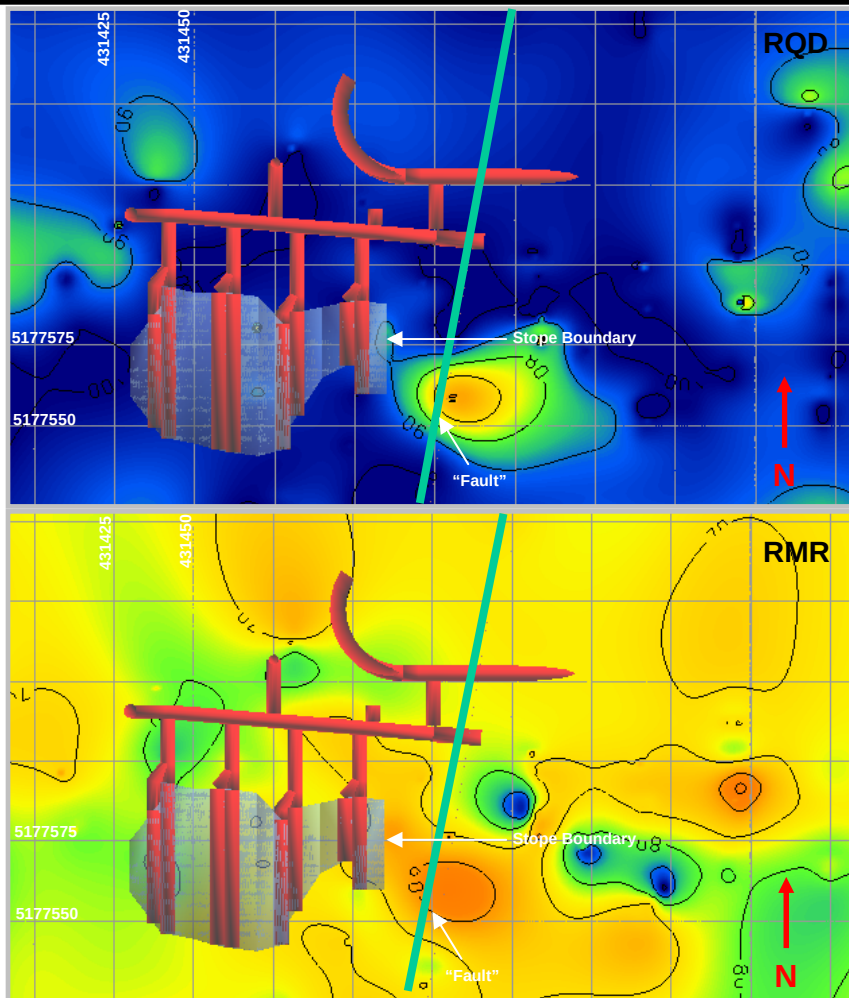
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Plan: RQD and RMR Contouring for 383 Elev.



Plan: RQD and RMR Contouring for 353 Elev.

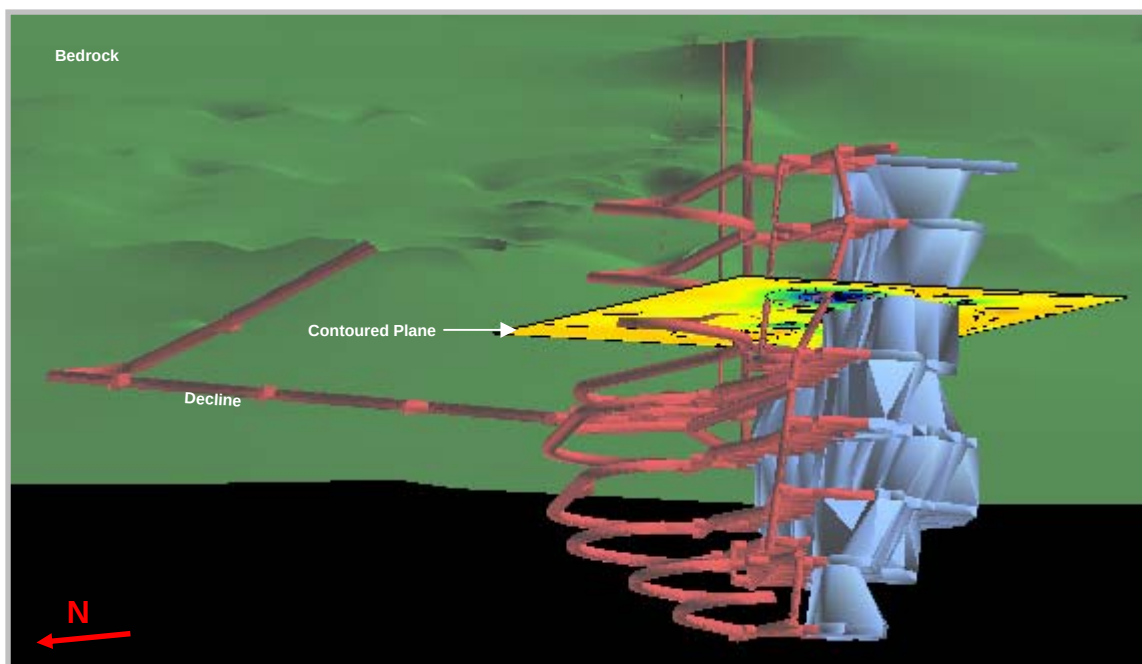
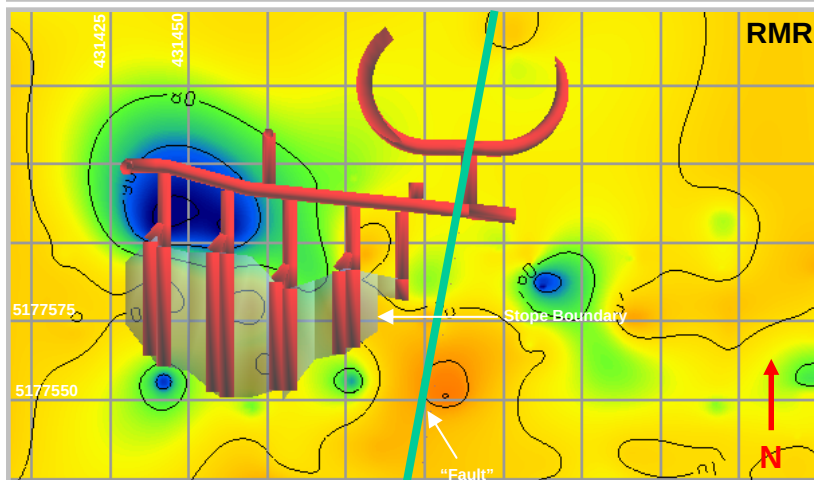
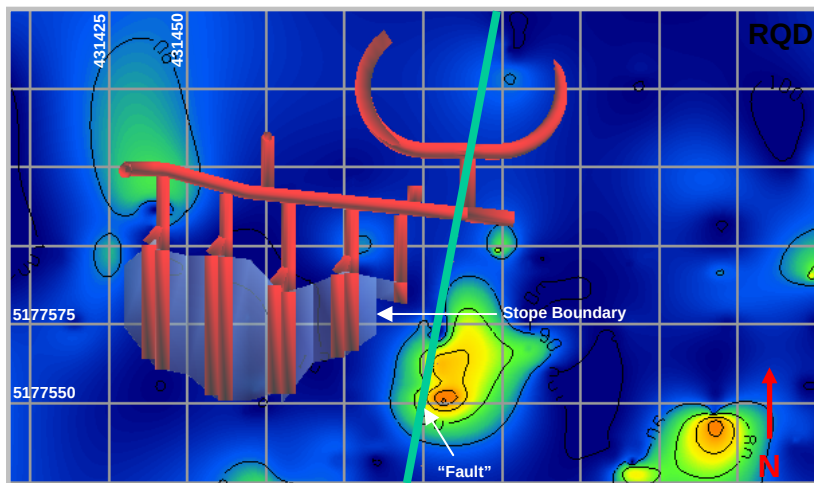


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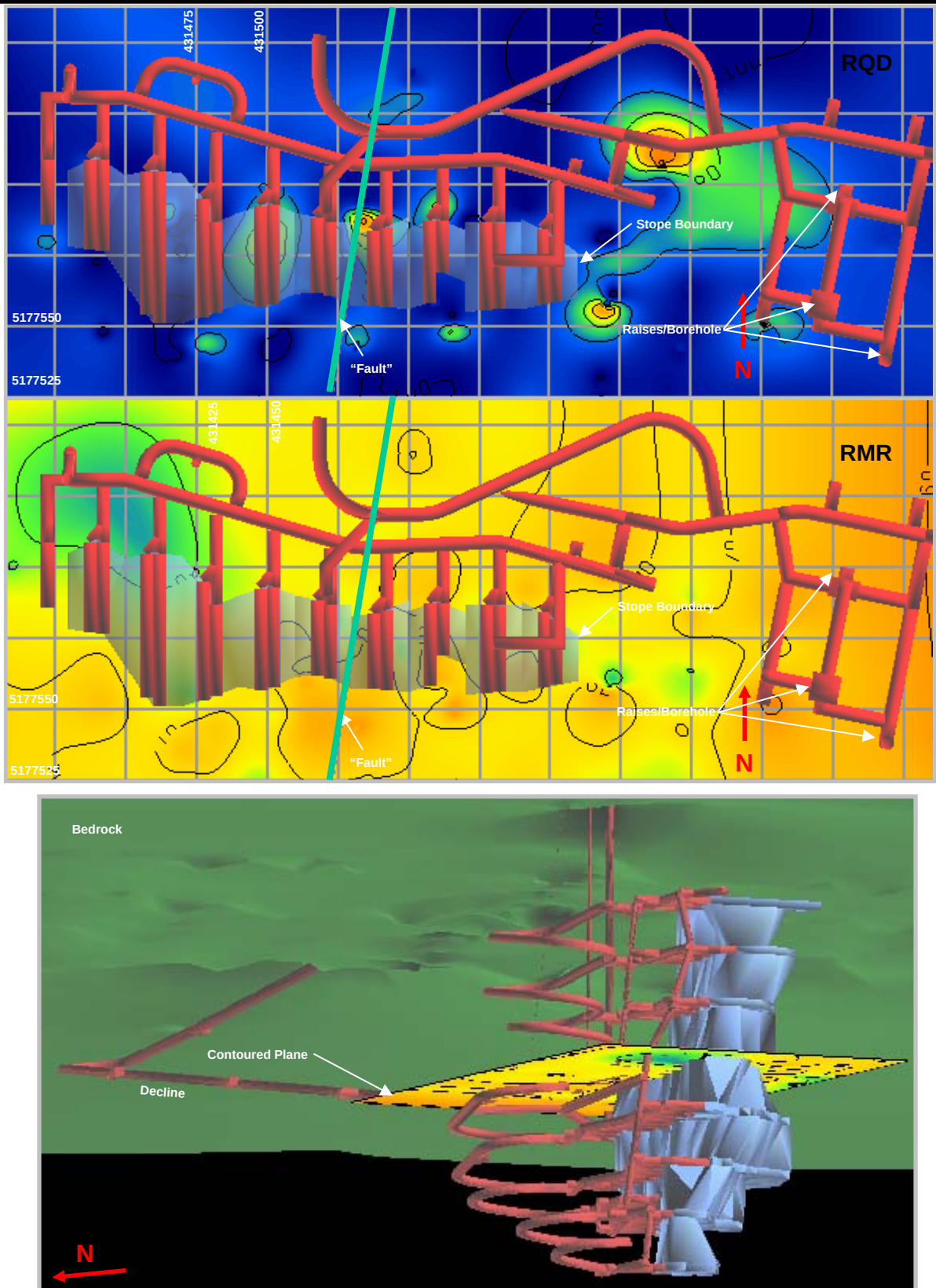


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CHKD..... KJB



Plan: RQD and RMR Contouring for 263 Elev.

DATE: NOVEMBER 2005
PROJECT: 05-1193-011



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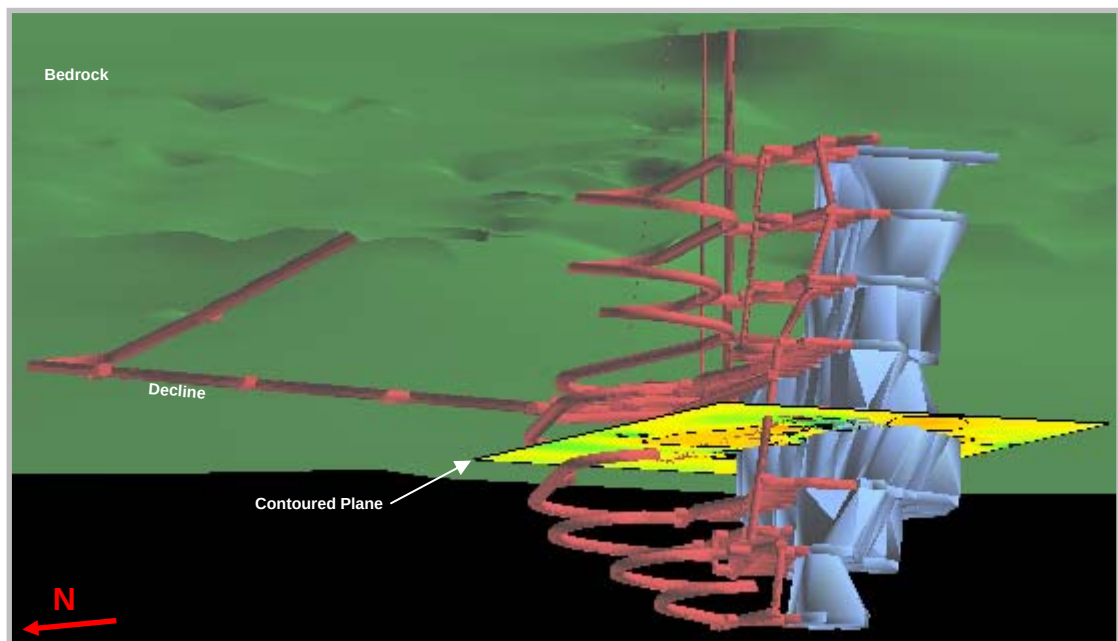
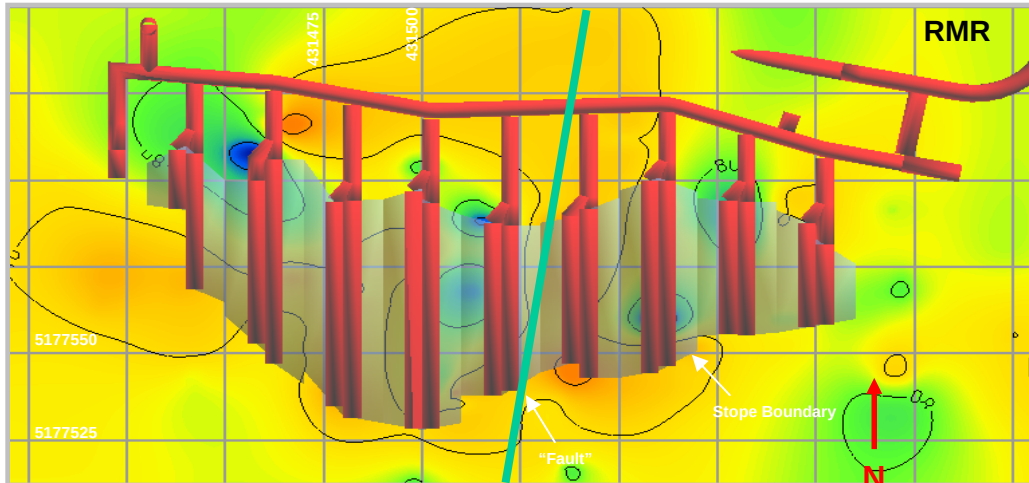
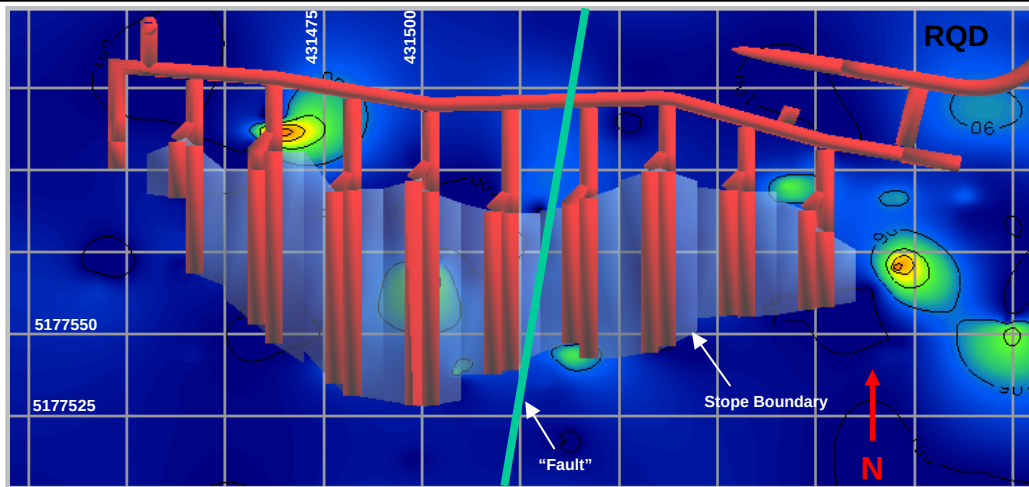


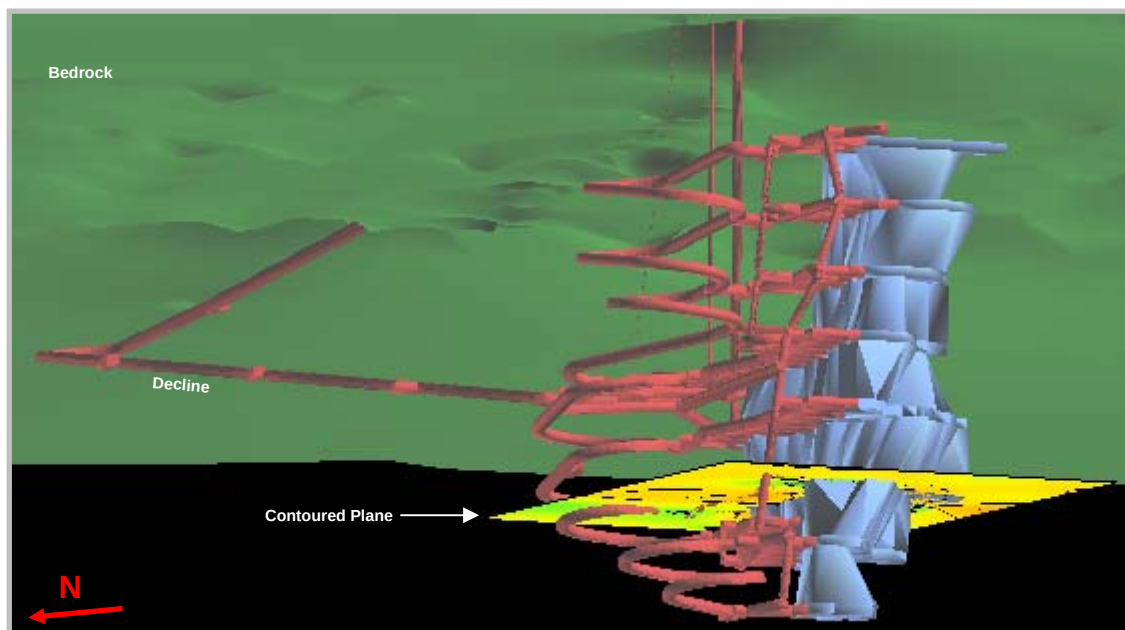
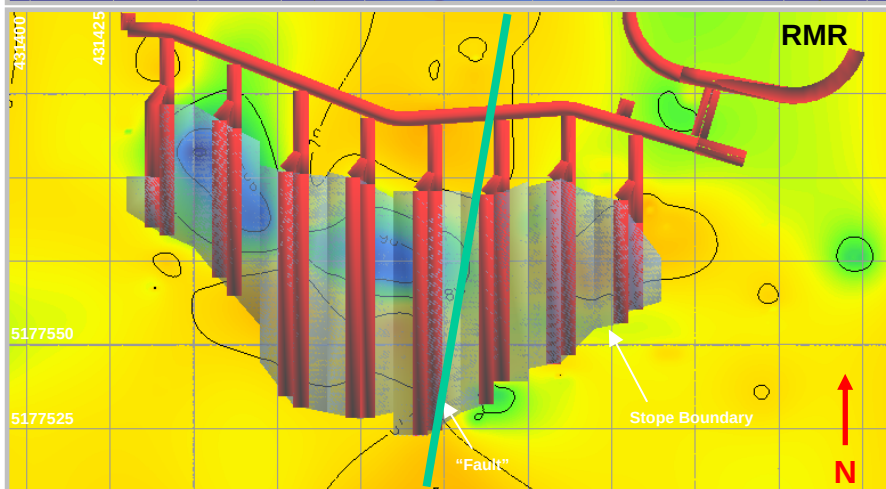
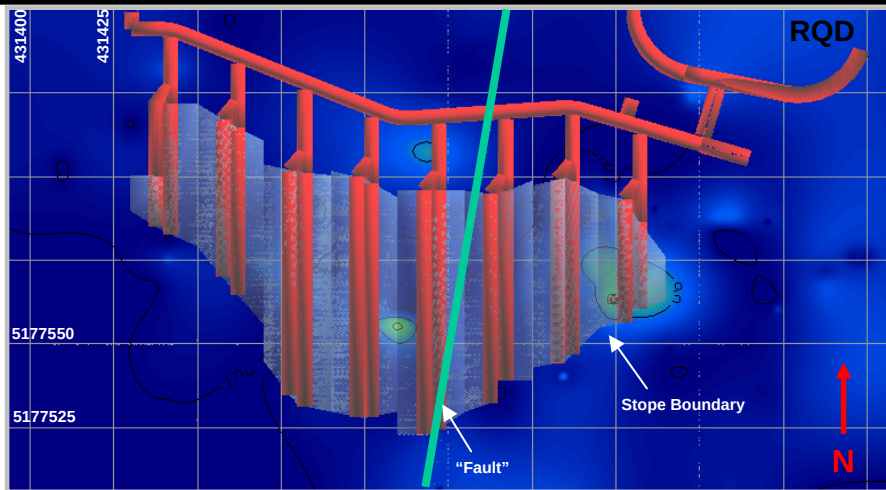
FIGURE 8

Plan: RQD and RMR Contouring for 233 Elev.

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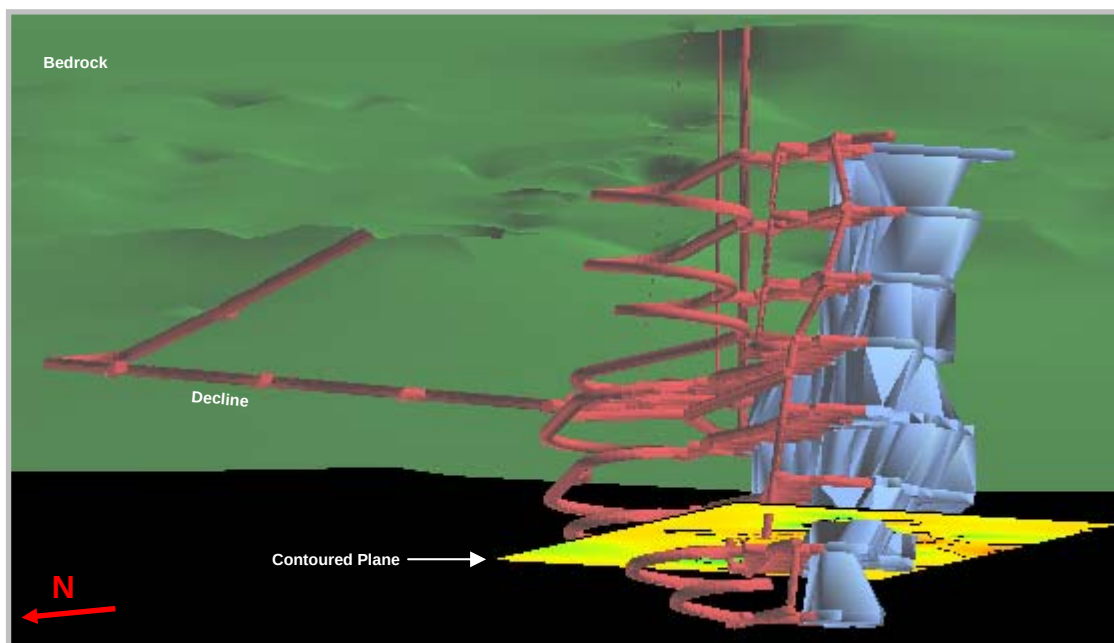
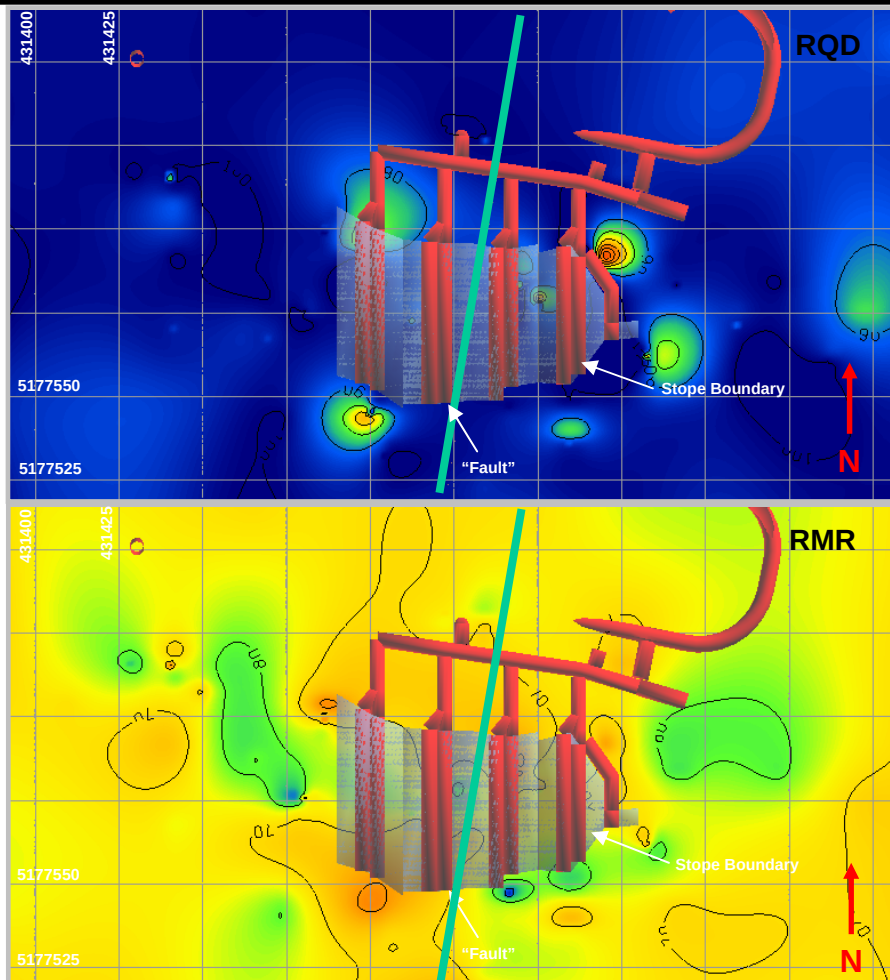


Plan: RQD and RMR Contouring for 203 Elev.

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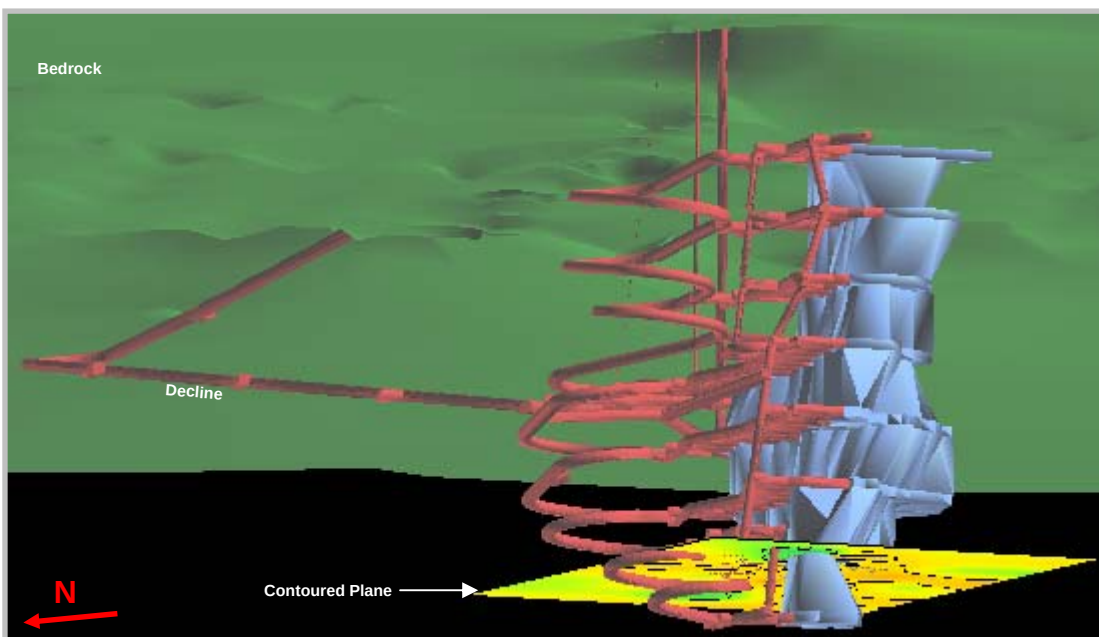
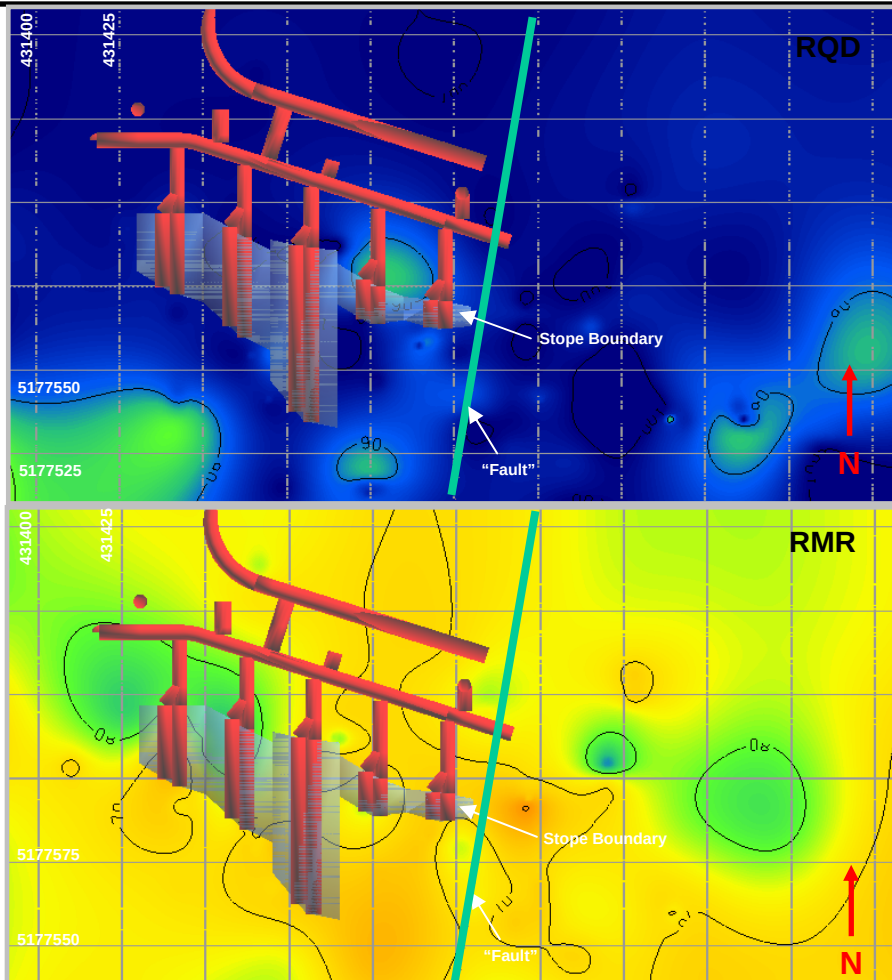


Plan: RQD and RMR Contouring for 188 Elev.

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CHKD..... KJB



Plan: RQD and RMR Contouring for 173 Elev.

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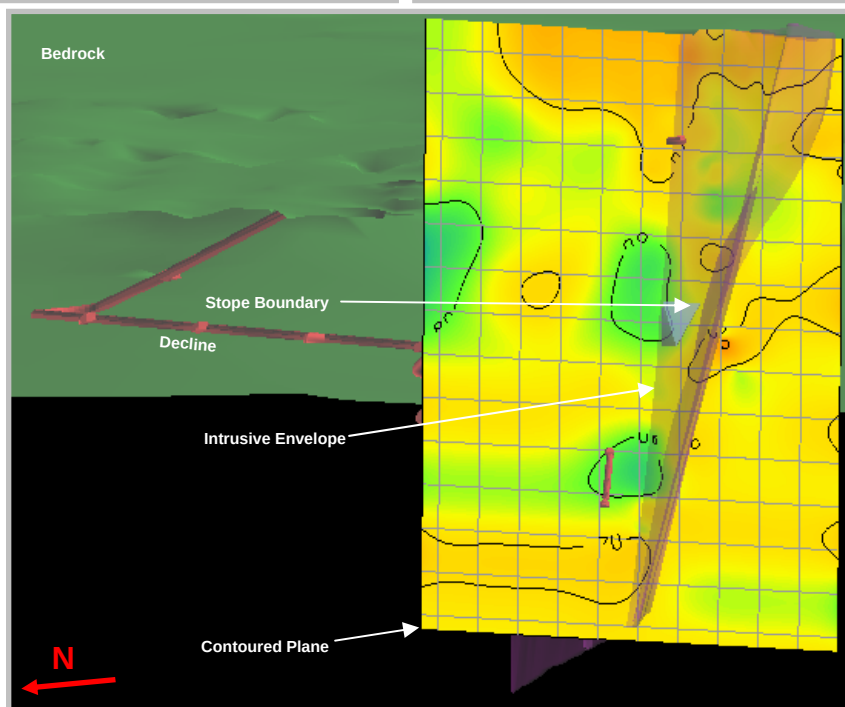
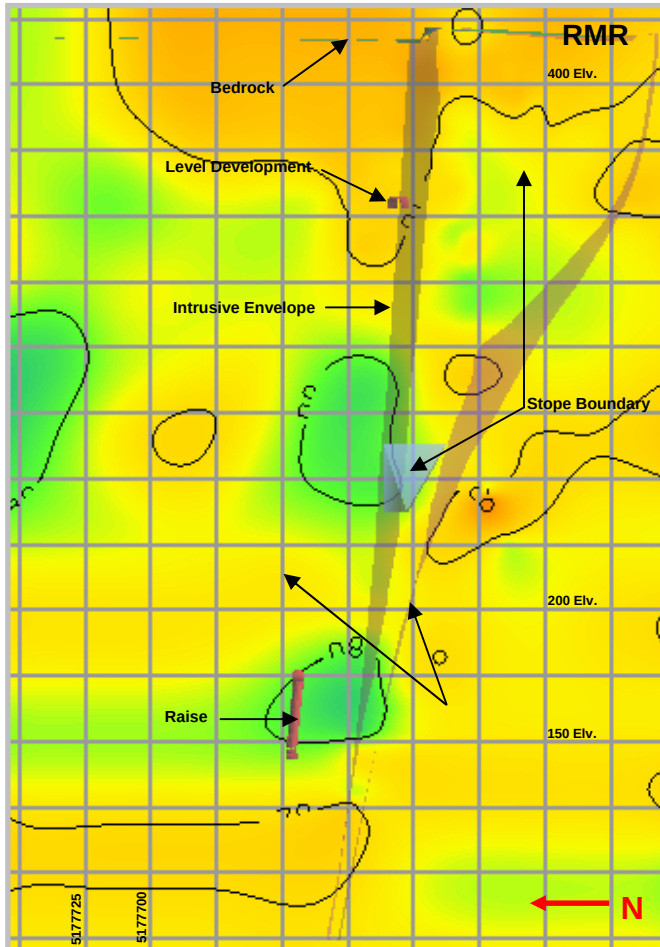
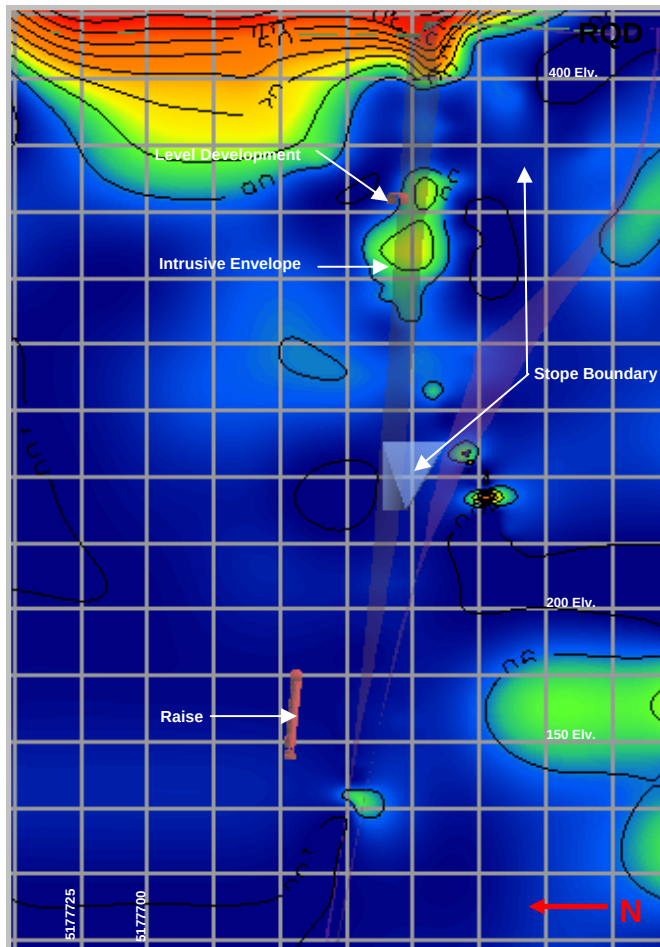


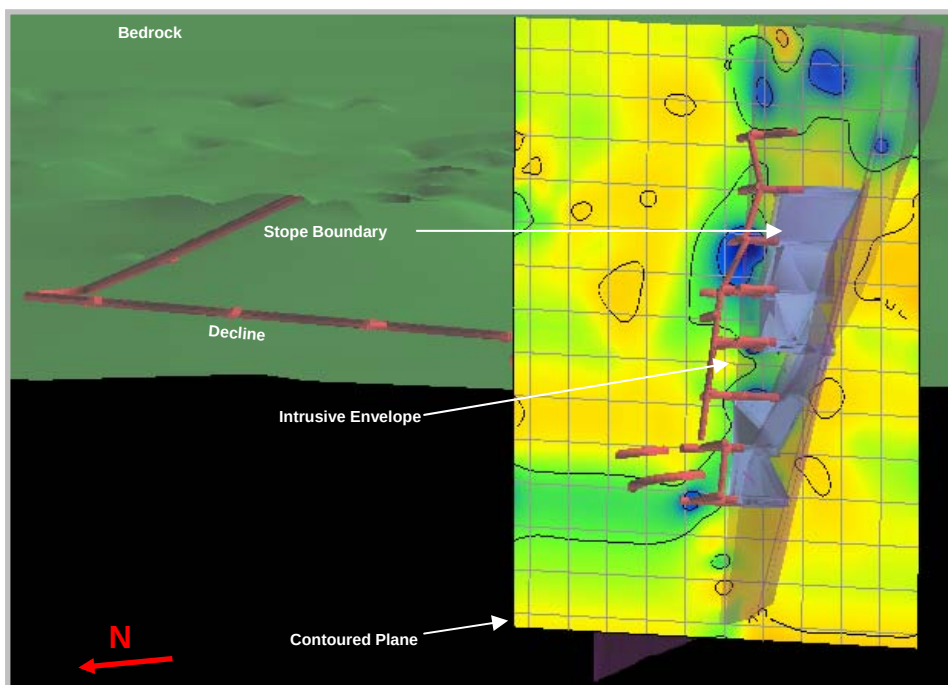
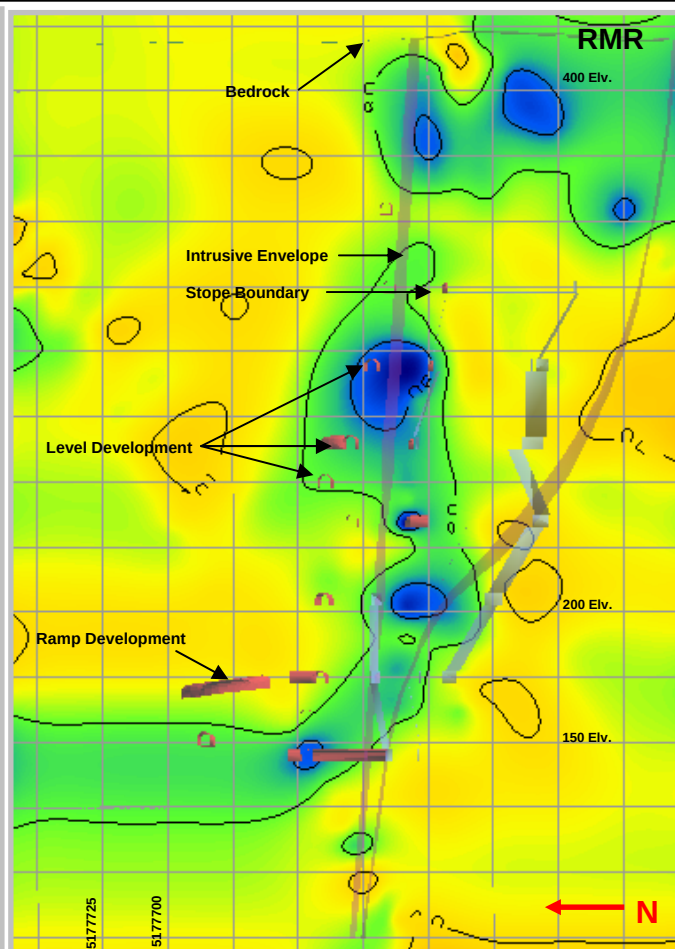
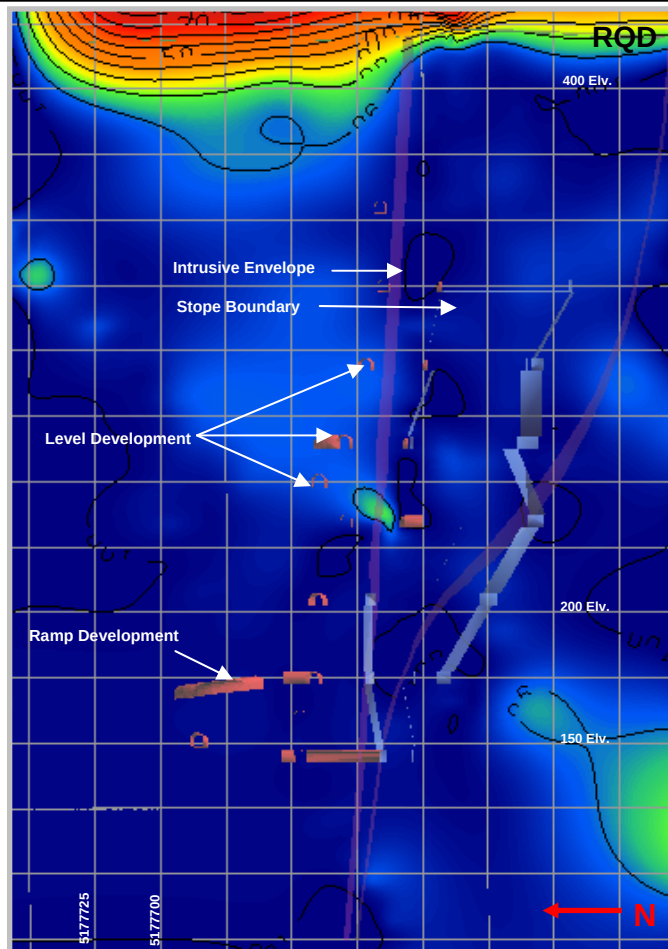
FIGURE 12

Traverse Section: RQD and RMR Contouring for 431420E Facing East

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Traverse Section: RQD and RMR Contouring for 431457E Facing East

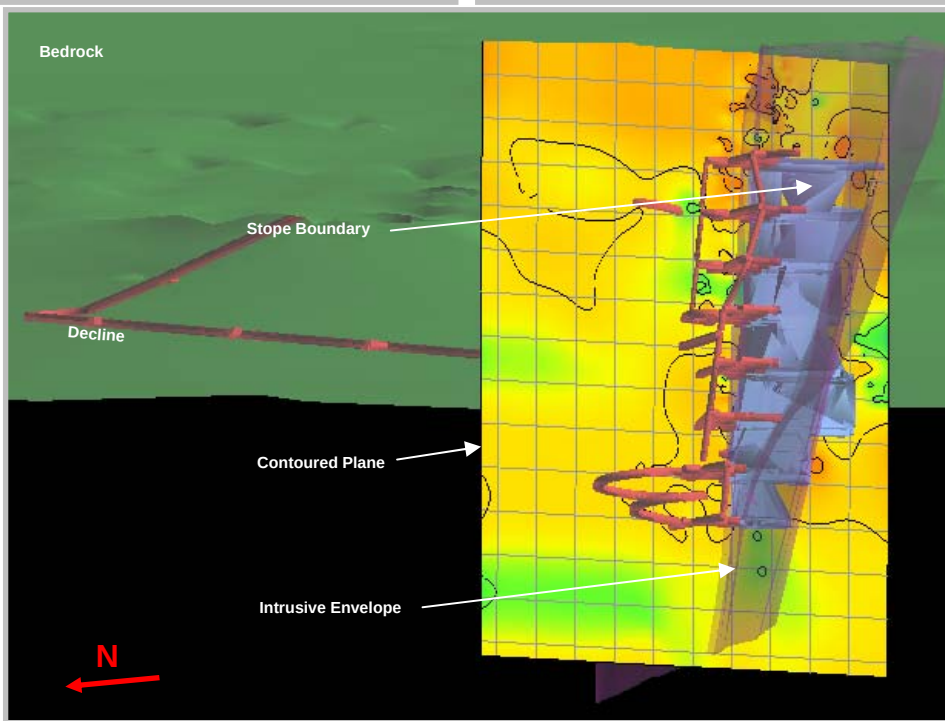
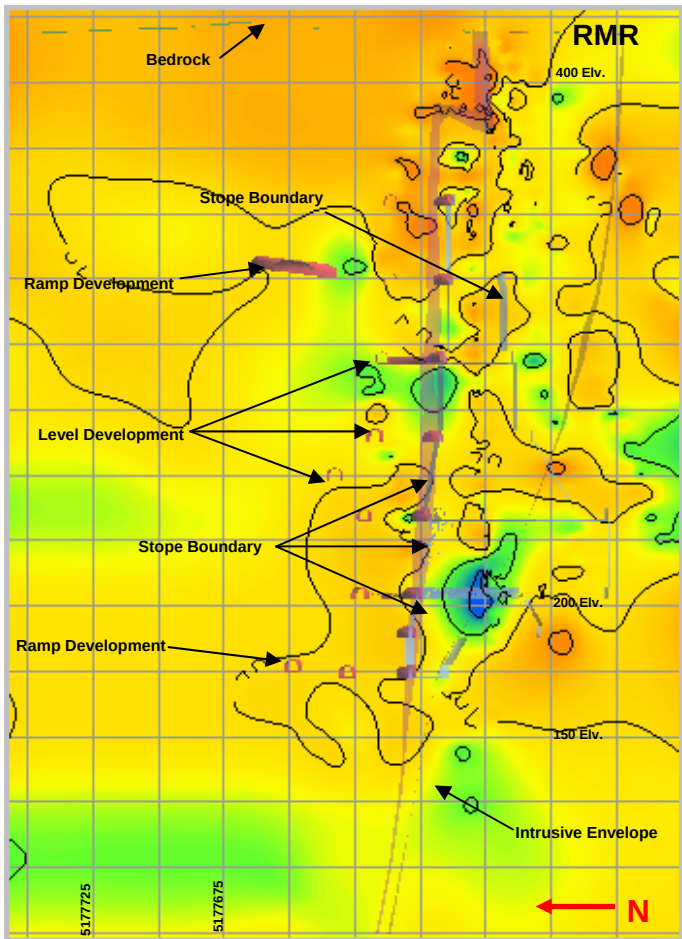
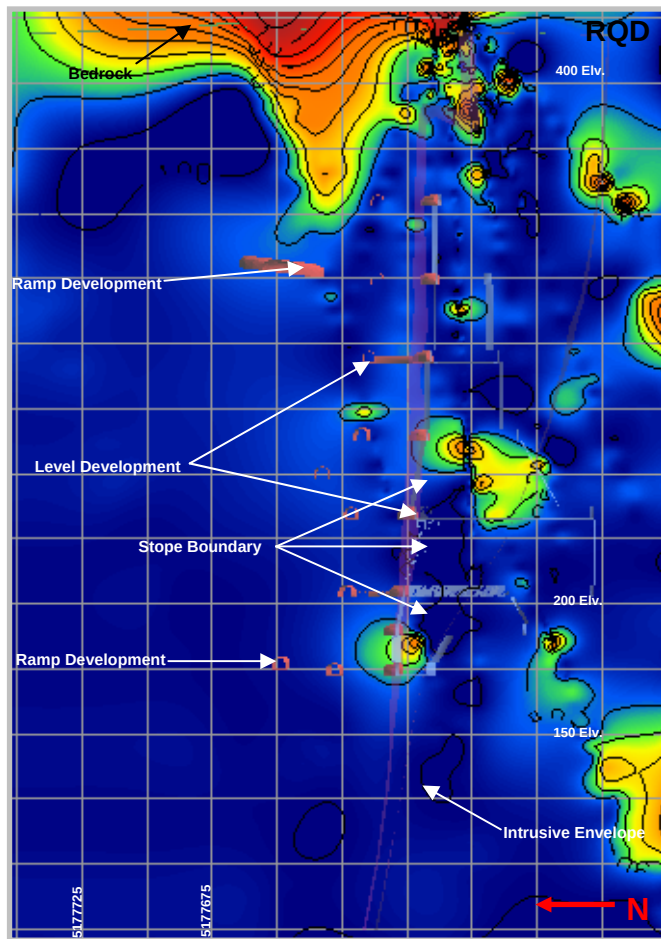


FIGURE 14

Traverse Section: RQD and RMR Contouring for 431500E Facing East

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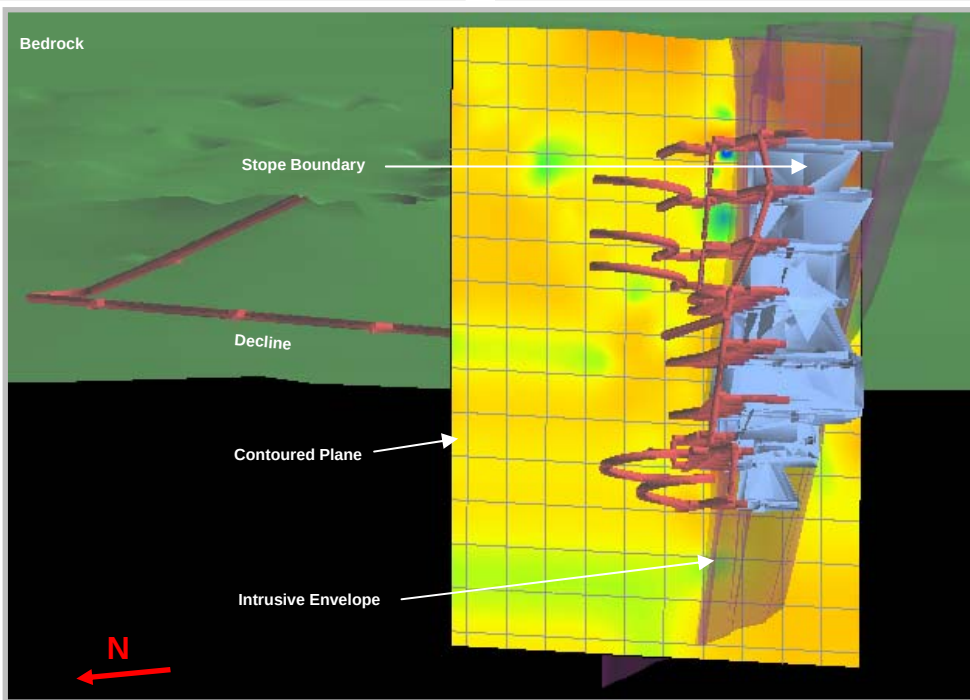
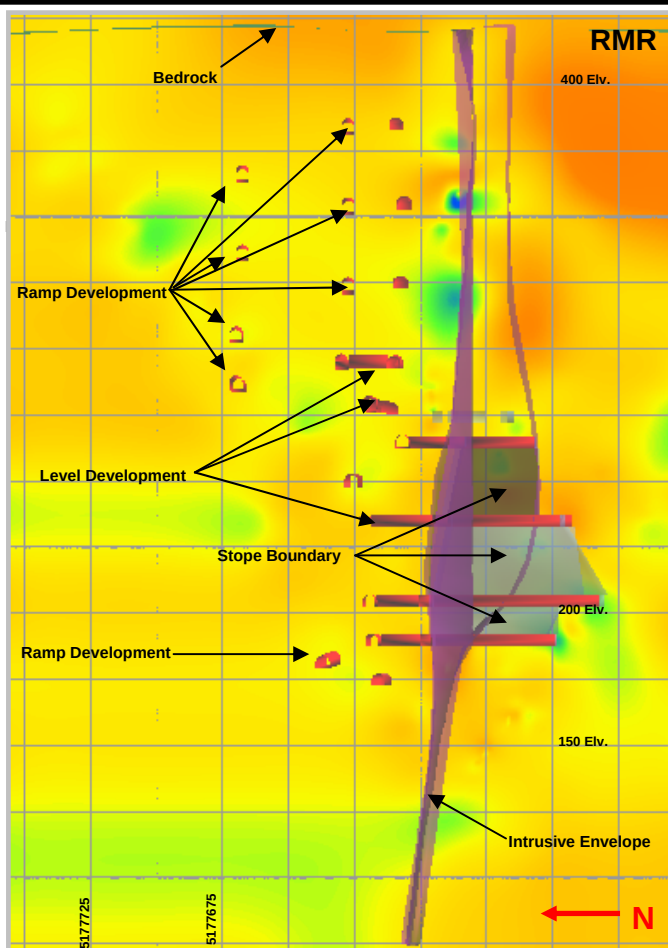
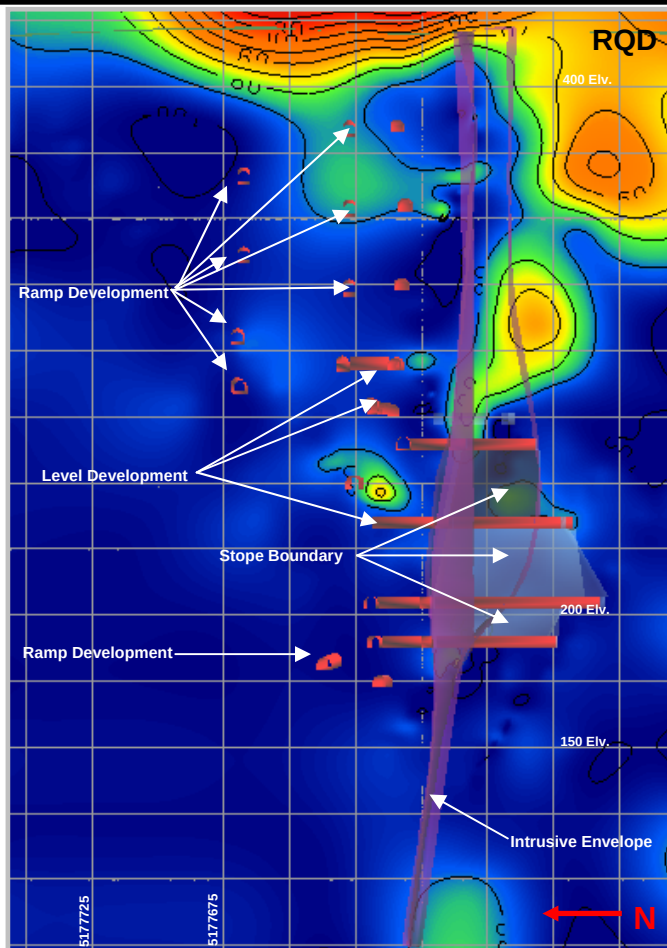


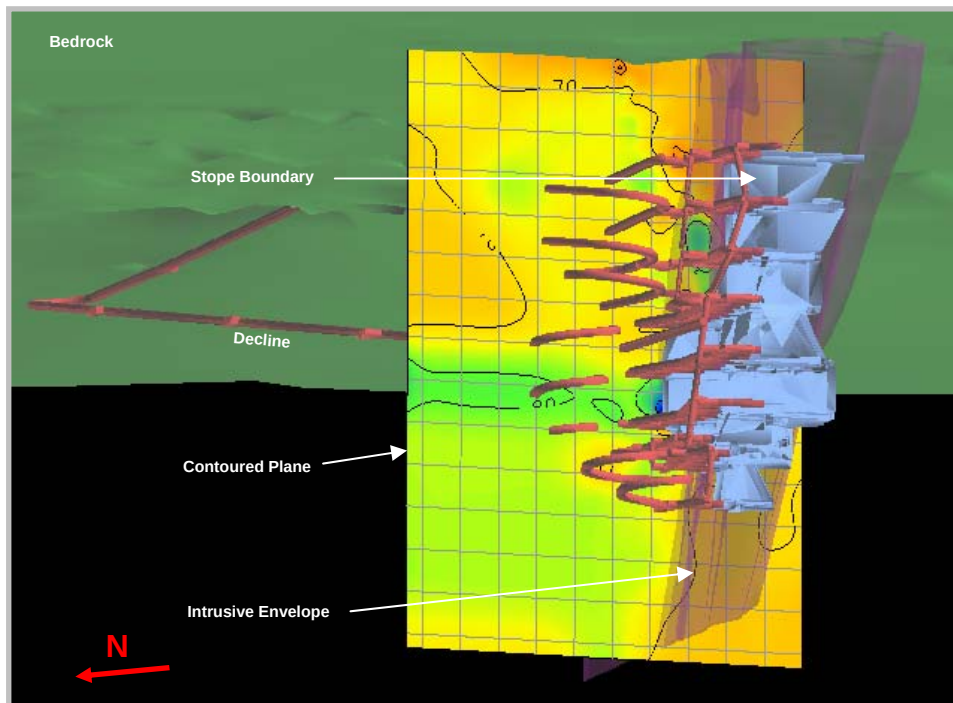
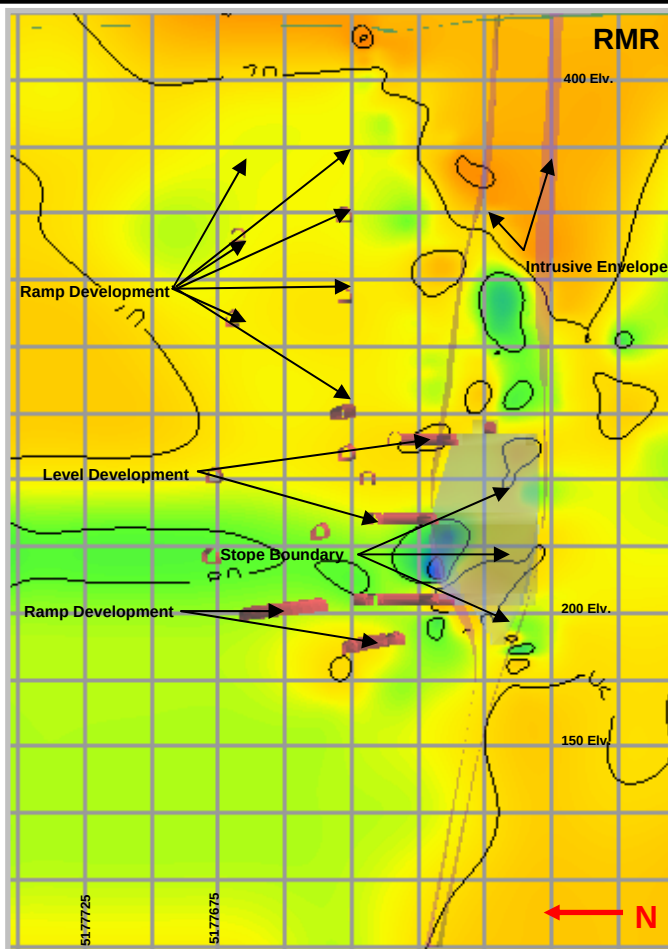
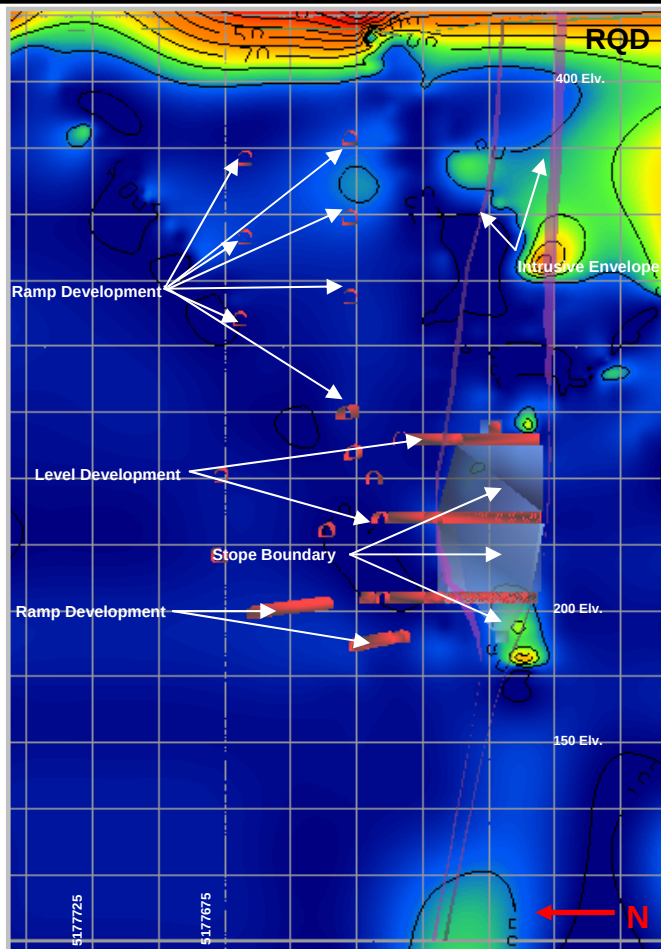
FIGURE 15

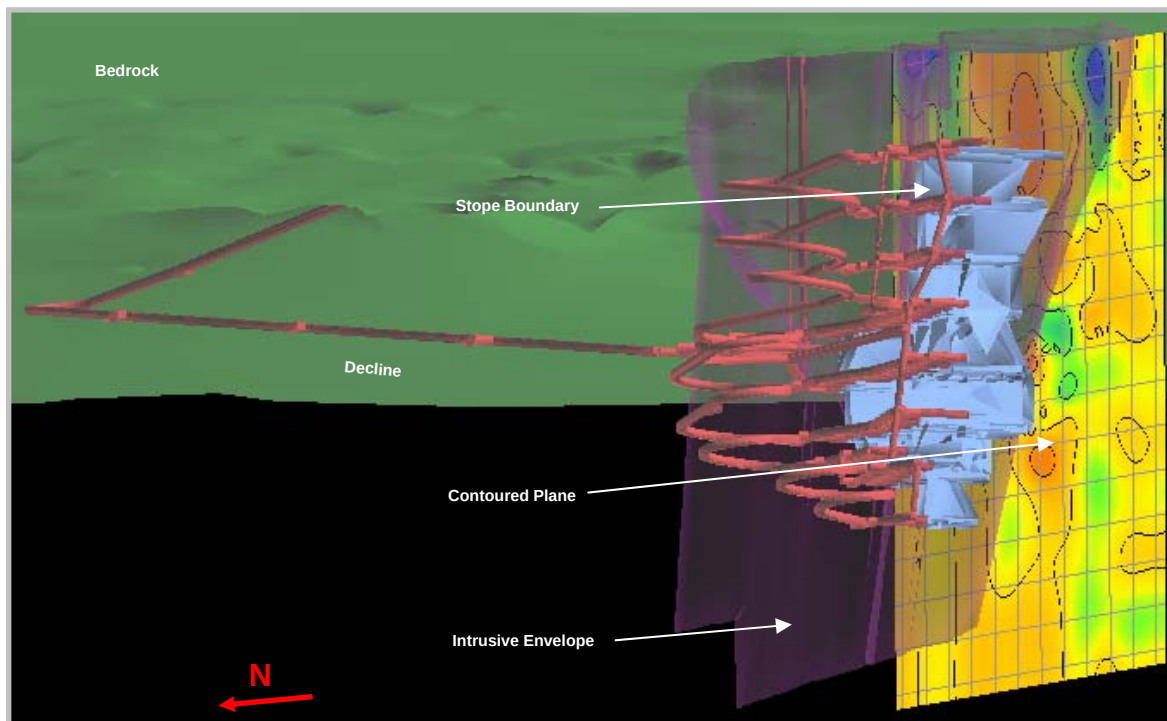
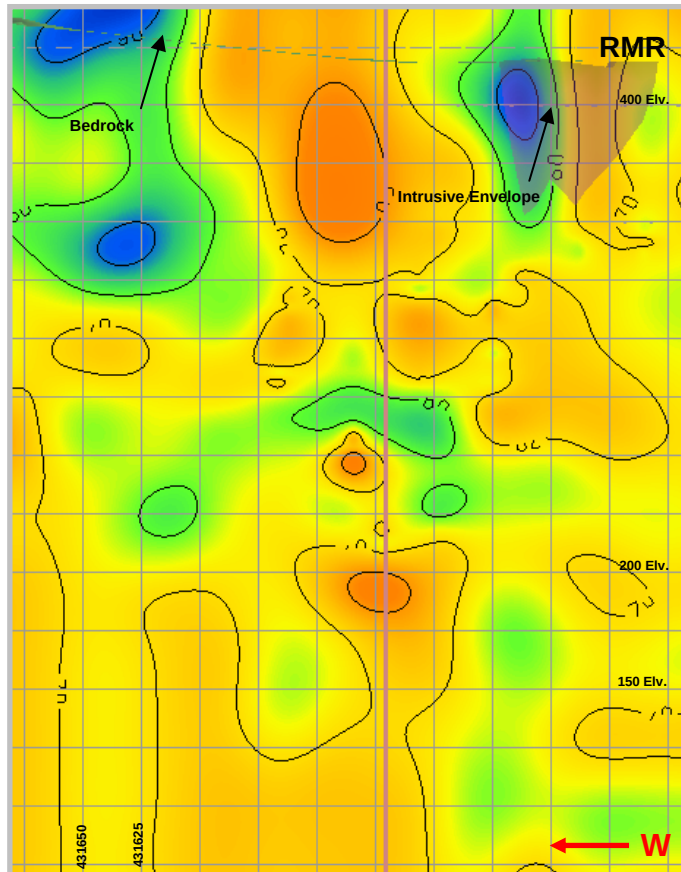
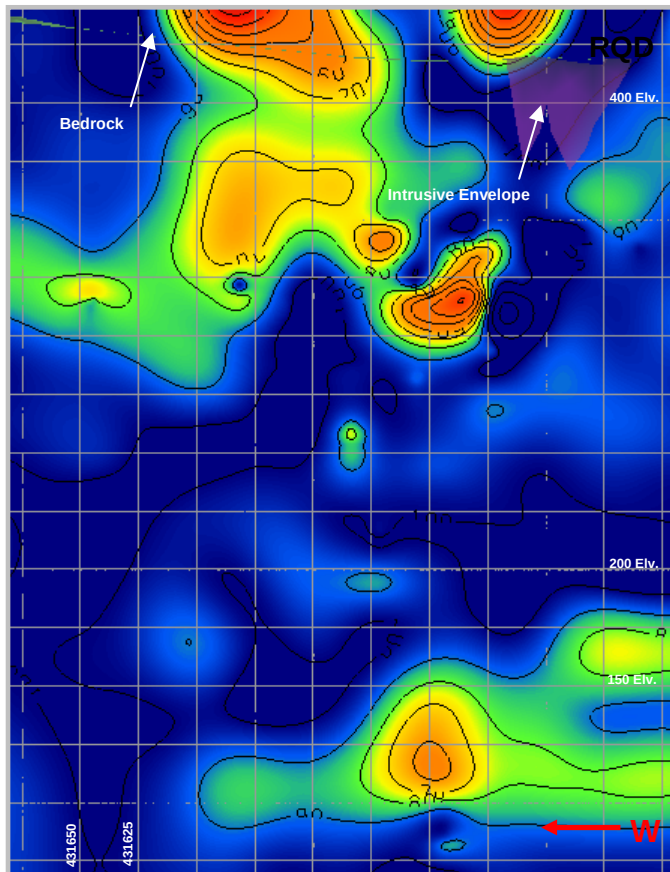
Traverse Section: RQD and RMR Contouring for 431545E Facing East

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CHKD..... KJB





Longitudinal Section: RQD and RMR Contouring for 5177500N Facing North

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PROJECT: 05-1193-011



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CHKD..... KJB

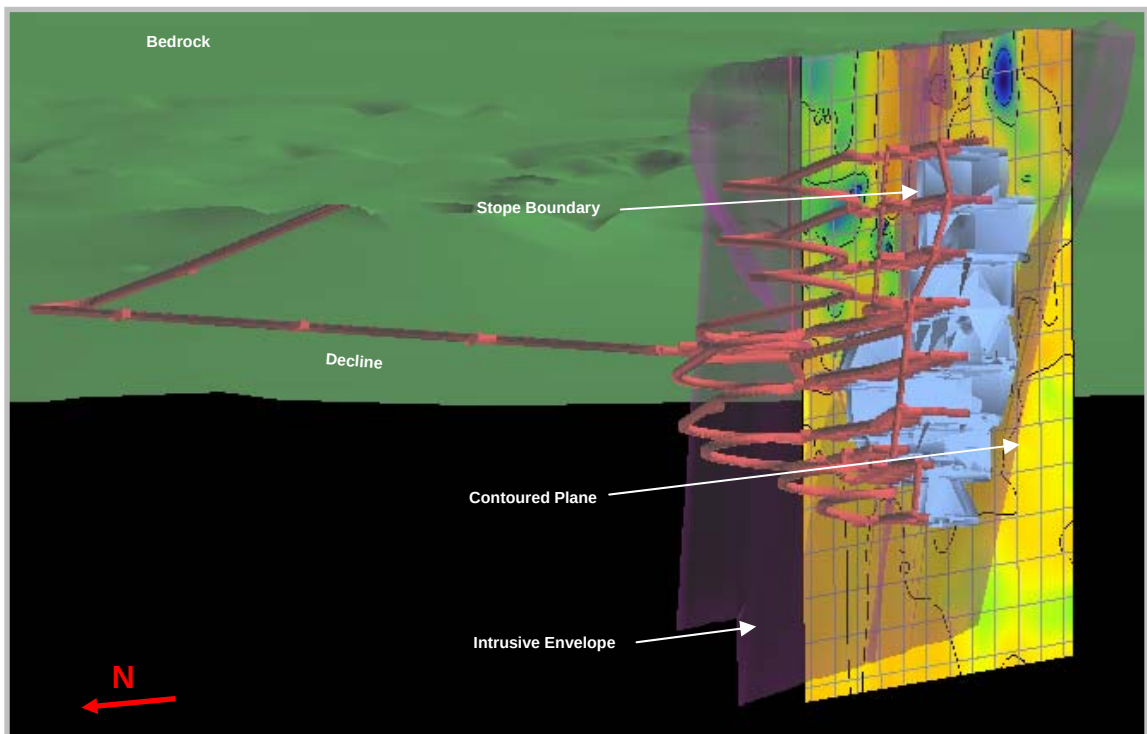
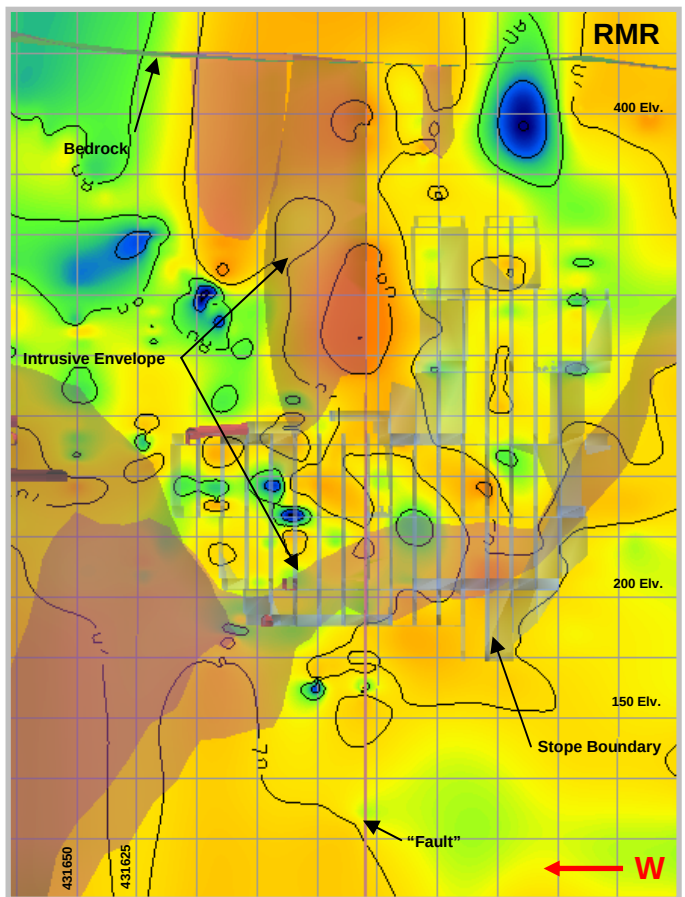
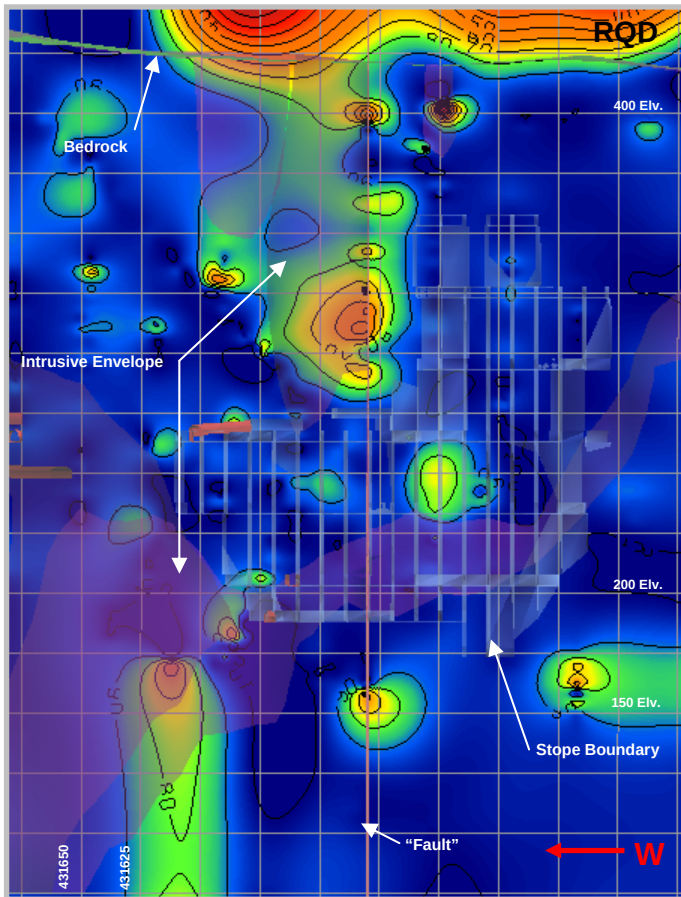


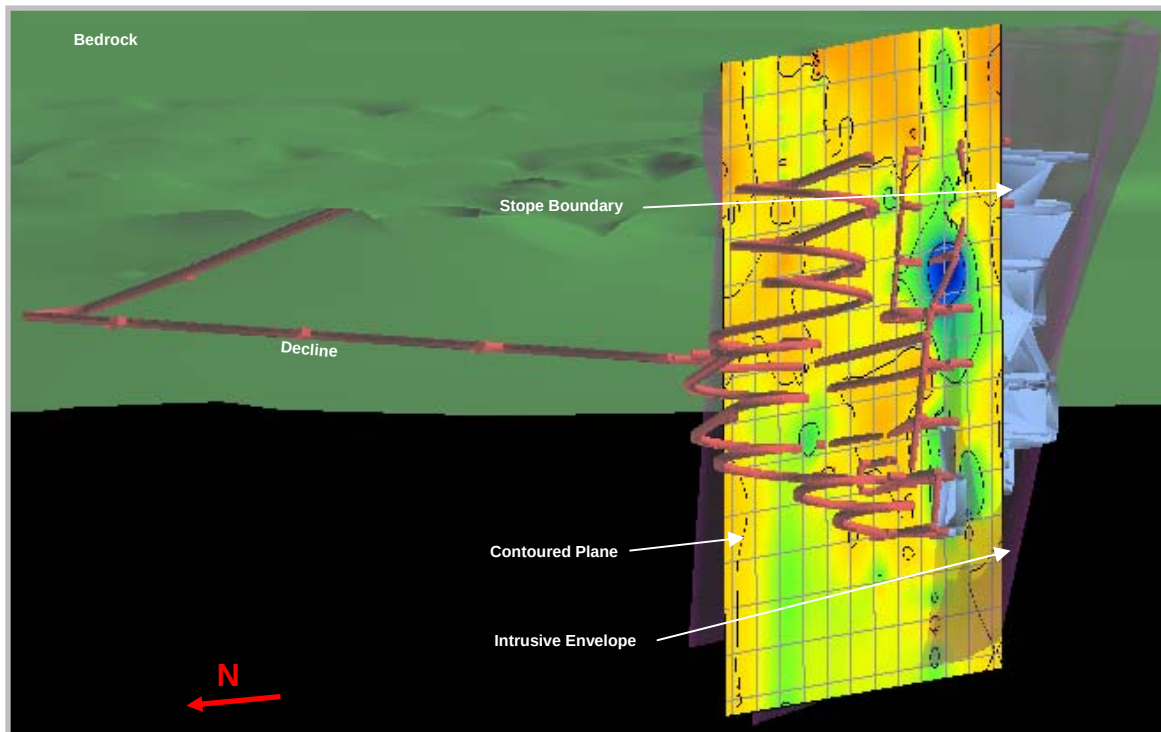
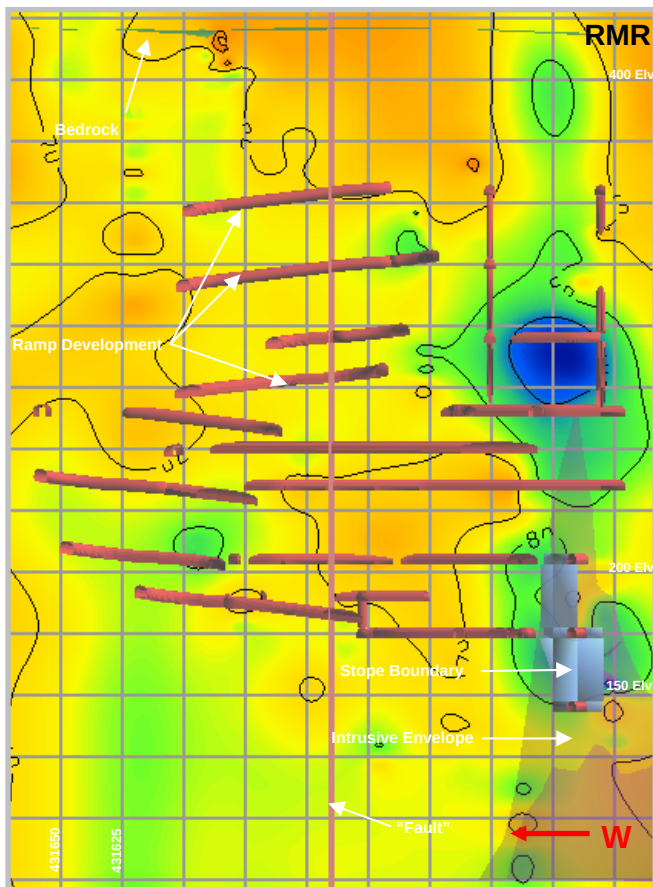
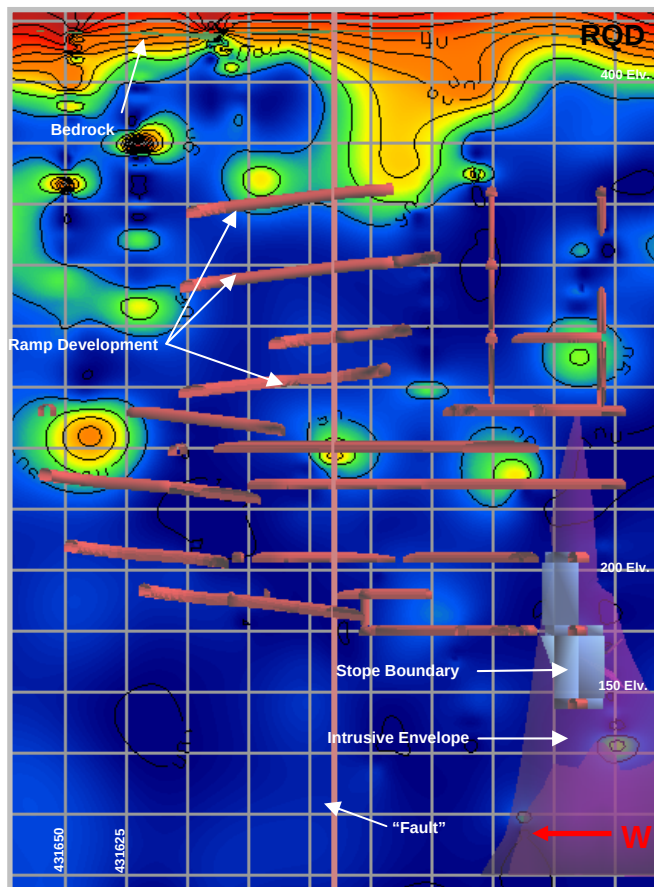
FIGURE 18

Longitudinal Section: RQD and RMR Contouring for 5177560N Facing North

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PROJECT: 05-1193-011



DRAWN..... CGL
CHKD..... KJB

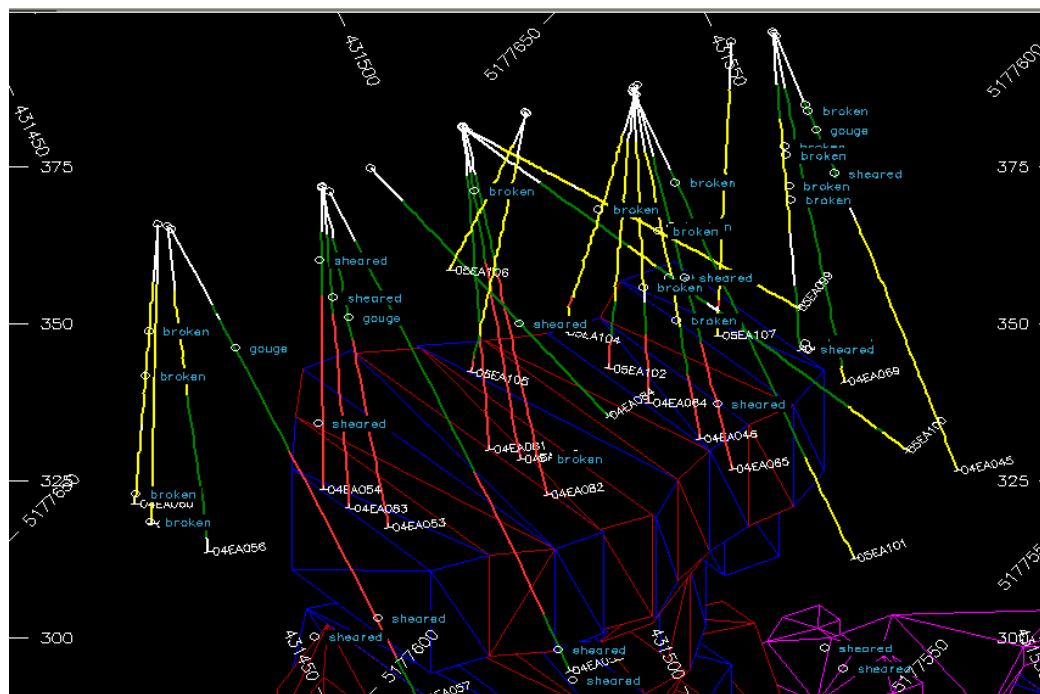
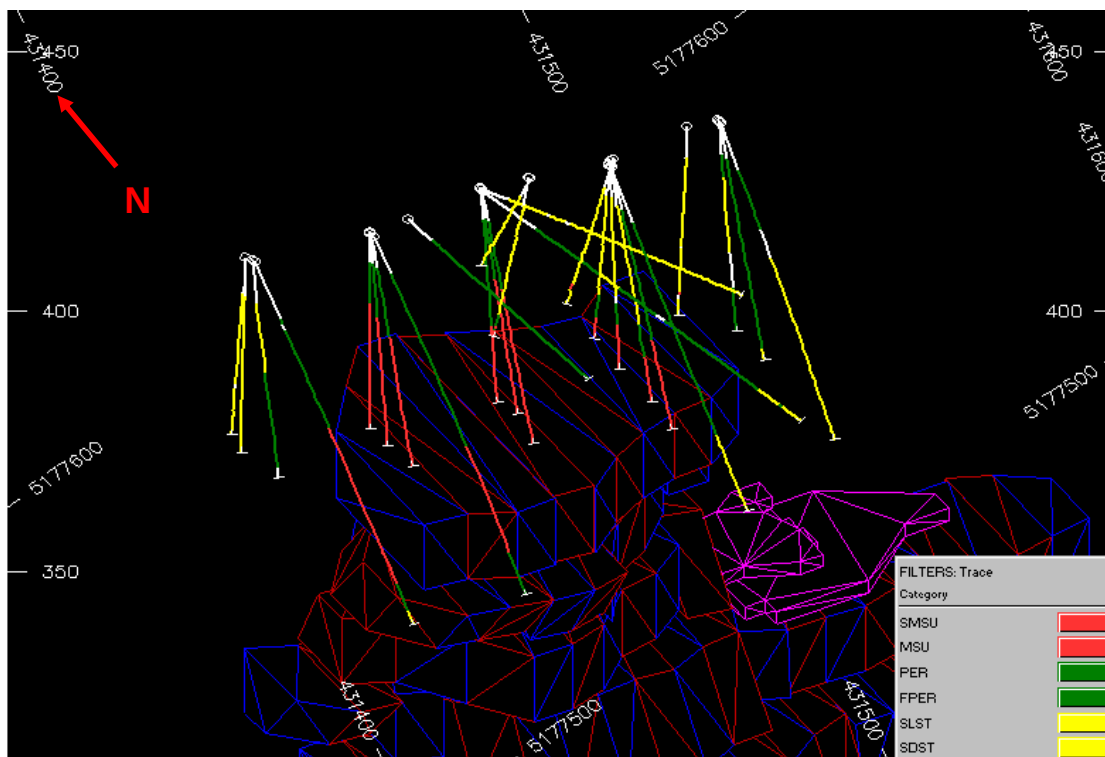


Longitudinal Section: RQD and RMR Contouring for 5177620N Facing North

DATE: NOVEMBER 2005
PROJECT: 05-1193-011



DRAWN..... CGL
CHKD..... KJB

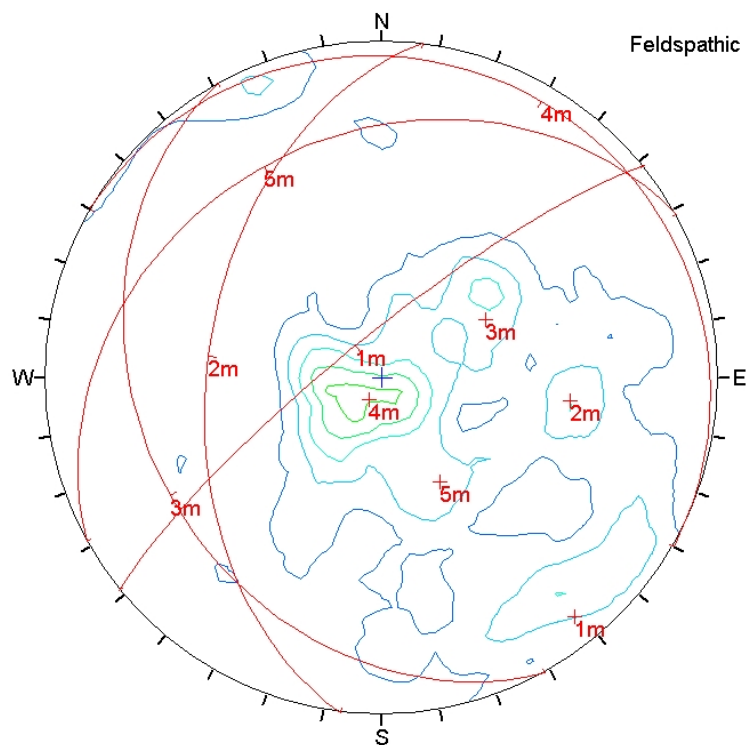


ISOMETRIC VIEW OF DRILLING INSIDE CROWN PILLARS

DATE: NOVEMBER 2005
PROJECT: 05-1193-011



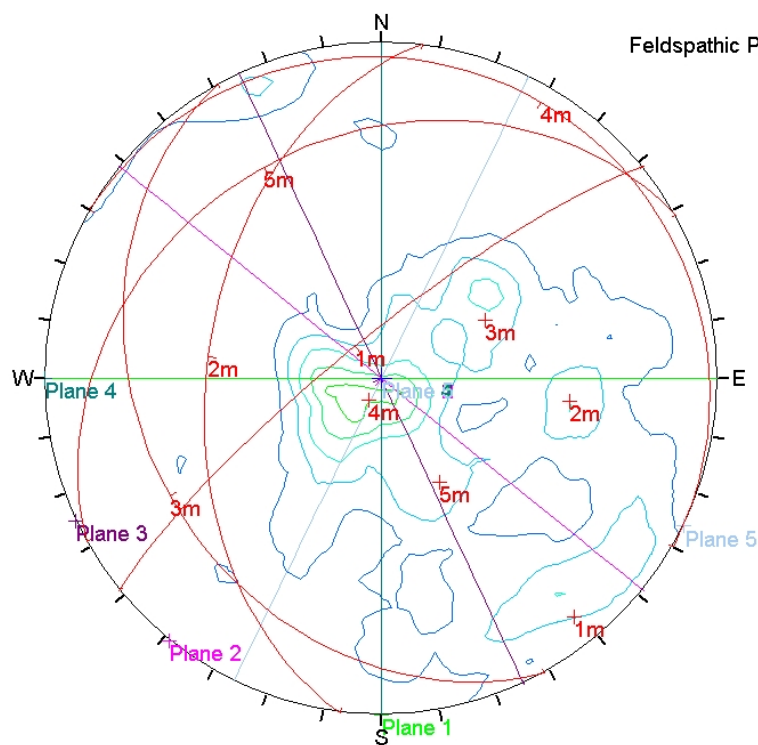
DRAWN..... CGL
CHKD..... KJB



Orientations
ID Dip / Direction

1	m	80 / 321
2	m	47 / 277
3	m	29 / 241
4	m	06 / 030
5	m	29 / 331

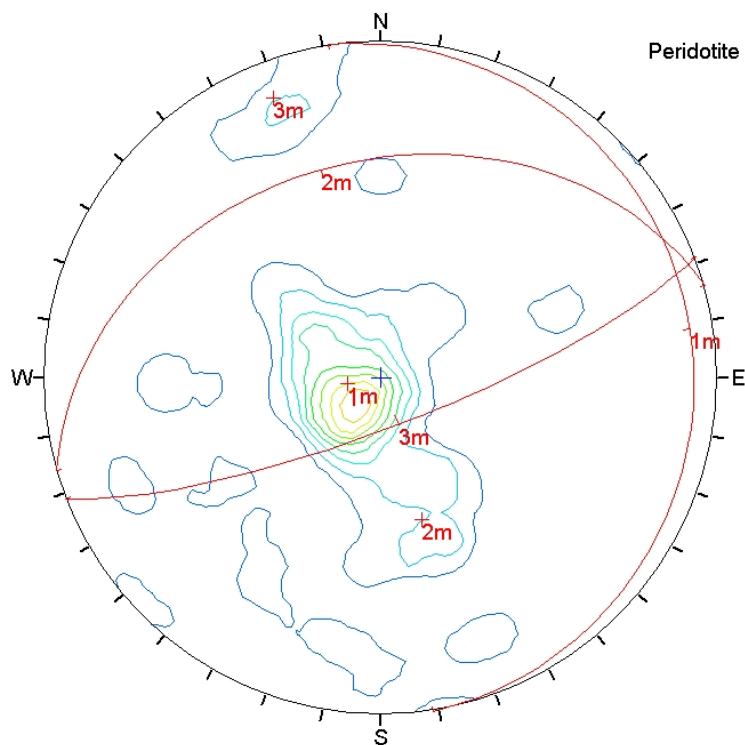
Equal Area
Lower Hemisphere
430 Poles
430 Entries



Orientations
ID Dip / Direction

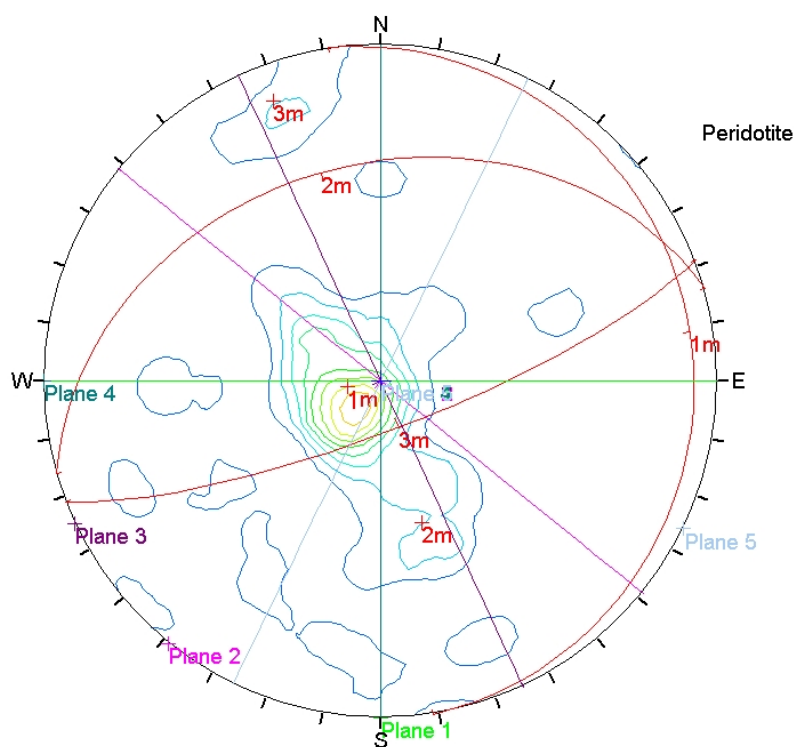
1		90 / 360
2		90 / 039
3		90 / 065
4		90 / 090
5		90 / 296
1	m	80 / 321
2	m	47 / 277
3	m	29 / 241
4	m	06 / 030
5	m	29 / 331

Equal Area
Lower Hemisphere
430 Poles
430 Entries



Orientations		
ID		Dip / Direction
1	m	08 / 081
2	m	36 / 344
3	m	78 / 159

Equal Area
Lower Hemisphere
106 Poles
106 Entries



Orientations		
ID		Dip / Direction
1		90 / 360
2		90 / 039
3		90 / 065
4		90 / 090
5		90 / 296
1	m	08 / 081
2	m	36 / 344
3	m	78 / 159

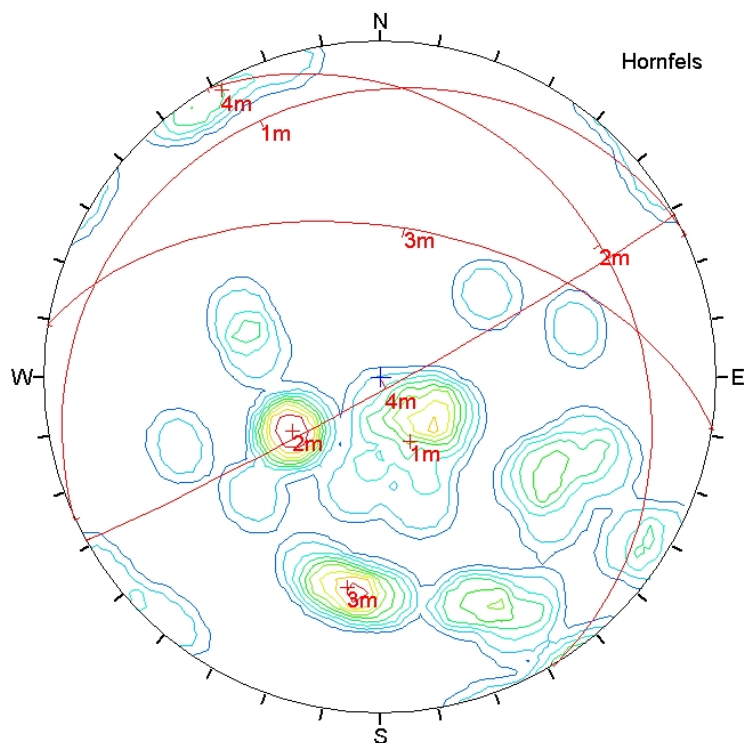
Equal Area
Lower Hemisphere
106 Poles
106 Entries

REVIEW OF MAPPING DATA PERIDOTITE (Regular and with Added Planes)

DATE: NOVEMBER 2005
PROJECT: 05-1193-011

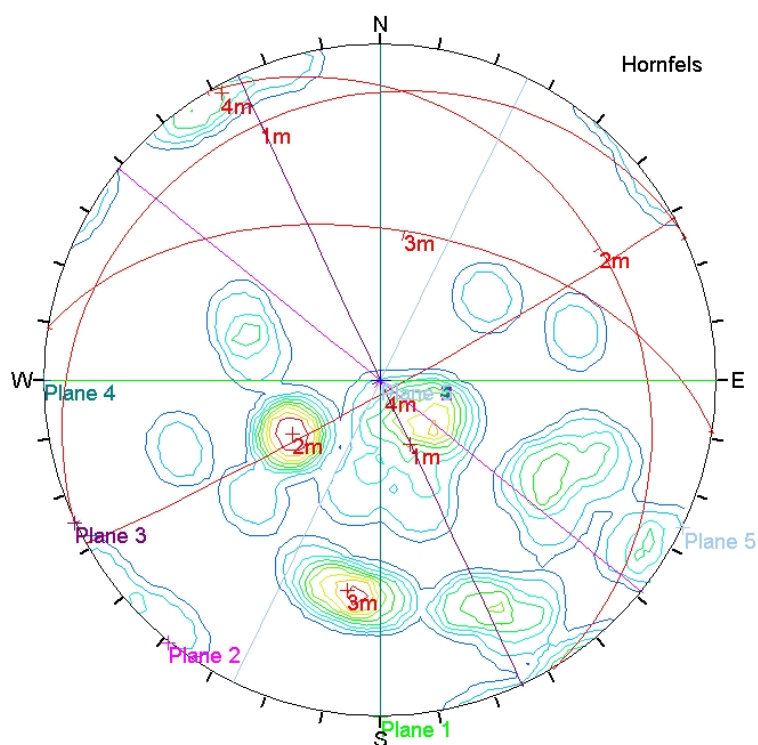


DRAWN..... GB
CHKD..... PP



Orientations		
ID		Dip / Direction
1	m	17 / 335
2	m	25 / 059
3	m	53 / 009
4	m	87 / 151

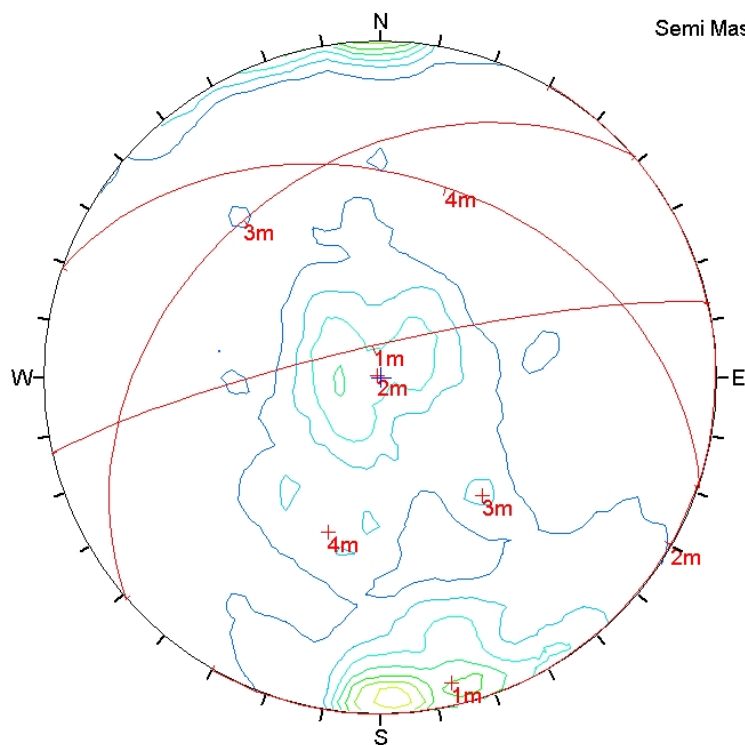
Equal Area
Lower Hemisphere
39 Poles
39 Entries



Orientations		
ID		Dip / Direction
1		90 / 360
2		90 / 039
3		90 / 065
4		90 / 090
5		90 / 296
1	m	17 / 335
2	m	25 / 059
3	m	53 / 009
4	m	87 / 151

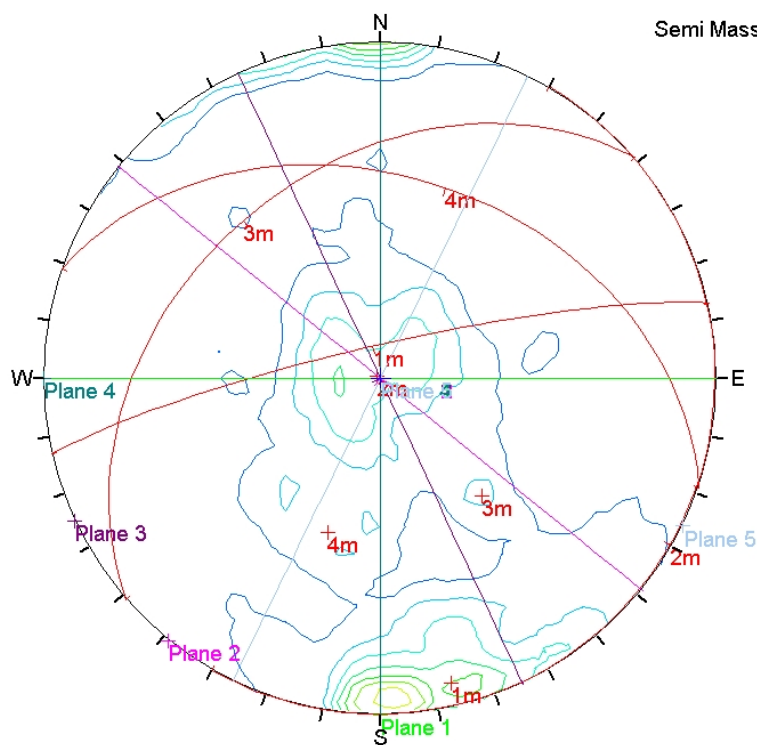
Equal Area
Lower Hemisphere
39 Poles
39 Entries

REVIEW OF MAPPING DATA HORNFELS (Regular and with Added Planes)



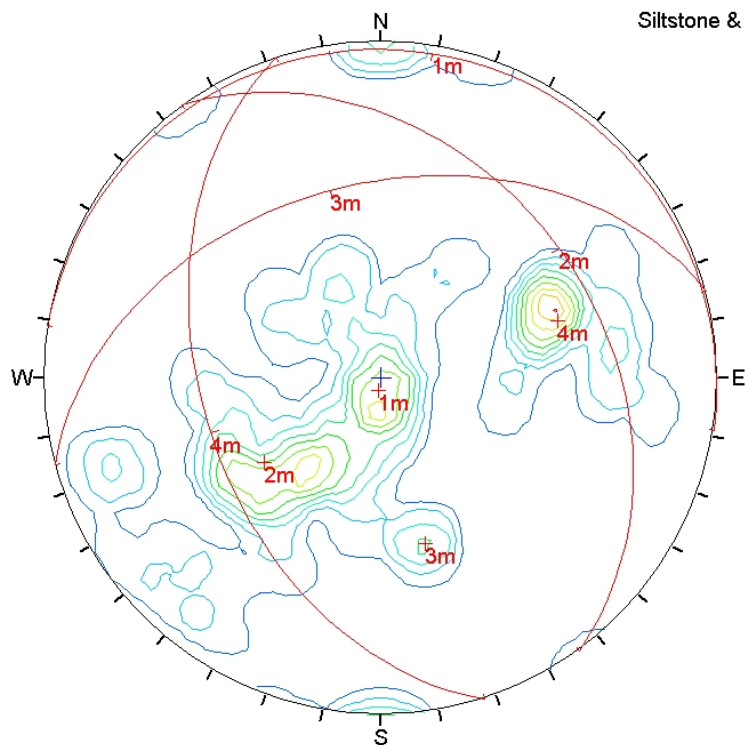
Orientations		
ID	Dip / Direction	
1 m	82	347
2 m	01	120
3 m	38	319
4 m	40	019

Equal Area
Lower Hemisphere
341 Poles
341 Entries



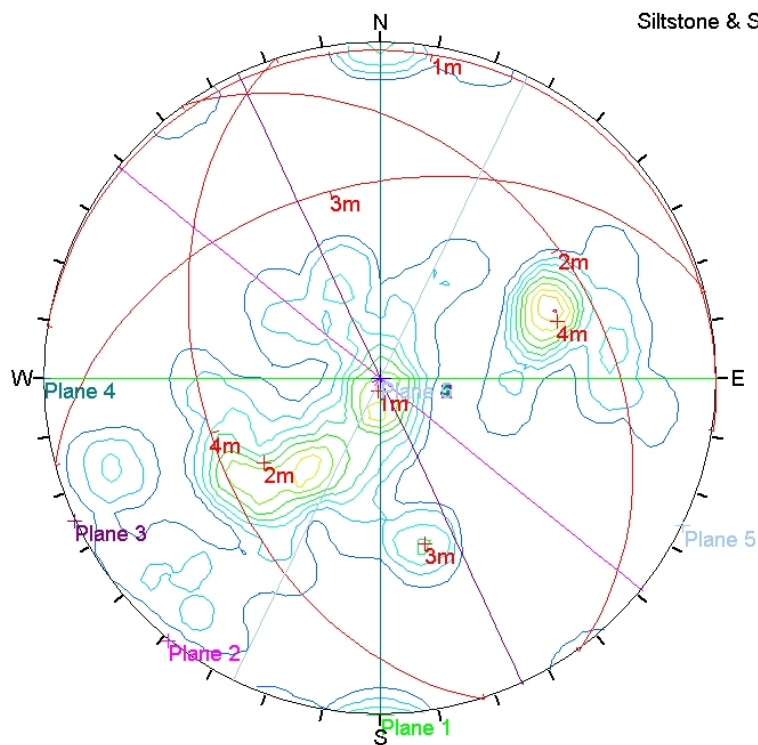
Orientations		
ID	Dip / Direction	
1	90	360
2	90	039
3	90	065
4	90	090
5	90	296
1 m	82	347
2 m	01	120
3 m	38	319
4 m	40	019

Equal Area
Lower Hemisphere
341 Poles
341 Entries



Orientations		
ID	Dip / Direction	
1	m	03 / 009
2	m	35 / 054
3	m	42 / 345
4	m	46 / 252

Equal Area
Lower Hemisphere
69 Poles
69 Entries



Orientations		
ID	Dip / Direction	
1		90 / 360
2		90 / 039
3		90 / 065
4		90 / 090
5		90 / 296
1	m	03 / 009
2	m	35 / 054
3	m	42 / 345
4	m	46 / 252

Equal Area
Lower Hemisphere
69 Poles
69 Entries

REVIEW OF MAPPING DATA SANDSTONE & SILTSTONE (Regular and with Added Planes)