Rock Slope Stability Assessment of an Abandoned Quarry for Reclamation to Recreational Use

Presented by:
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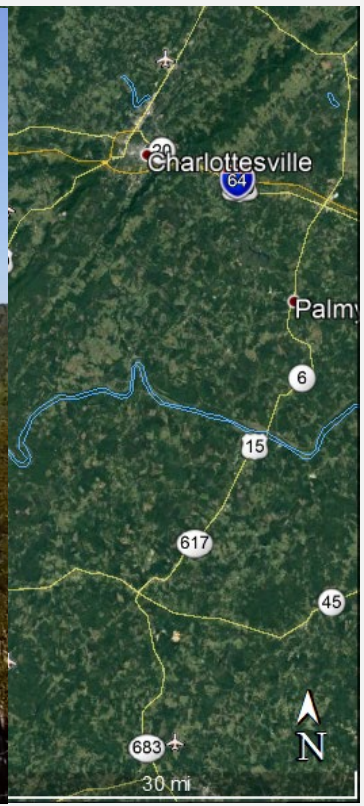
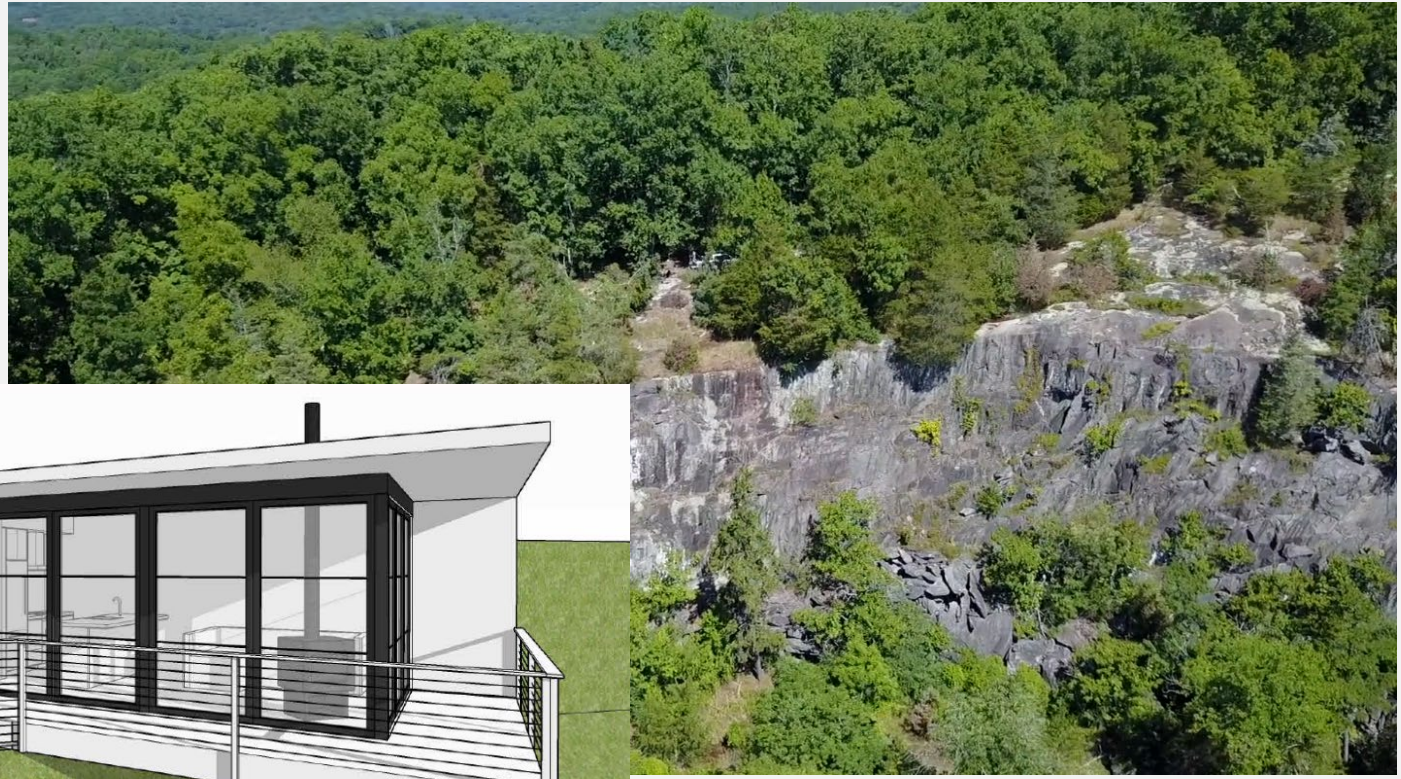
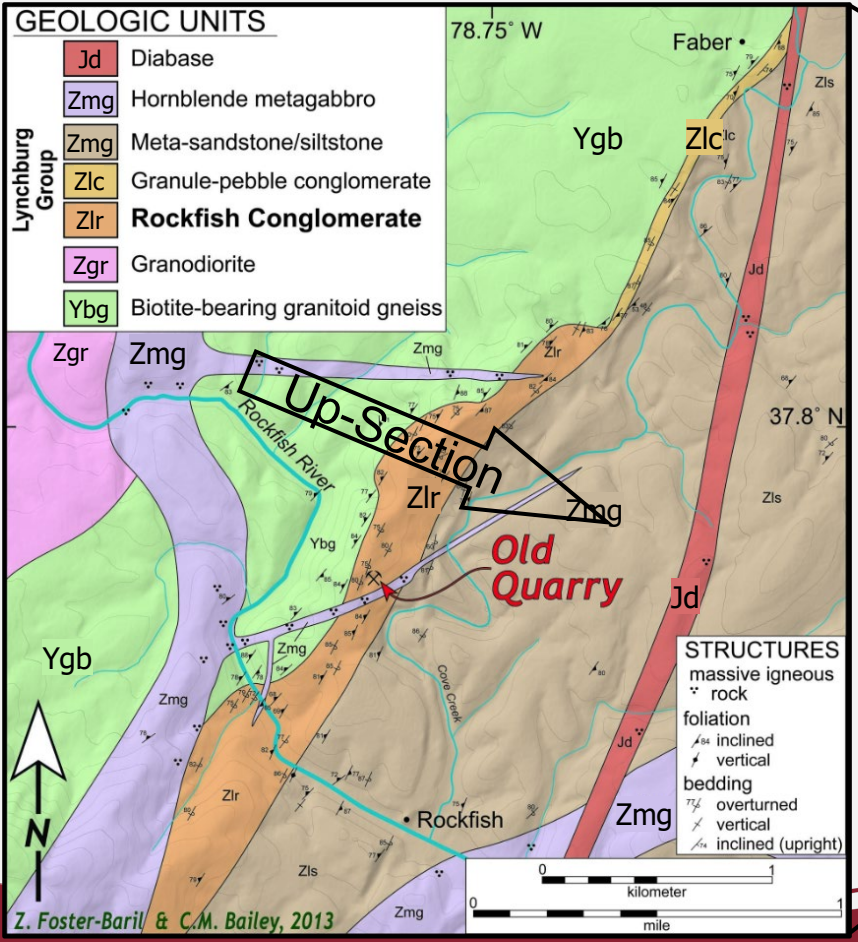
Background

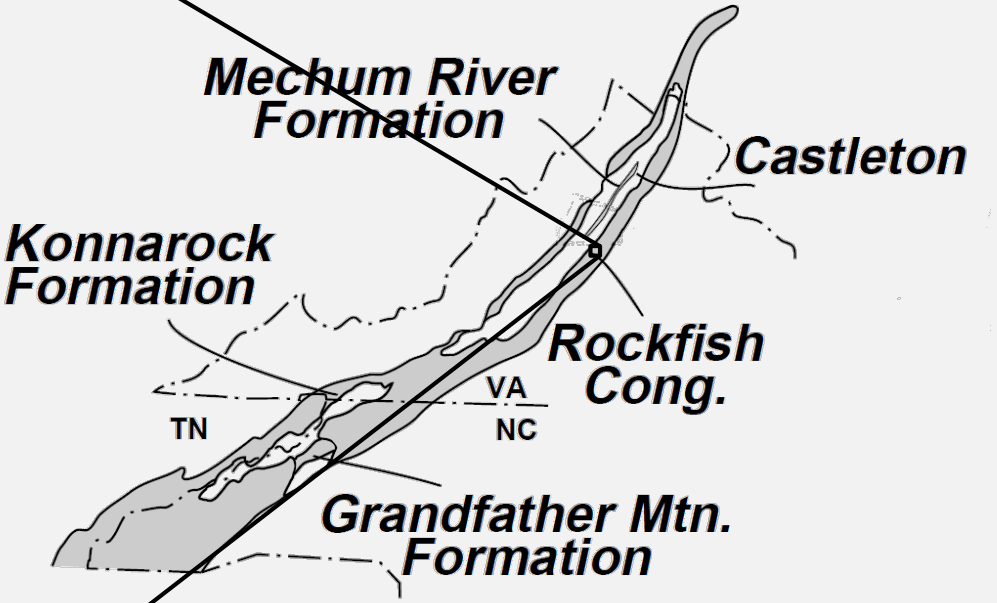


Owner's Vision



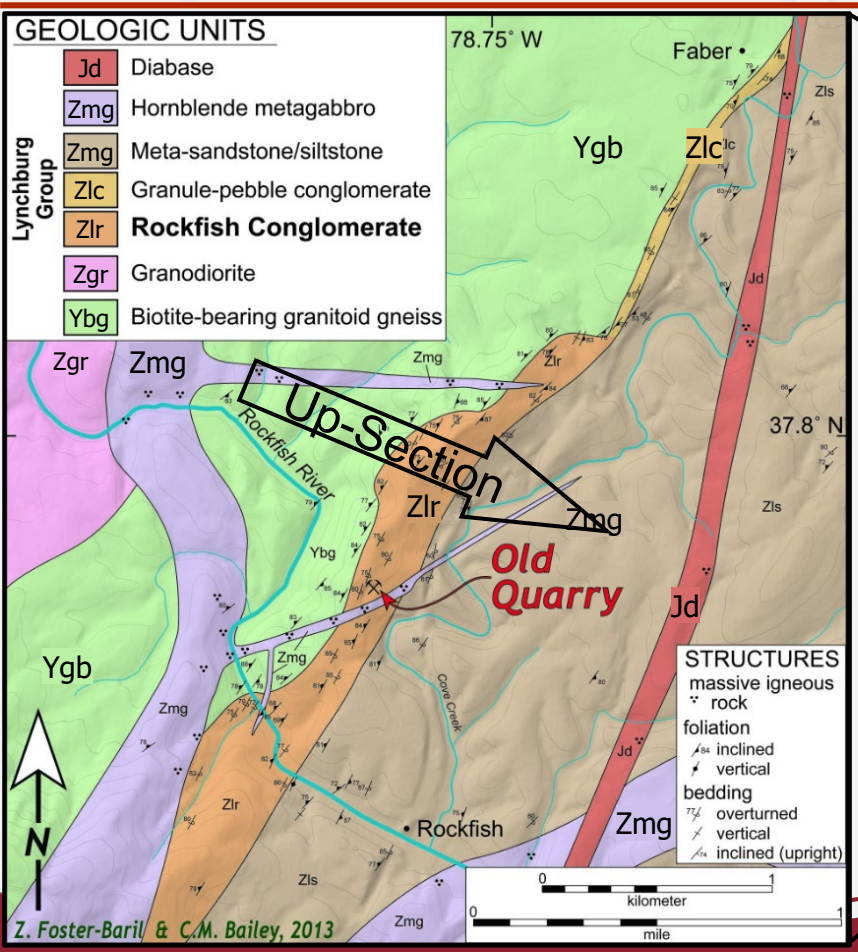
Regional Geology

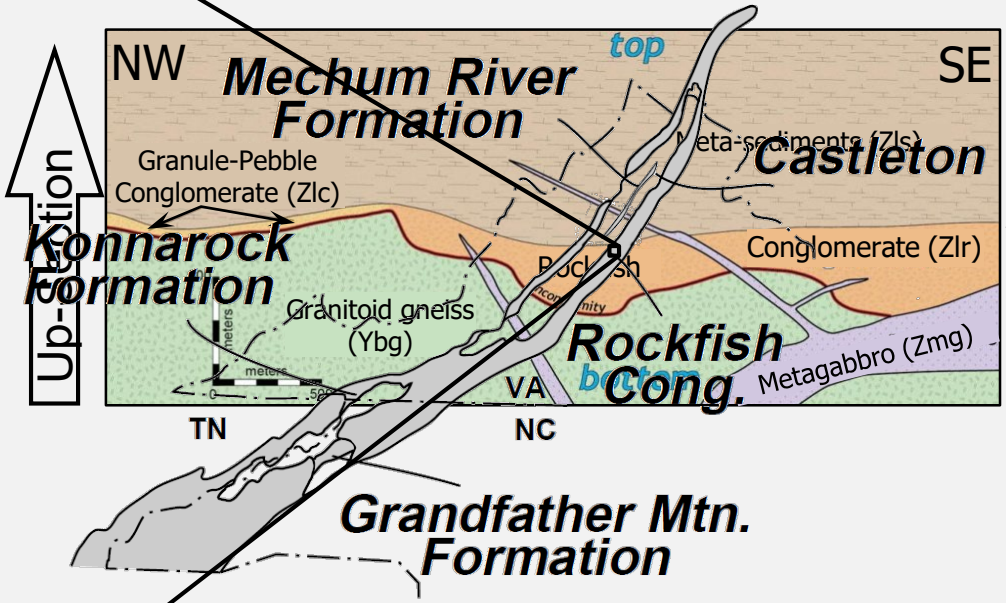




After C.M. Baily and S.E. Peters, 1998

Regional Geology





After C.M. Baily and S.E. Peters, 1998

Local Geology

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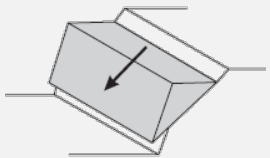
Bedding

Minor Schistosity

Fracturing

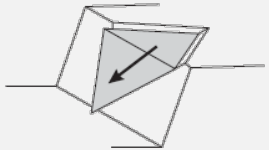
Basic Types of Rock Failures

(a)



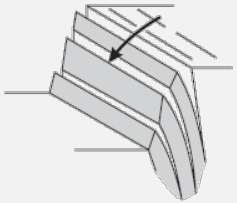
Planar Failure

(b)



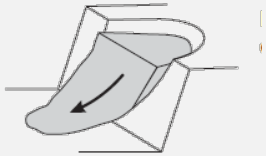
Wedge Failure

(c)



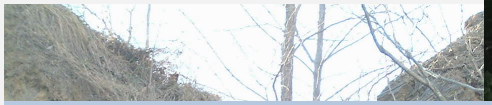
Toppling Failure

(d)



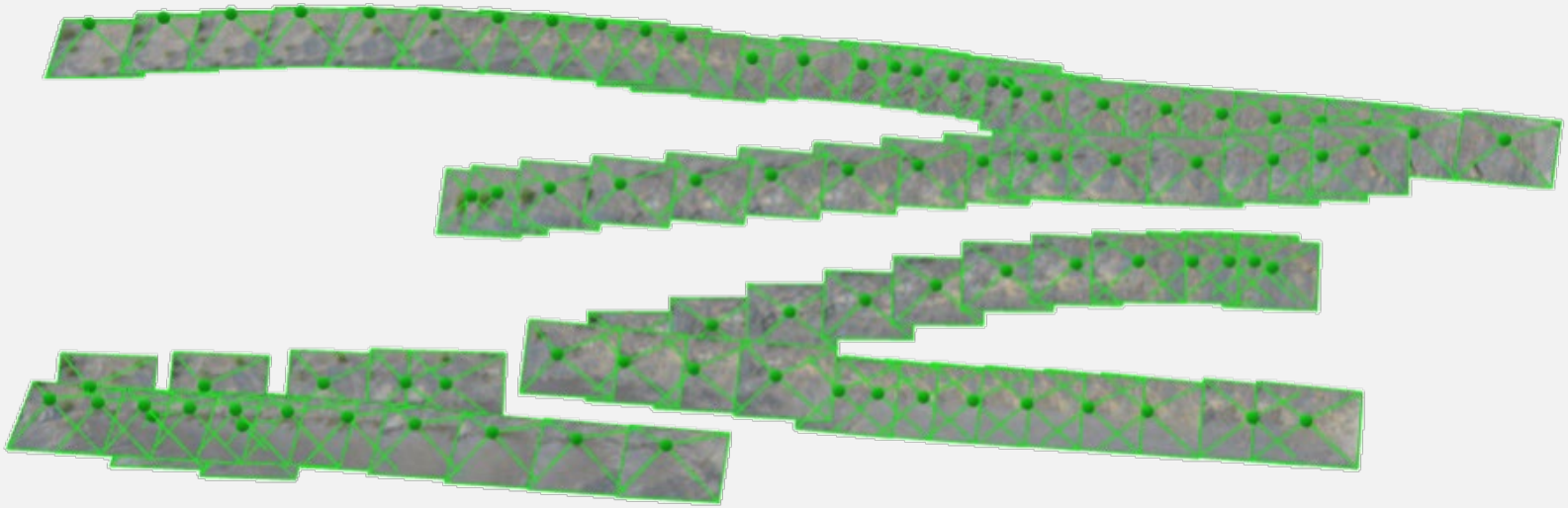
Circular Failure

Collecting Discontinuity Data

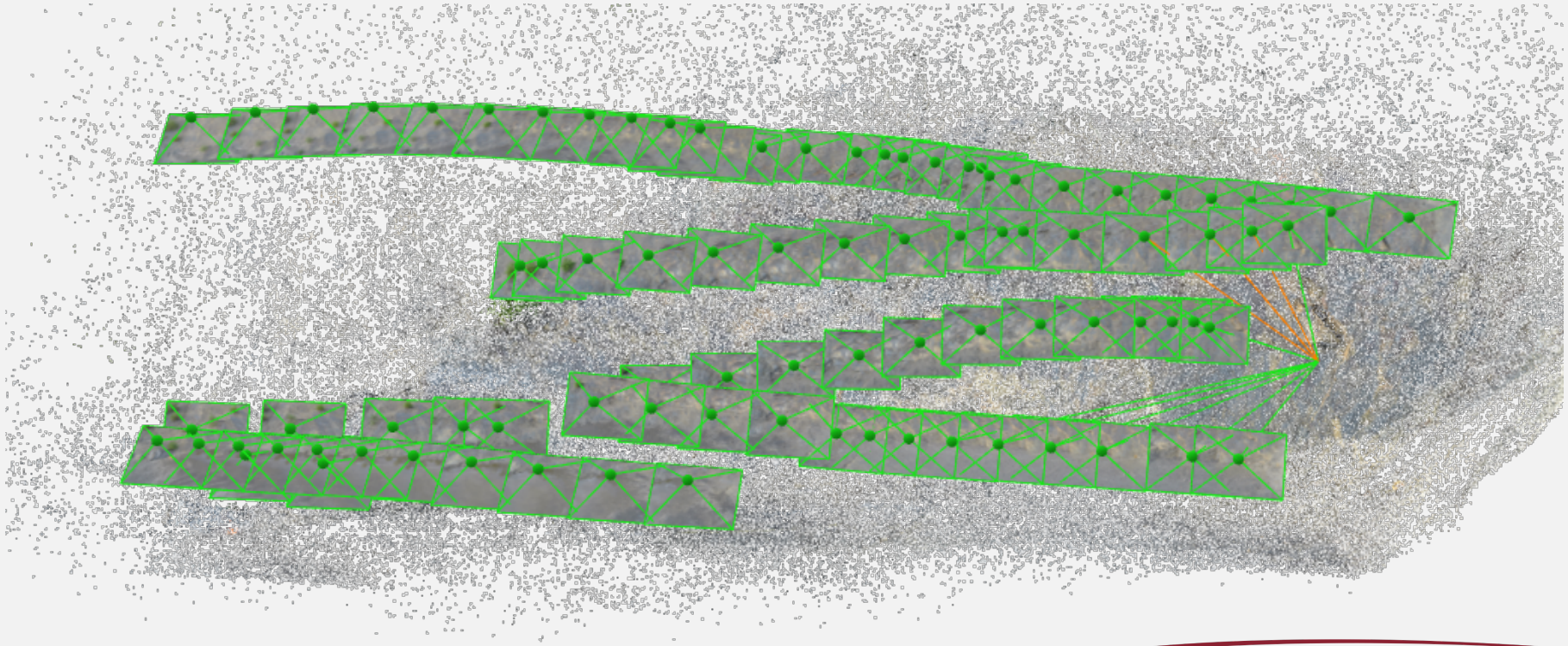


Aerial Photography

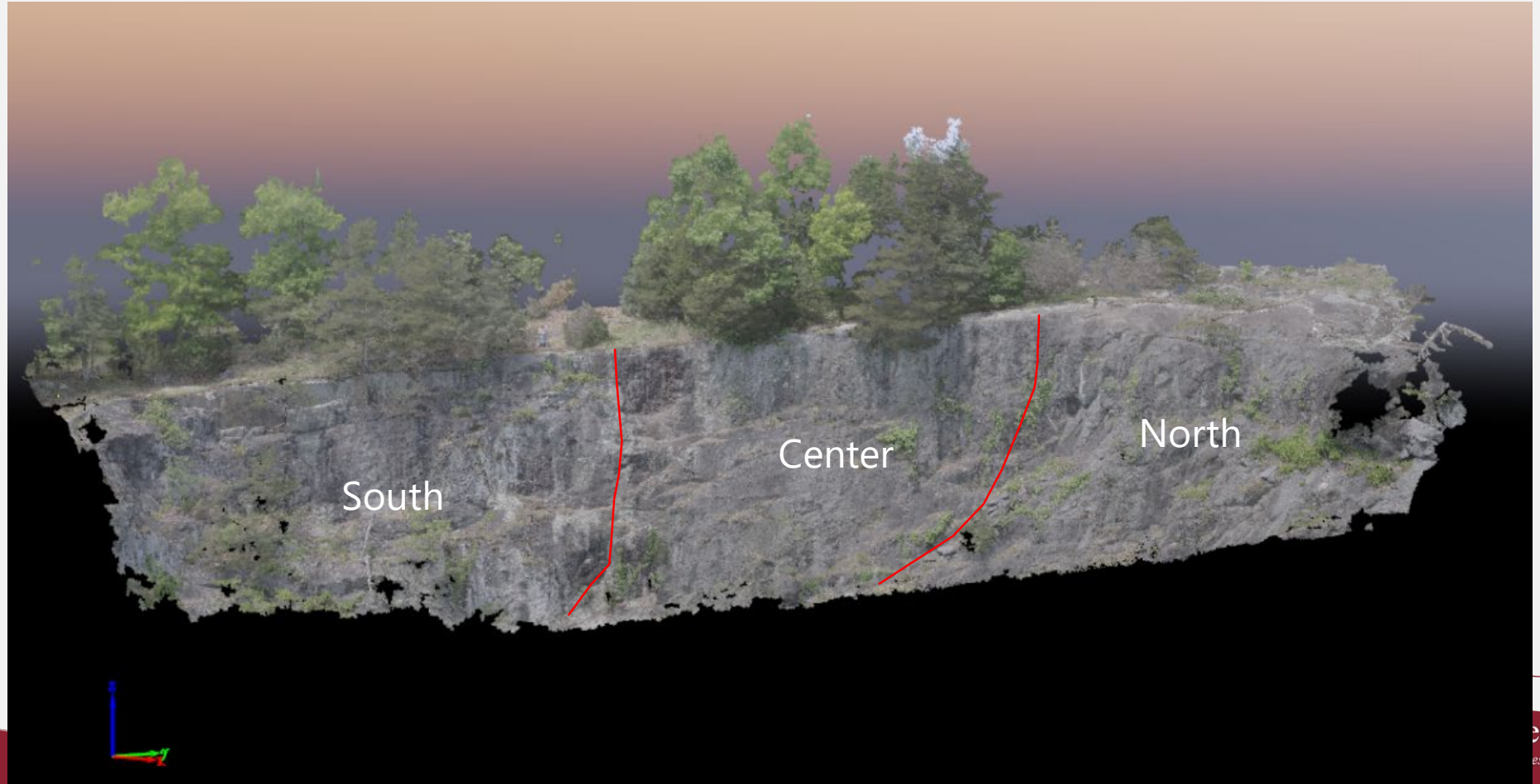
- Spatial Referencing



Point Cloud



Point Cloud

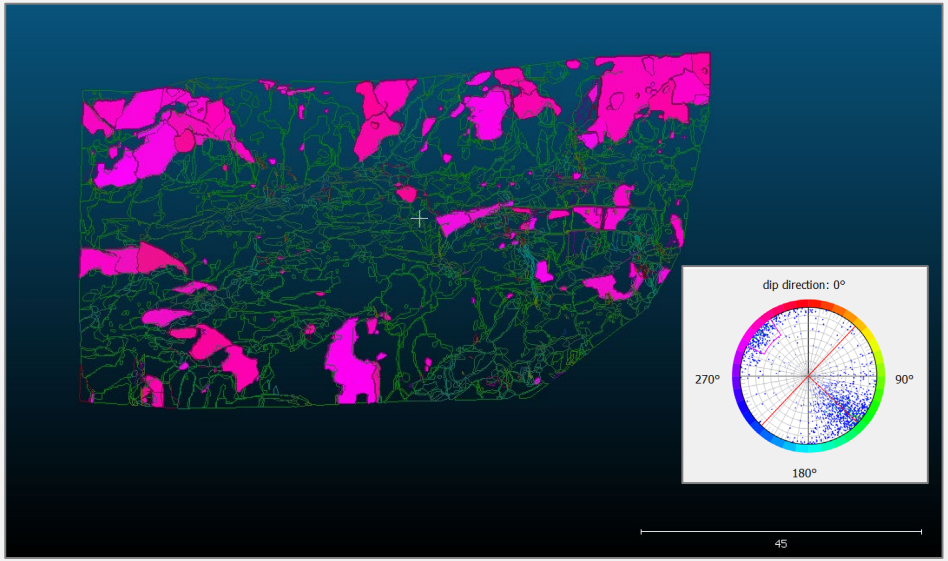


Identifying Surfaces or “Facets”

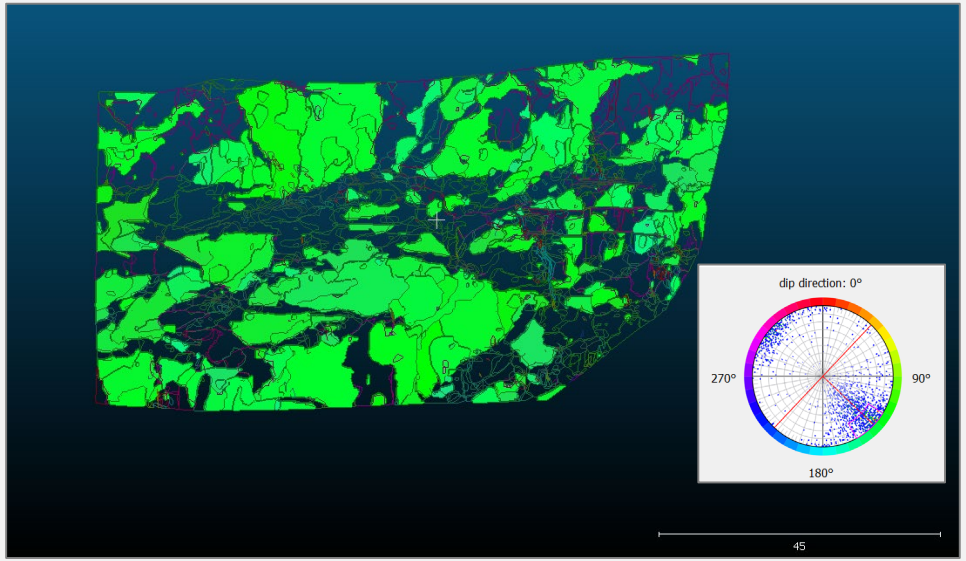
- Triangular mesh from the point cloud
- User-defined parameters to identify planes
- Export dip vectors
- Planar failures are the most likely

High-Angle Facets Most Critical

Facets Dipping into the Slope



Facets Dipping out of the Slope



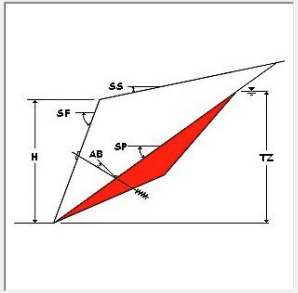
Factor of Safety

- RockPAK III
- Typical Parameters
  - Height
  - Inclination of the Slope Face
  - Inclination of the Upper Slope
  - Inclination of the Failure Plane
  - Cohesive Strength of the Failure
  - Friction Angle of the Failure Surface
  - Density of Rock
  - Density of Water

Static Conditions

Plane Failure Analysis Input Screen - C:\Users\cwatts\Documents\Cook Qry.PLN

File View Units Reset Help



Status: READY

CALCULATE FACTOR OF SAFETY

Optional Input Data

(AC) Horizontal Acceleration	0	G
(TZ) Amount of Discontinuity Saturated	0	decimal%
(VSUR) Vertical Surcharge	0	lb(f)
(HSUR) Horizontal Surcharge	0	lb(f)

Standard Input Data

(H) Height	35	ft
(SF) Inclination of Slope Face	90	°
(SS) Inclination of Upper Slope	5	°
(SP) Inclination of Failure Plane	67	°
(CO) Cohesive Strength of Failure Surface	1000	lb(f)
(PH) Friction Angle of Failure Surface	30	°
(GR) Density of Rock	160	lb(f)/ft³
(GW) Density of Water	62.4	lb(f)/ft³

Bolt Data

(AB) Starting Rock Bolt Angle	0	°	(T1) Starting Bolt Tension	0	lb(f)
(AR) Ending Rock Bolt Angle	0	°	(T2) Ending Bolt Tension	0	lb(f)
(AA) Bolt Angle Increment	0	°	(T3) Bolt Tension Increment	0	lb(f)

Tension Crack Data

- (•) No Tension Crack
- ( ) Tension Crack Location Known
- ( ) Tension Crack Location Unknown

(B) Horizontal Distance of Tension Crack from Crest	0	ft
(DZ) Relative Height of Water in Tension Crack	0	decimal%

(•) Dry Slope ( ) Tension Crack filled with Water

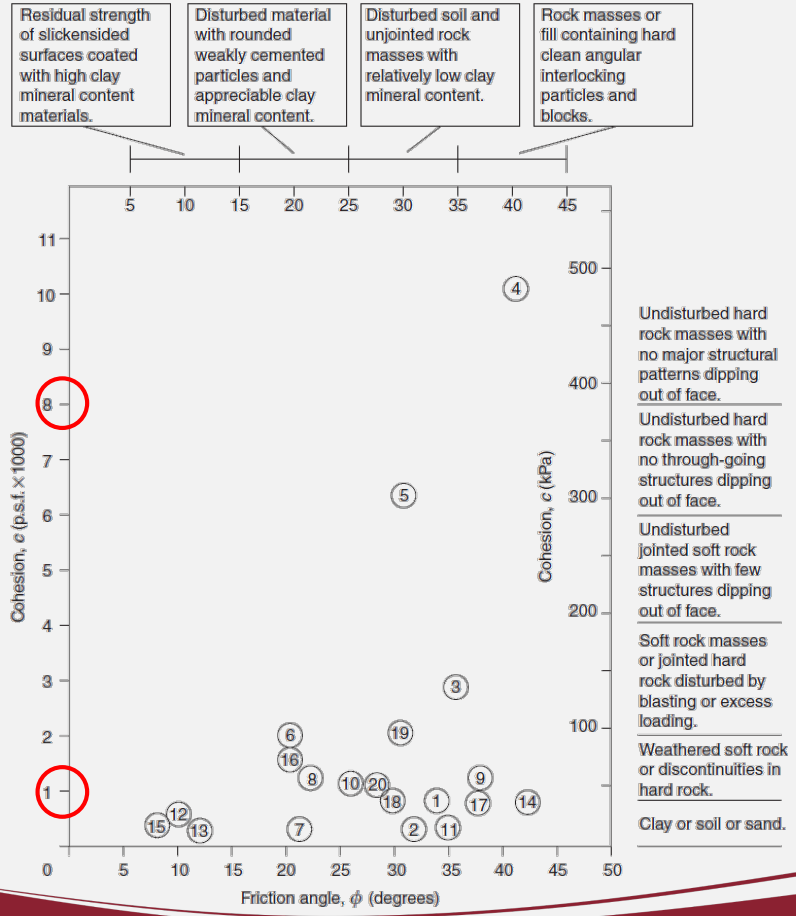
Plane Failure Analysis Output Screen

Print Units Graph Mode Help

Results

(F) Factor of Safety =	1.24		(T) Tension =	0 lb(f)
(A) Contact Area =	39.49	ft²	(TH) Bolt Angle =	0 °
(W) Weight of Slice =	43202.95	lb(f)	(Z) Tension Crack Depth =	0 ft
(U) Water Force Normal to Failure Plane =	0	lb(f)	(Z1) Height/Length of Crack =	0 ft
(V) Horizontal Water Force on Tension Crack =	0	lb(f)	(ZW) Depth of Water in Crack =	0 ft
(B) Horizontal Distance of Tension Crack from Crest =	15.43	ft	(B) Worst Location, Horizontal Distance =	0 ft

Shear Strength

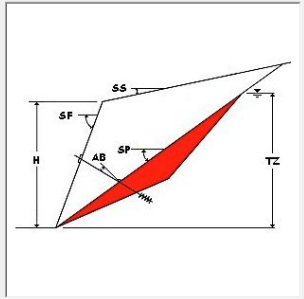


Wyllie, D.C., and Mah, C.W., 2004

FOS Beyond the Daylighting Plane

Plane Failure Analysis Input Screen - C:\Users\cwatts\Documents\Cook Qry.PLN

File View Units Reset Help



Status: READY

CALCULATE FACTOR OF SAFETY

Optional Input Data

(AC) Horizontal Acceleration	0	G
(TZ) Amount of Discontinuity Saturated	0	decimal%
(VSUR) Vertical Surcharge	0	lb(f)
(HSUR) Horizontal Surcharge	0	lb(f)

Standard Input Data

(H) Height	30	ft
(SF) Inclination of Slope Face	90	°
(SS) Inclination of Upper Slope	5	°
(SP) Inclination of Failure Plane	67	°
(CO) Cohesive Strength of Failure Surface	8000	lb(f)
(PH) Friction Angle of Failure Surface	30	°
(GR) Density of Rock	160	lb(f)/ft³
(GW) Density of Water	62.4	lb(f)/ft³

Bolt Data

(AB) Starting Rock Bolt Angle	0	°	(T1) Starting Bolt Tension	0	lb(f)
(AR) Ending Rock Bolt Angle	0	°	(T2) Ending Bolt Tension	0	lb(f)
(AA) Bolt Angle Increment	0	°	(T3) Bolt Tension Increment	0	lb(f)

Tension Crack Data

- (•) No Tension Crack
- ( ) Tension Crack Location Known
- ( ) Tension Crack Location Unknown

(B) Horizontal Distance of Tension Crack from Crest	0	ft
(DZ) Relative Height of Water in Tension Crack	0	decimal%

(•) Dry Slope ( ) Tension Crack filled with Water

Plane Failure Analysis Output Screen

Print Units Graph Mode Help

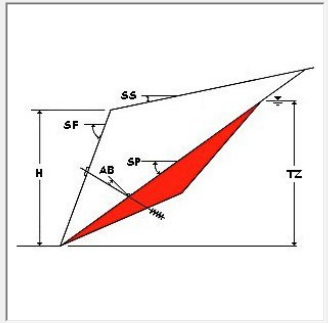
Results

(F) Factor of Safety =	9.51		(T) Tension =	0 lb(f)
(A) Contact Area =	33.85	ft²	(TH) Bolt Angle =	0 °
(W) Weight of Slice =	31740.94	lb(f)	(Z) Tension Crack Depth =	0 ft
(U) Water Force Normal to Failure Plane =	0	lb(f)	(Z1) Height/Length of Crack =	0 ft
(V) Horizontal Water Force on Tension Crack =	0	lb(f)	(ZW) Depth of Water in Crack =	0 ft
(B) Horizontal Distance of Tension Crack from Crest =	13.23	ft	(B) Worst Location, Horizontal Distance =	0 ft

FOS with Loading

Plane Failure Analysis Input Screen - C:\Users\cwatts\Documents\Cook Qry.PLN

File View Units Reset Help



Status: READY

CALCULATE FACTOR OF SAFETY

Standard Input Data

(H) Height	30	ft
(SF) Inclination of Slope Face	90	°
(SS) Inclination of Upper Slope	5	°
(SP) Inclination of Failure Plane	67	°
(CO) Cohesive Strength of Failure Surface	8000	lb(f)
(PH) Friction Angle of Failure Surface	30	°
(GR) Density of Rock	160	lb(f)/ft³
(GW) Density of Water	62.4	lb(f)/ft³

Bolt Data

(AB) Starting Rock Bolt Angle	0	°	(T1) Starting Bolt Tension	0	lb(f)
(AR) Ending Rock Bolt Angle	0	°	(T2) Ending Bolt Tension	0	lb(f)
(AA) Bolt Angle Increment	0	°	(T3) Bolt Tension Increment	0	lb(f)

Optional Input Data

(AC) Horizontal Acceleration	0	G
(TZ) Amount of Discontinuity Saturated	0	decimal%
(VSUR) Vertical Surcharge	8250	lb(f)
(HSUR) Horizontal Surcharge	0	lb(f)

Tension Crack Data

- (•) No Tension Crack
- ( ) Tension Crack Location Known
- ( ) Tension Crack Location Unknown

(B) Horizontal Distance of Tension Crack from Crest	0	ft
(DZ) Relative Height of Water in Tension Crack	0	decimal%

(•) Dry Slope ( ) Tension Crack filled with Water

Plane Failure Analysis Output Screen

Print Units Graph Mode Help

Results

(F) Factor of Safety =	**7.6**		(T) Tension =	0 lb(f)
(A) Contact Area =	33.85	ft²	(TH) Bolt Angle =	0 °
(W) Weight of Slice =	31740.94	lb(f)	(Z) Tension Crack Depth =	0 ft
(U) Water Force Normal to Failure Plane =	0	lb(f)	(Z1) Height/Length of Crack =	0 ft
(V) Horizontal Water Force on Tension Crack =	0	lb(f)	(ZW) Depth of Water in Crack =	0 ft
(B) Horizontal Distance of Tension Crack from Crest =	13.23	ft	(B) Worst Location, Horizontal Distance =	0 ft

Conclusions

- With the conservative assumptions, the rim is not safe.
- Critical distance from the rim is 15 feet.
- The concept is feasible as long as the loading is farther back than 15 feet.