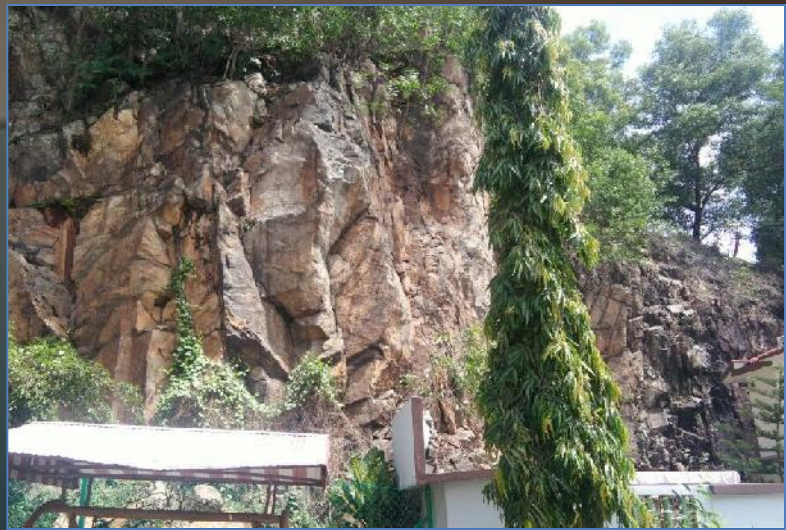
KURSUS PENSIJILAN CERUN TAHAP 2

GEOLOGY PART 2:

ROCK MASS DESCRIPTION & CHARACTERISATION, ROCK SLOPE STABILITY ANALYSIS & STABILIZATION AND PROTECTION METHODS



NURUL IFFAH ISMAIL (GEOLOGIST)

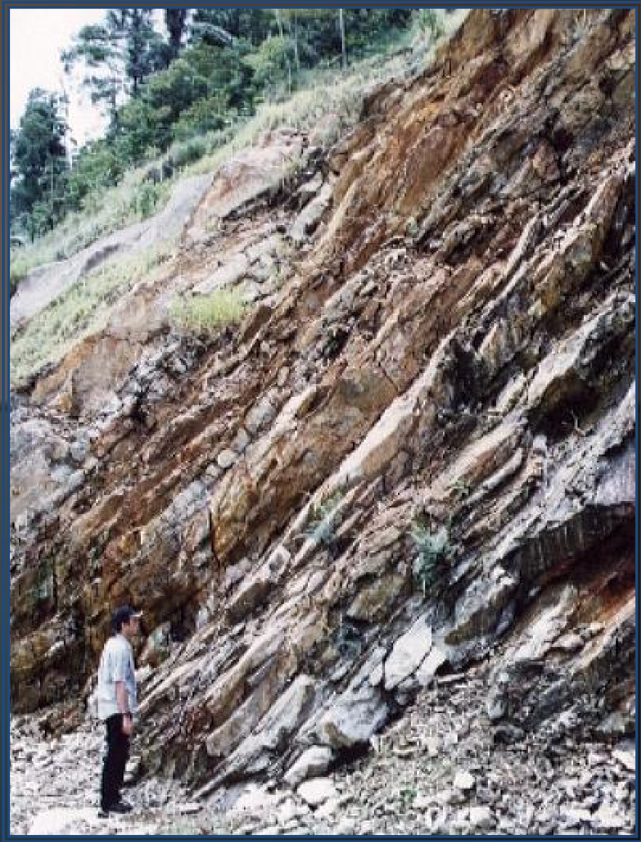
GEOTECHNICAL FORENSIC ENGINEERING, KUMPULAN IKRAM SDN BHD

16 MARCH 2020 (MONDAY)

Pusat Kecemerlangan Kejuruteraan dan Teknologi JKR (CREaTE)

OUTLINE

1. Rock Mass Description & Characterization
2. Rock Mass Rating (RMR)
3. Rock slope stability analysis
4. Rock Slope Stabilization & Protection



DESCRIPTION OF ROCK MASS OUTCROP FLOW CHART

General Description of the outcrop (e.g. rock, soils, areas with water, dominant discontinuities)

→

Division into zones based on lithological and structural criteria

→

Detailed description of each zone

-Intact rock

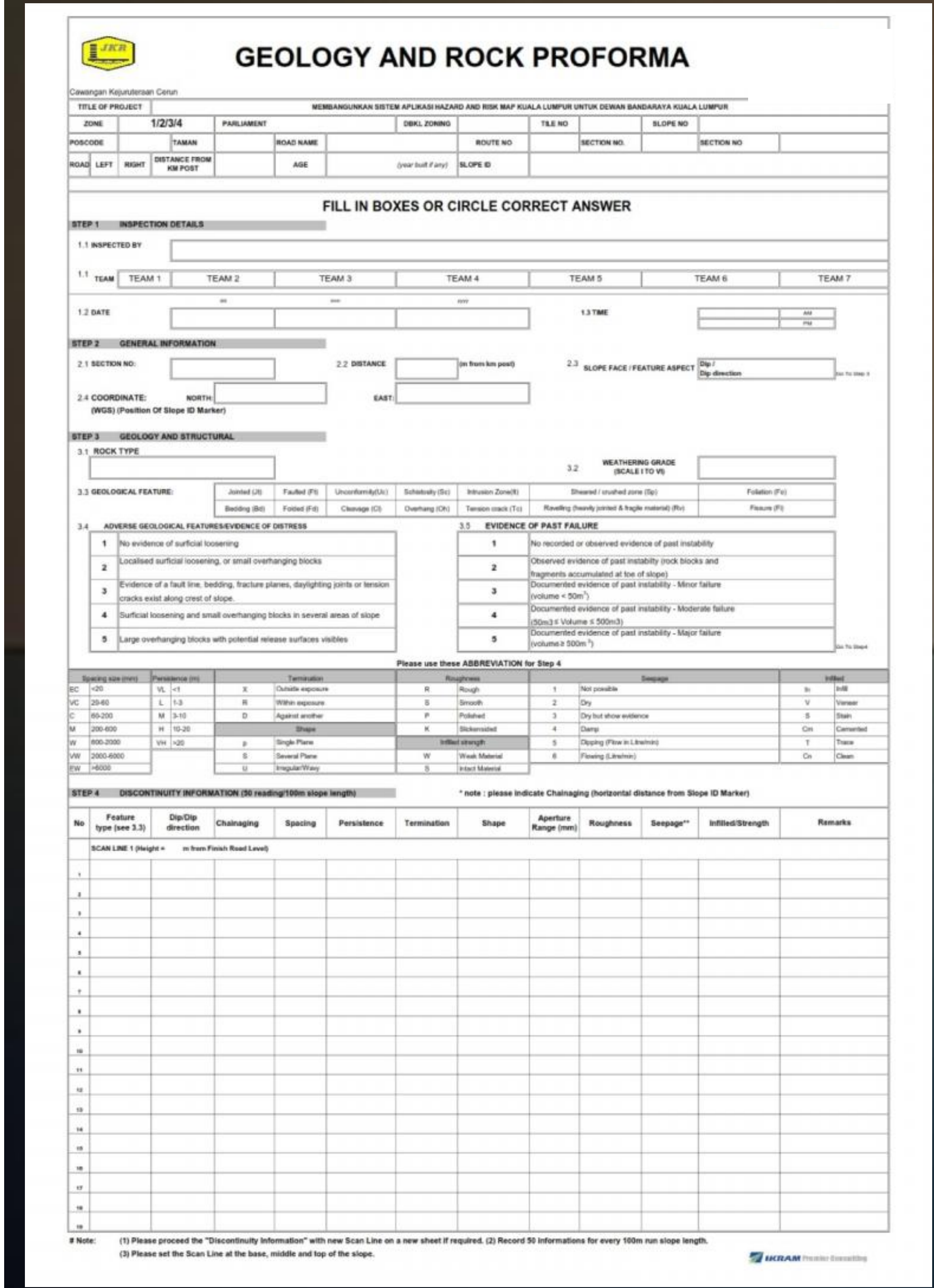
-Discontinuities

- Rock mass

→

Global Characterization and Rock Mass Geomechanical classification

GEOLOGY PROFORMA



GEOLOGY AND ROCK PROFORMA

Cawangan Kejuruteraan Cerun

TITLE OF PROJECT	MEMBANGUNKAN SISTEM APLIKASI HAZARD AND RISK MAP KUALA LUMPUR UNTUK DEWAN BANDARAYA KUALA LUMPUR										
ZONE	1/2/3/4	PARLIAMENT		DBKL ZONING		TILE NO		SLOPE NO			
POSCODE		TAMAN		ROAD NAME		ROUTE NO		SECTION NO.		SECTION NO	
ROAD	LEFT	RIGHT	DISTANCE FROM KM POST		AGE	(year built if any)	SLOPE ID				

FILL IN BOXES OR CIRCLE CORRECT ANSWER

STEP 1 INSPECTION DETAILS

1.1 INSPECTED BY

1.1 TEAM: TEAM 1 | TEAM 2 | TEAM 3 | TEAM 4 | TEAM 5 | TEAM 6 | TEAM 7

1.2 DATE — dd / mm / yyyy

1.3 TIME — AM / PM

STEP 2 GENERAL INFORMATION

2.1 SECTION NO:

2.2 DISTANCE (m from km post)

2.3 SLOPE FACE / FEATURE ASPECT — Dip / Dip direction — Go To Step 3

2.4 COORDINATE: (WGS) (Position Of Slope ID Marker) NORTH: EAST:

STEP 3 GEOLOGY AND STRUCTURAL

3.1 ROCK TYPE

3.2 WEATHERING GRADE (SCALE I TO VI)

3.3 GEOLOGICAL FEATURE:

Jointed (Jt)	Faulted (Ft)	Unconformity(Uc)	Schistosity (Sc)	Intrusion Zone(It)	Sheared / crushed zone (Sp)	Foliation (Fo)
Bedding (Bd)	Folded (Fd)	Cleavage (Cl)	Overhang (Oh)	Tension crack (Tc)	Ravelling (heavily jointed & fragile material) (Rv)	Fissure (Fi)

3.4 ADVERSE GEOLOGICAL FEATURES/EVIDENCE OF DISTRESS

1	No evidence of surficial loosening
2	Localised surficial loosening, or small overhanging blocks
3	Evidence of a fault line, bedding, fracture planes, daylighting joints or tension cracks exist along crest of slope.
4	Surficial loosening and small overhanging blocks in several areas of slope
5	Large overhanging blocks with potential release surfaces visibles

3.5 EVIDENCE OF PAST FAILURE

1	No recorded or observed evidence of past instability
2	Observed evidence of past instability (rock blocks and fragments accumulated at toe of slope)
3	Documented evidence of past instability - Minor failure (volume < $50m^3$)
4	Documented evidence of past instability - Moderate failure ($50m3 \leq$ Volume $\leq 500m3$)
5	Documented evidence of past instability - Major failure (volume $\geq 500m^3$)

Go To Step 4

Please use these ABBREVIATION for Step 4

Spacing size (mm)		Persistence (m)		Termination		Roughness		Seepage		Infilled	
EC	<20	VL	<1	X	Outside exposure	R	Rough	1	Not possible	In	Infill
VC	20-60	L	1-3	R	Within exposure	S	Smooth	2	Dry	V	Veneer
C	60-200	M	3-10	D	Against another	P	Polished	3	Dry but show evidence	S	Stain
M	200-600	H	10-20	Shape		K	Slickensided	4	Damp	Cm	Cemented
W	600-2000	VH	>20	p	Single Plane	Infilled strength		5	Dipping (Flow in Litre/min)	T	Trace
VW	2000-6000			S	Several Plane	W	Weak Material	6	Flowing (Litre/min)	Cn	Clean
EW	>6000			U	Irregular/Wavy	S	Intact Material				

STEP 4 DISCONTINUITY INFORMATION (50 reading/100m slope length)

* note : please indicate Chainaging (horizontal distance from Slope ID Marker)

No	Feature type (see 3.3)	Dip/Dip direction	Chainaging	Spacing	Persistence	Termination	Shape	Aperture Range (mm)	Roughness	Seepage**	Infilled/Strength	Remarks
	SCAN LINE 1 (Height = m from Finish Road Level)											
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												

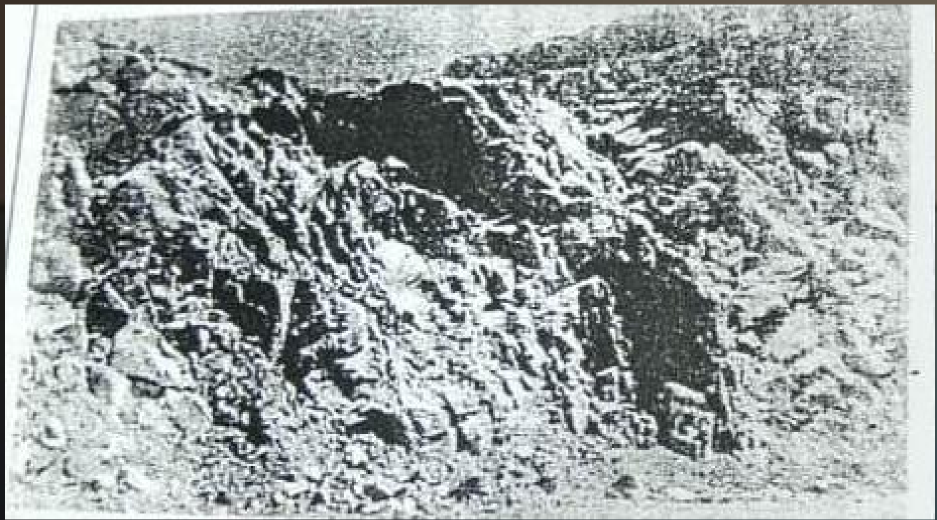
\# Note: (1) Please proceed the "Discontinuity Information" with new Scan Line on a new sheet if required. (2) Record 50 informations for every 100m run slope length.
(3) Please set the Scan Line at the base, middle and top of the slope.

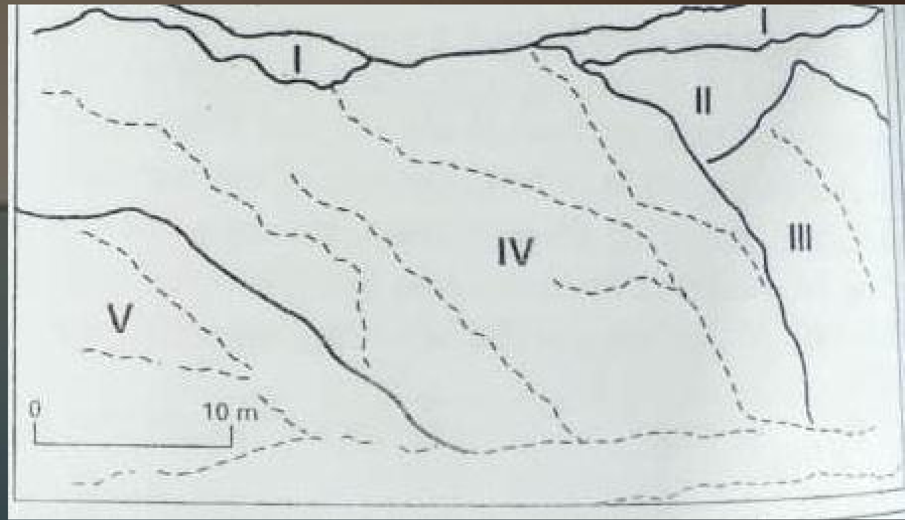
IKRAM

DIVISION INTO ZONES AND GENERAL DESCRIPTION OF EACH ZONE

PHOTO

SKETCH



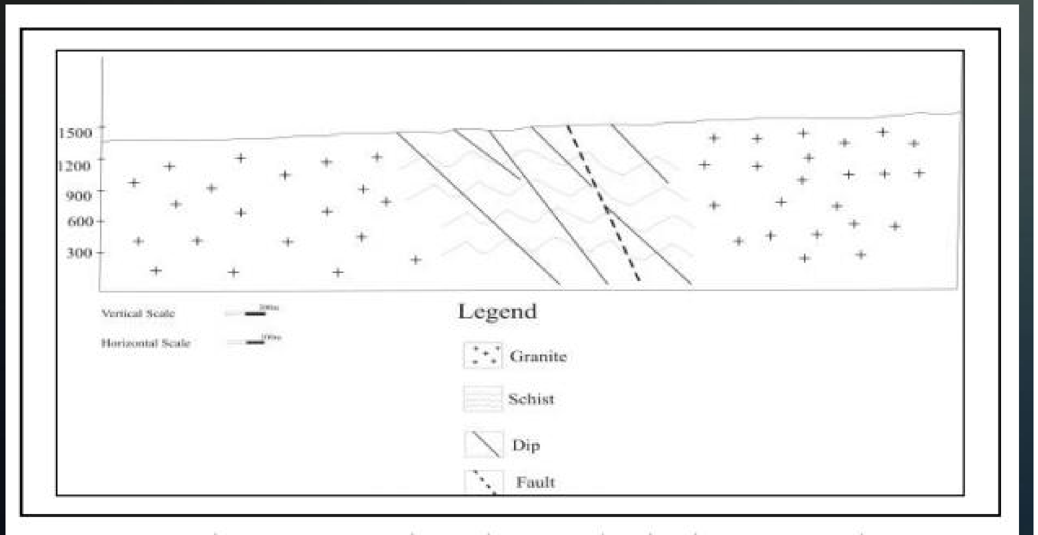


DETAILED INVESTIGATION BY GEOLOGICAL MAPPING AND DISCONTINUITY SURVEYS

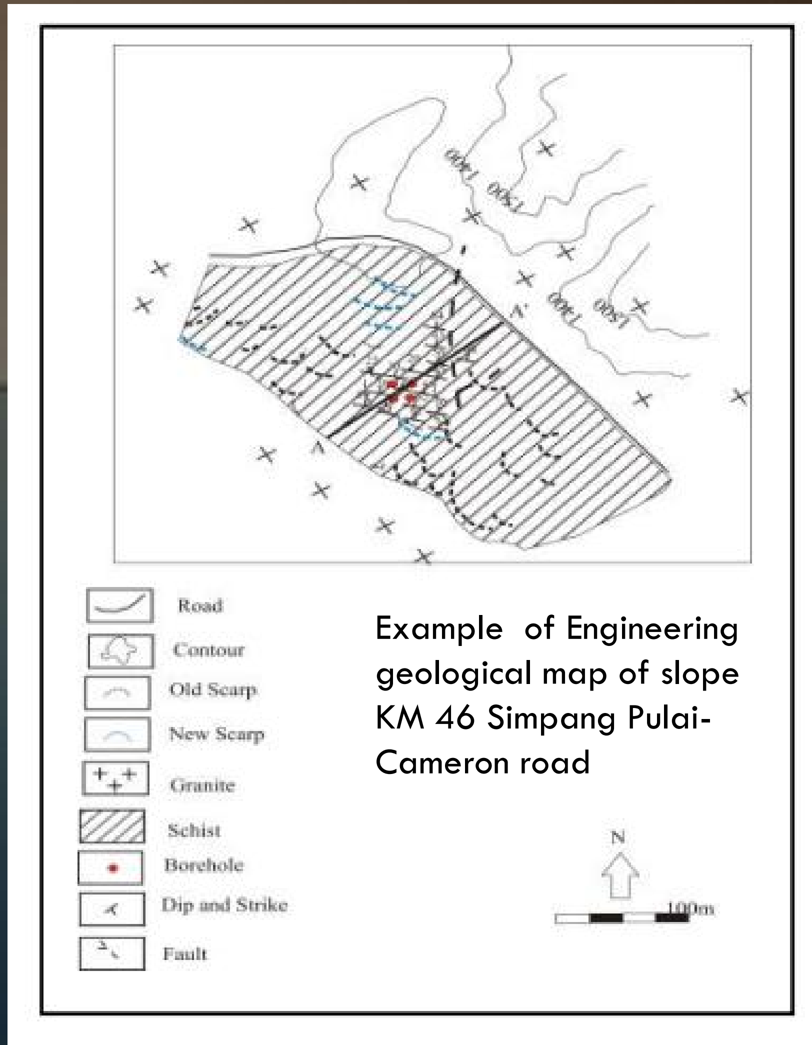
OUTPUTS FROM GEOLOGICAL MAPPING & DISCONTINUITY SURVEY

Production of geological models

1. Engineering geological map
2. Field sketches
3. Cross sections



Engineering geological cross section



Example of Engineering geological map of slope KM 46 Simpang Pulai-Cameron road

- The strength of a **large piece of rock** is usually weaker than the strength of the small pieces of rock tested in the lab
- This is due to the presence of **large scale discontinuities**

Discontinuities

- Foliation

Bedding Plane & Joints

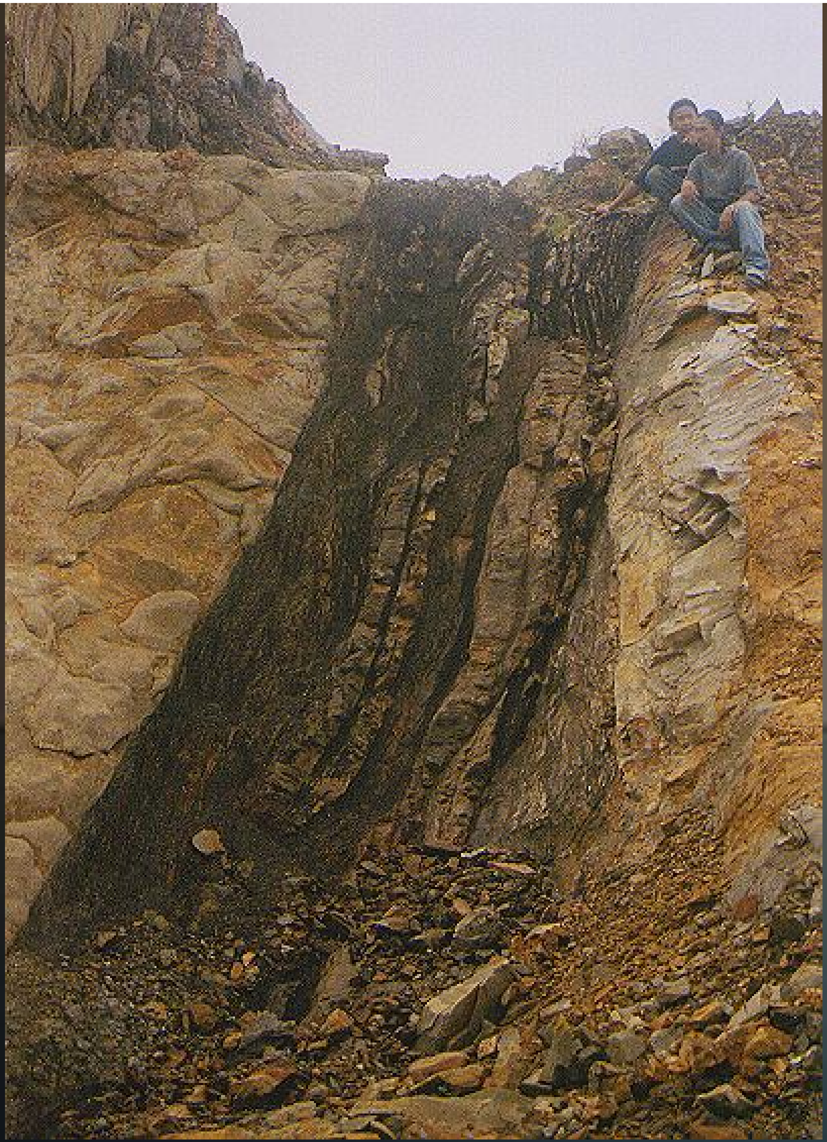
Fault & bedding plane

Discontinuities

Fault (Thrust)

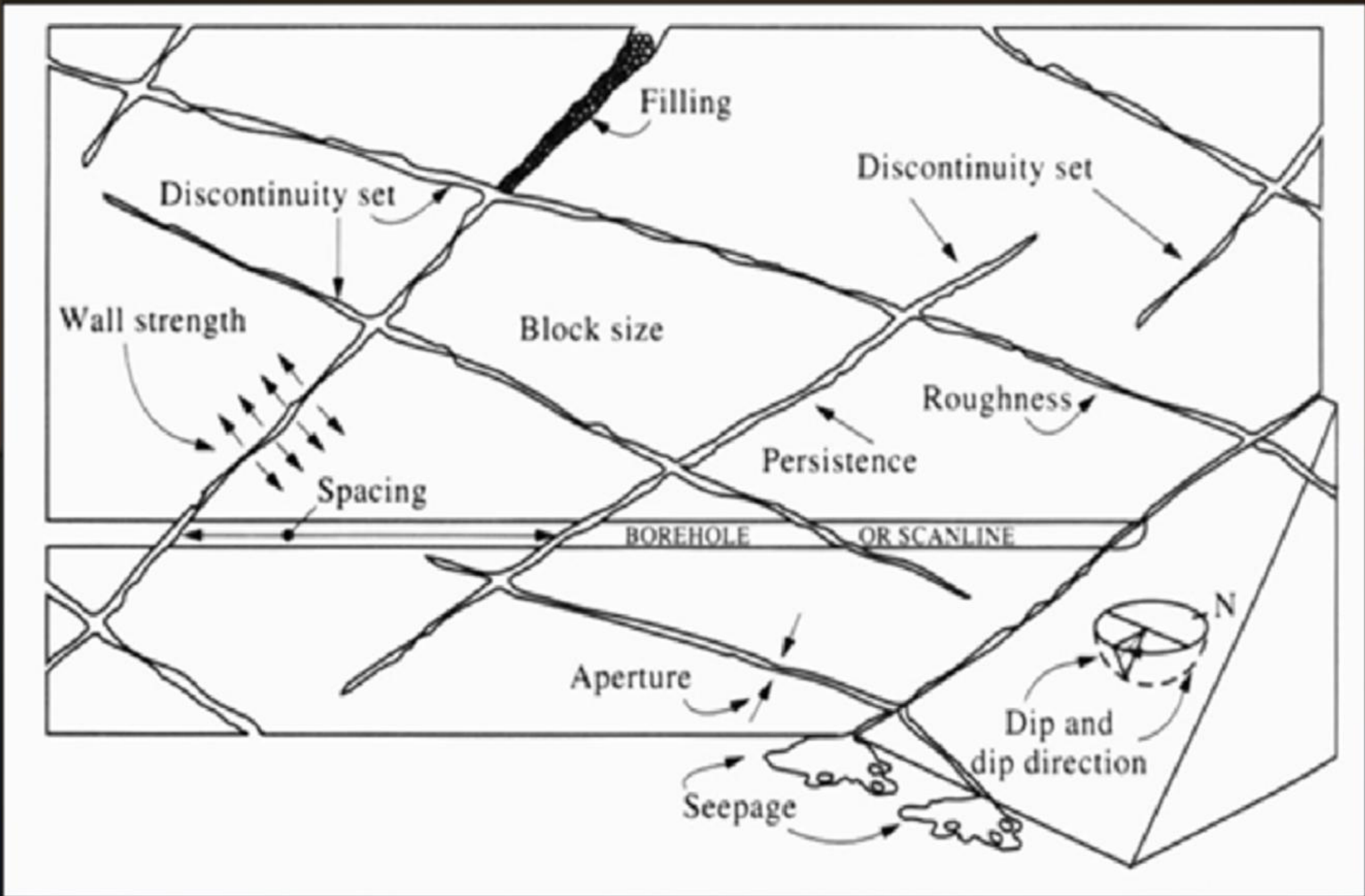
Thrust Fault

Shear zone



Shear Zone

Major fault



Filling
Discontinuity set
Discontinuity set
Wall strength
Block size
Roughness
Persistence
Spacing
BOREHOLE OR SCANLINE
N
Aperture
Dip and
dip direction
Seepage

DESCRIPTION OF DISCONTINUITIES

GEOMETRY

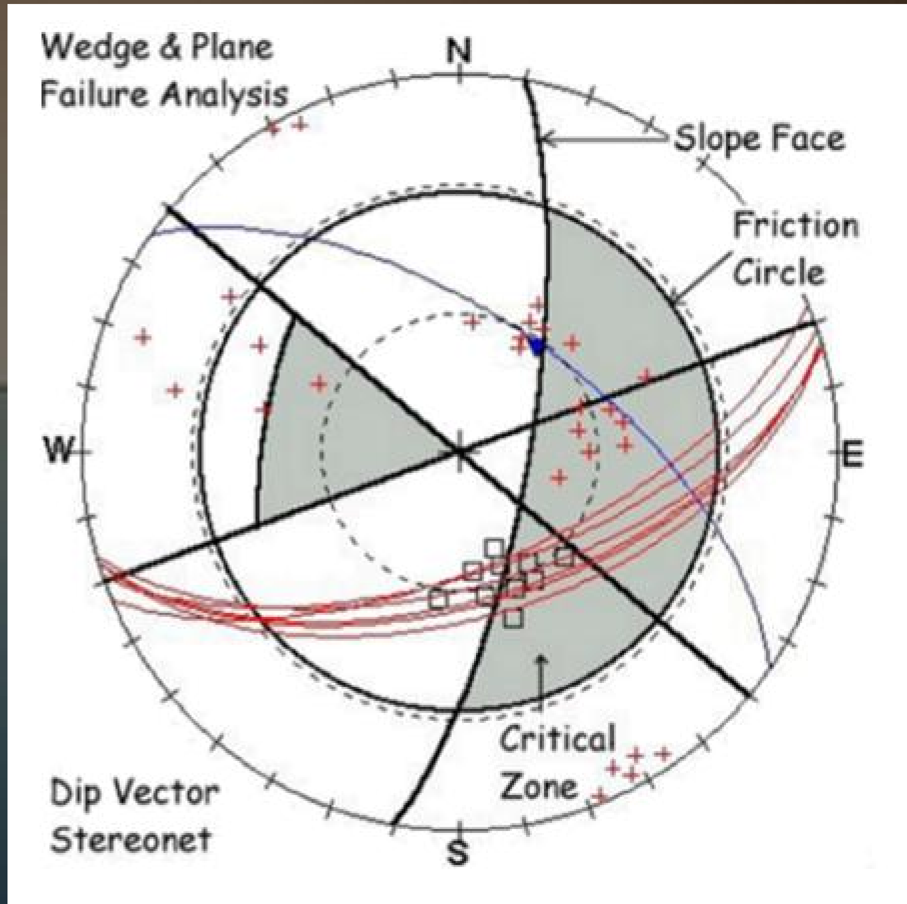
1. Orientation
2. Spacing
3. Persistence

SHEAR STRENGTH

4. Roughness
5. Aperture
6. Filling
7. Seepage (water)

1. ORIENTATION

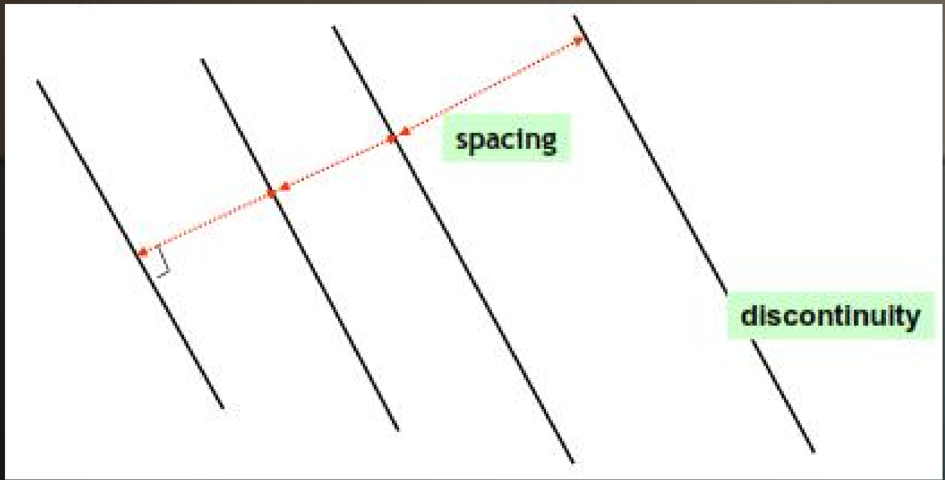
- Using compass
- Dip and dip direction of the plane
- Plot using Kinematic stereonet analyses for rock slope stability - ‘ROCKPACK III’
- – Enable the number of joint sets
- – Mean orientation



DIP AND DIP DIRECTION

2.SPACING
(how far apart the discontinuities are)

- The perpendicular distance between adjacent discontinuities

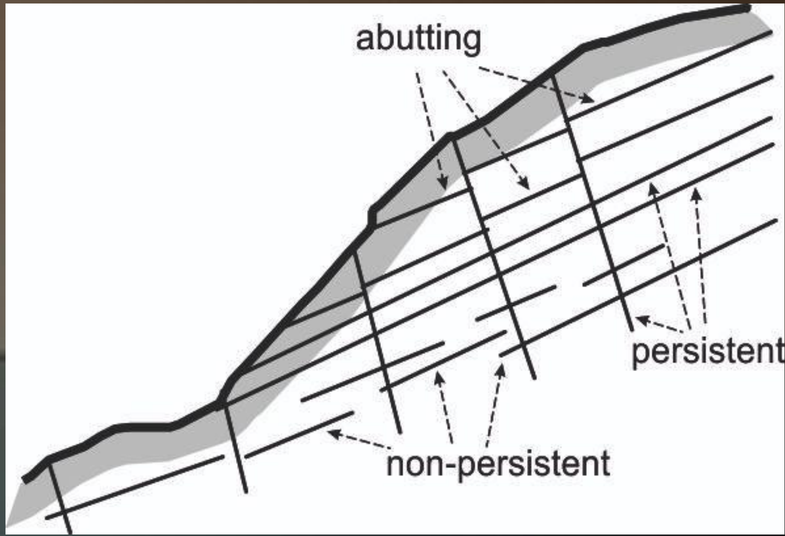


Description	Spacing
Extremely narrow spacing	< 2 cm
Very close spacing	2-6 cm
Narrow spacing	6-20 cm
Moderate spacing	20-60 cm
Wide spacing	60-200 cm
Very wide spacing	200-600 cm
Extremely large spacing	> 600 cm

ISRM classification according to the spacing

3. PERSISTENCE (how continuous are they)

- A measure of the areal extent of a discontinuity
  - Inception to termination in solid rock or against another discontinuity
- Major joints;
  - the plane may extend beyond the limits of the exposure
  - Measure the maximum trace length

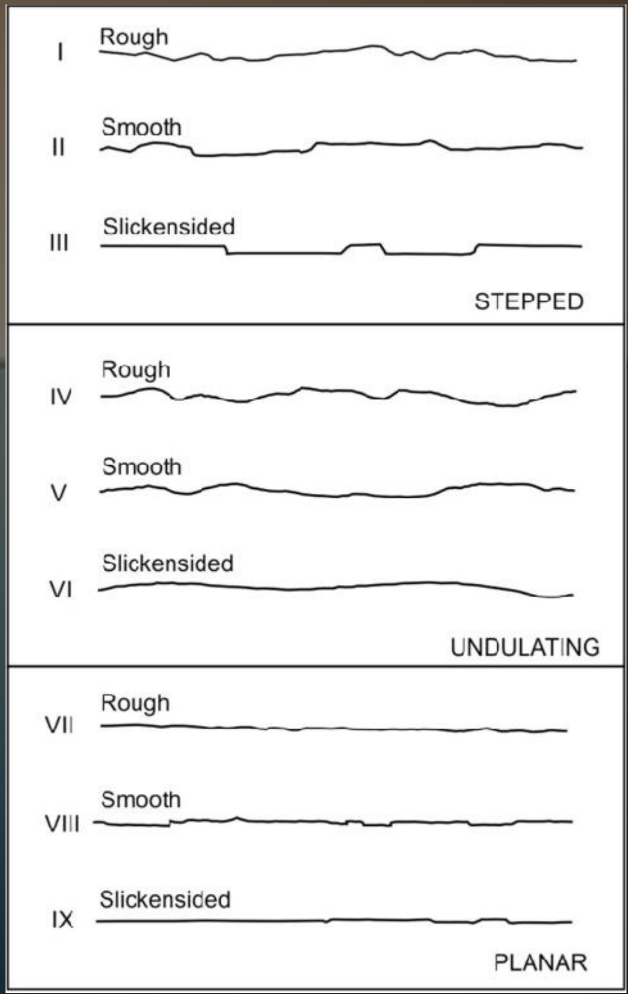


Description	Persistence
Very low persistence	<1 m
Low persistence	1-3 m
Average persistence	3-10 m
High persistence	10-20 m
Very high persistence	>20 m

ISRM classification according to the persistence

4. ROUGHNESS (rough to smooth)

- Discontinuity surface
  - Stepped
  - Undulating
  - Planar
- Based on two scales:-
  - Small scale: several centimeters
  - Large scale: several meters
- The roughness gives indications for the <u>**evaluation of the shear strength**</u> of not filled discontinuities



Strength Decreases

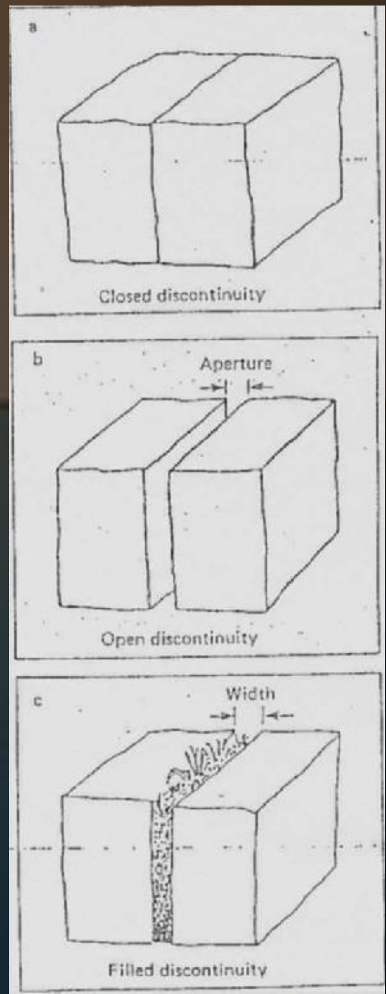
Typical ISRM surface roughness profiles.

5.APERTURE
(is the discontinuity open or closed)

- The mean perpendicular distance between adjacent walls of a discontinuity.
- Space between walls that is filled with air or water

Aperture	Description	Discontinuity
<0.1 mm	Very narrow	Closed
0.1-0.25 mm	Narrow	
0.25-2.5 mm	Partly opened	
0.5-2.5 mm	Opened	Semi-open
2.5-10 mm	Moderately large	
>10 mm	Large	
1-10 cm	Very large	Open
10-100 cm	Extremely large	
> 1 m	Cavernous	

ISRM classification according to aperture



6.FILLING

(is the discontinuity empty or filled and with what?)

- The infilling between discontinuity
- surfaces
- • The infilling may be:
  - Soil introduced into the opening
  - Minerals such as calcite
  - Faults clay gouge (deep hole)
  - Breccia
- • Must be identified and described
- • The strength of the infill must be assessed
- visually and manually.

7.SEEPAGE (water)

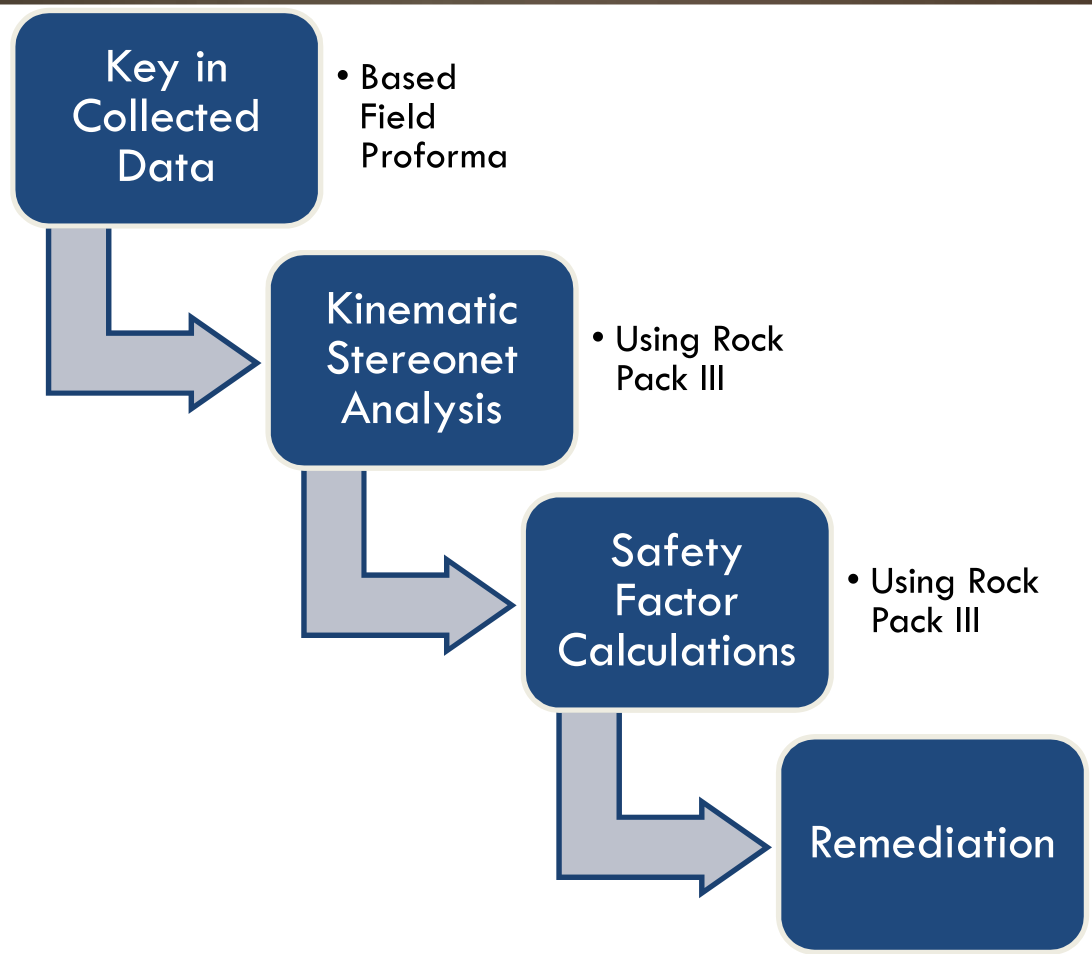
- Water flow
- Free moisture
- Describe and rate of flow
  - estimated (liter/hr)

ROCK MASS RATING (RMR)

- **SIX parameters** are required:
  1. Uniaxial Compressive Strength (J_{A1})
  2. Rock Quality Design, RQD(J_{A2})
  3. Discontinuity spacing(J_{A3})
  4. Conditions of the discontinuities(J_{A4})
  5. Groundwater (flow and general condition)(J_{A5})
  6. Rating adjustment for discontinuity orientations(J_B)
- Based on ratings (total of 6 ratings)
- Total ratings (0-100) will give rock mass classes (I to V).
- Higher rating – better rock
  - **RMR = JA1 + JA2 + JA3 + JA4 + JA5 + JB**

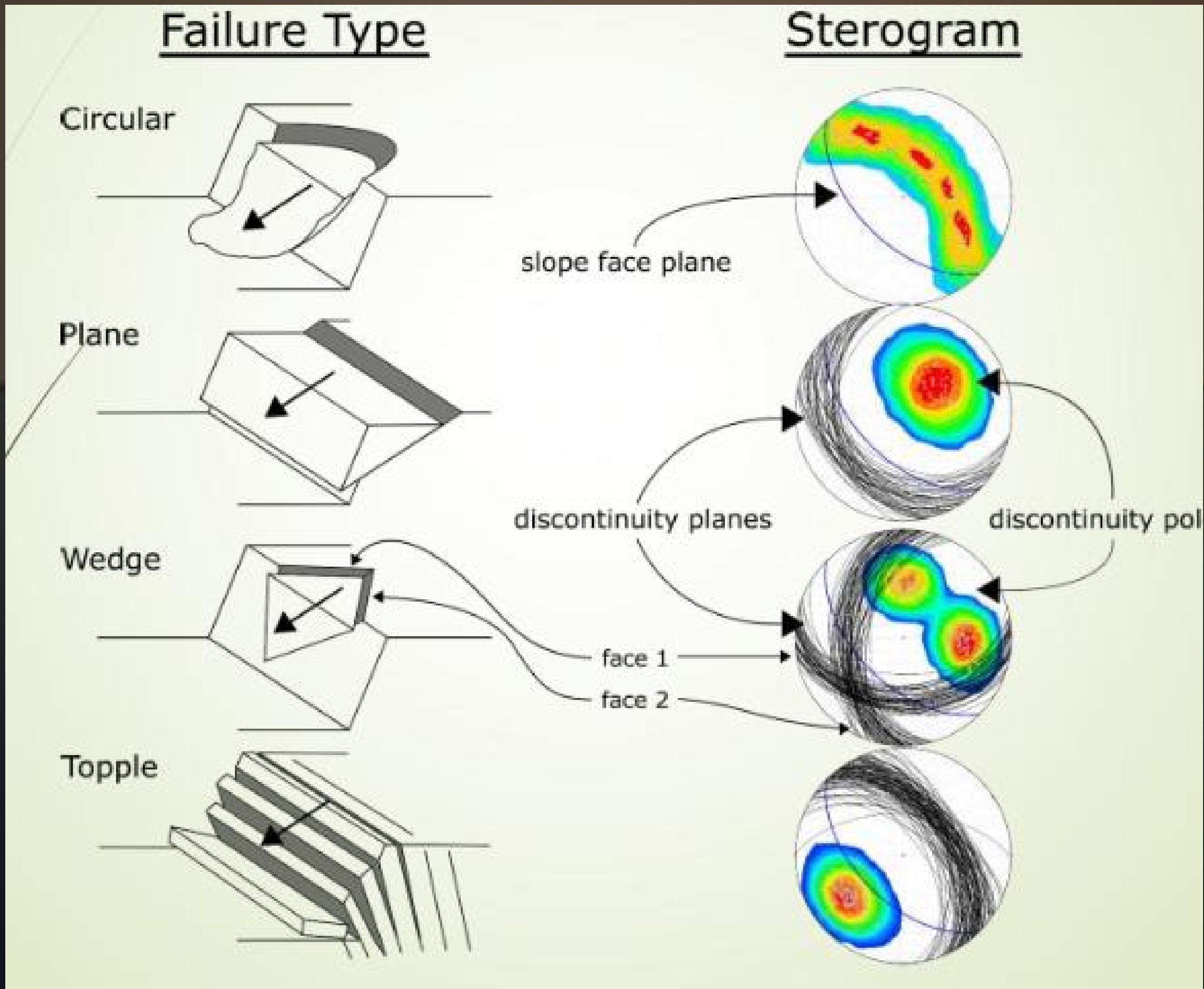
ROCK SLOPE STABILITY ANALYSIS

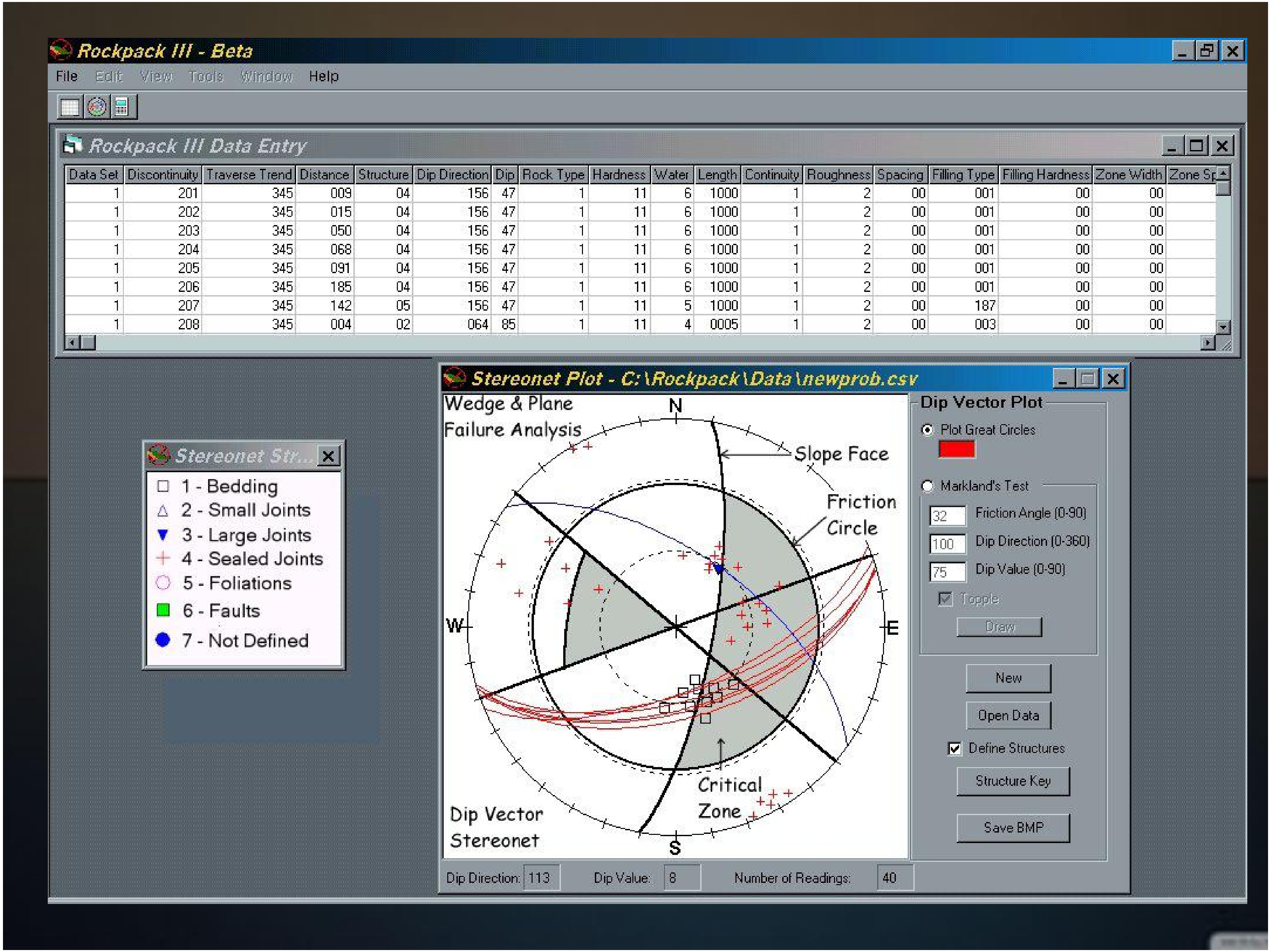
FLOW CHART OF ROCK SLOPE STABILITY ANALYSIS



A.KINEMATIC STEREONET ANALYSIS

STEREONET BASED KINEMATIC ANALYSIS




Rockpack III - Beta
File Edit View Tools Window Help
Rockpack III Data Entry

Data Set	Discontinuity	Traverse Trend	Distance	Structure	Dip Direction	Dip	Rock Type	Hardness	Water	Length	Continuity	Roughness	Spacing	Filling Type	Filling Hardness	Zone Width	Zone Sp
1	201	345	009	04	156	47	1	11	6	1000	1	2	00	001	00	00	
1	202	345	015	04	156	47	1	11	6	1000	1	2	00	001	00	00	
1	203	345	050	04	156	47	1	11	6	1000	1	2	00	001	00	00	
1	204	345	068	04	156	47	1	11	6	1000	1	2	00	001	00	00	
1	205	345	091	04	156	47	1	11	6	1000	1	2	00	001	00	00	
1	206	345	185	04	156	47	1	11	6	1000	1	2	00	001	00	00	
1	207	345	142	05	156	47	1	11	5	1000	1	2	00	187	00	00	
1	208	345	004	02	064	85	1	11	4	0005	1	2	00	003	00	00	

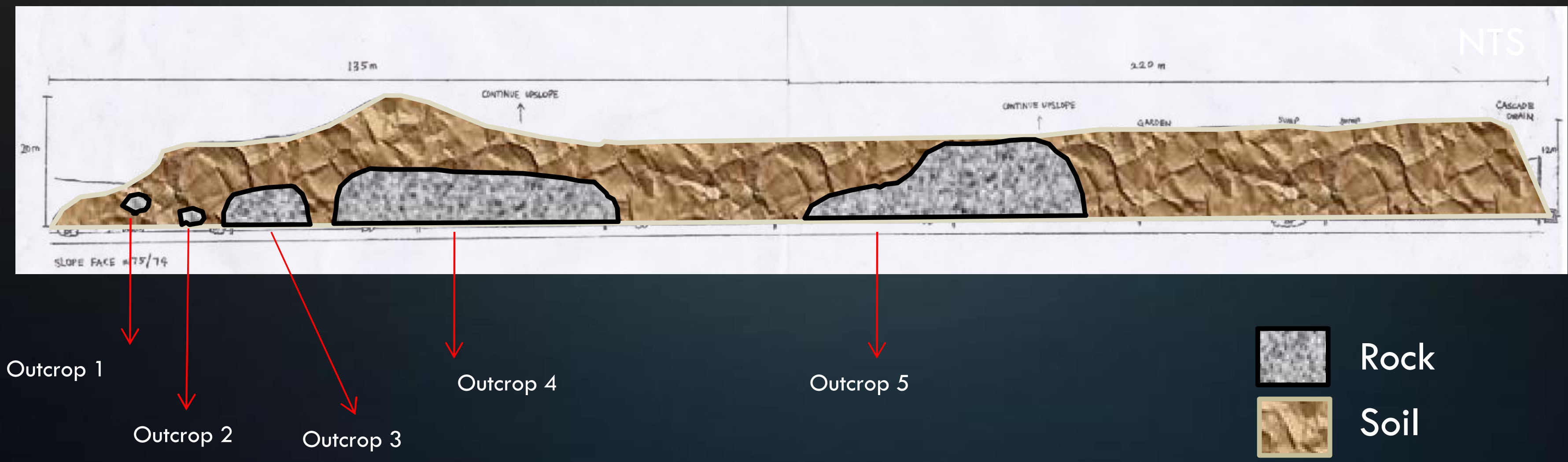
Stereonet Str...
1 - Bedding
2 - Small Joints
3 - Large Joints
4 - Sealed Joints
5 - Foliations
6 - Faults
7 - Not Defined
Stereonet Plot - C:\Rockpack\Data\newprob.csv
Wedge & Plane
Failure Analysis
N
W
E
S
Slope Face
Friction
Circle
Critical
Zone
Dip Vector
Stereonet
Dip Vector Plot
Plot Great Circles
Markland's Test
32 Friction Angle (0-90)
100 Dip Direction (0-360)
75 Dip Value (0-90)
Topple
Draw
New
Open Data
Define Structures
Structure Key
Save BMP
Dip Direction: 113
Dip Value: 8
Number of Readings: 40

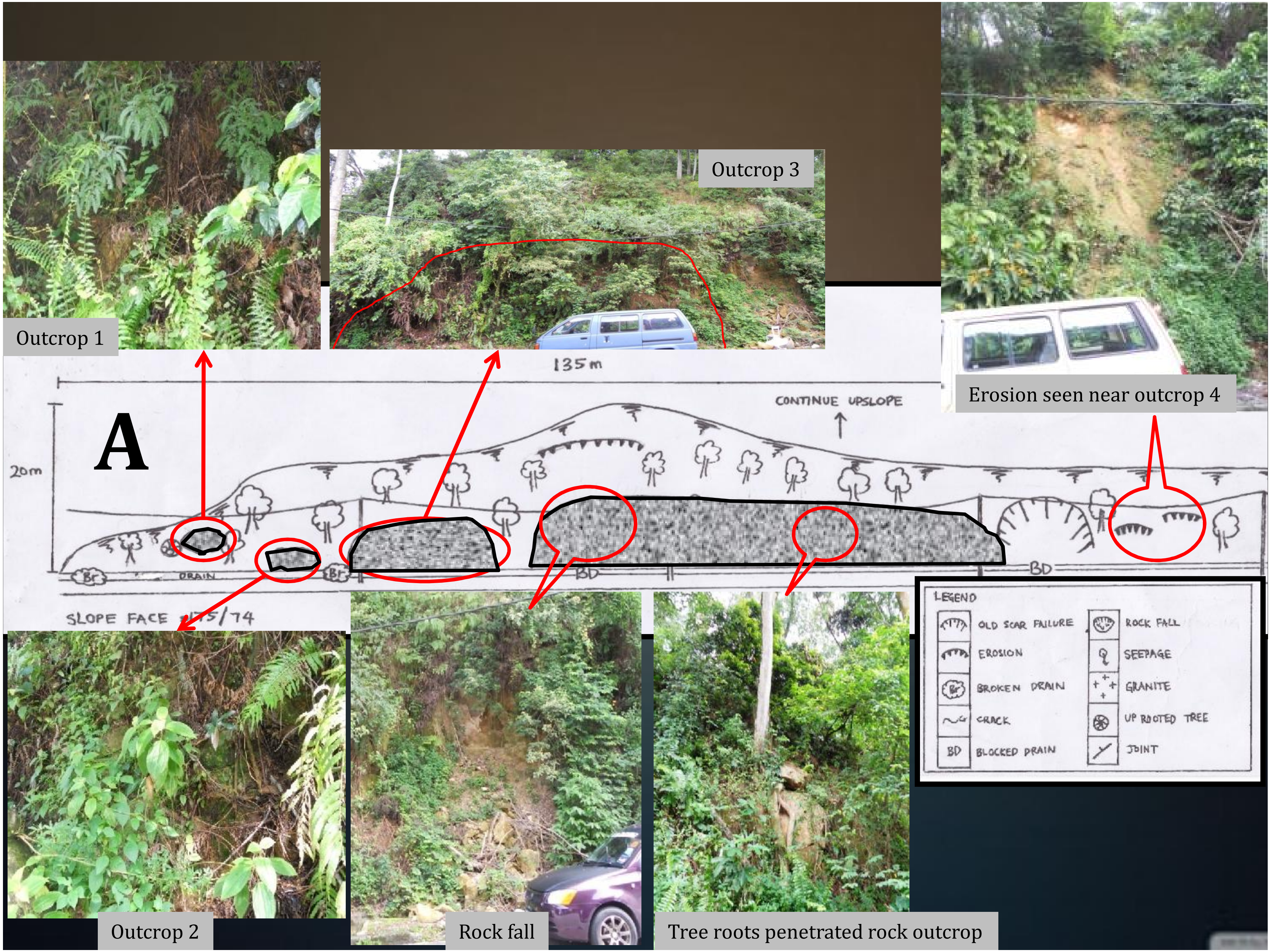
CASE STUDY BUKIT ANGGERIK

1. Site Sketch
2. Geomorphological Map
3. Stereonet Analysis

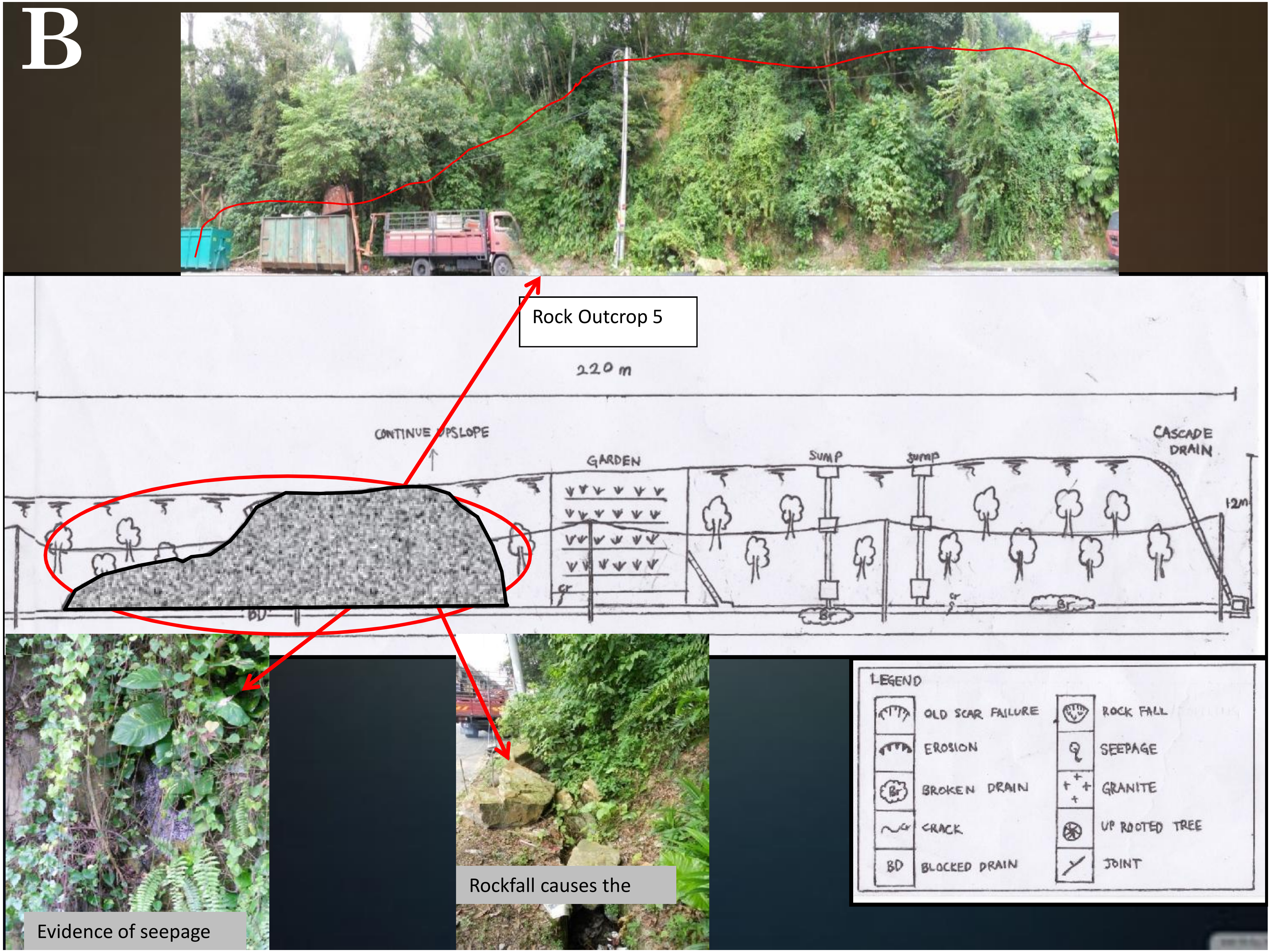
Site Sketch

Rock and Soil Boundary

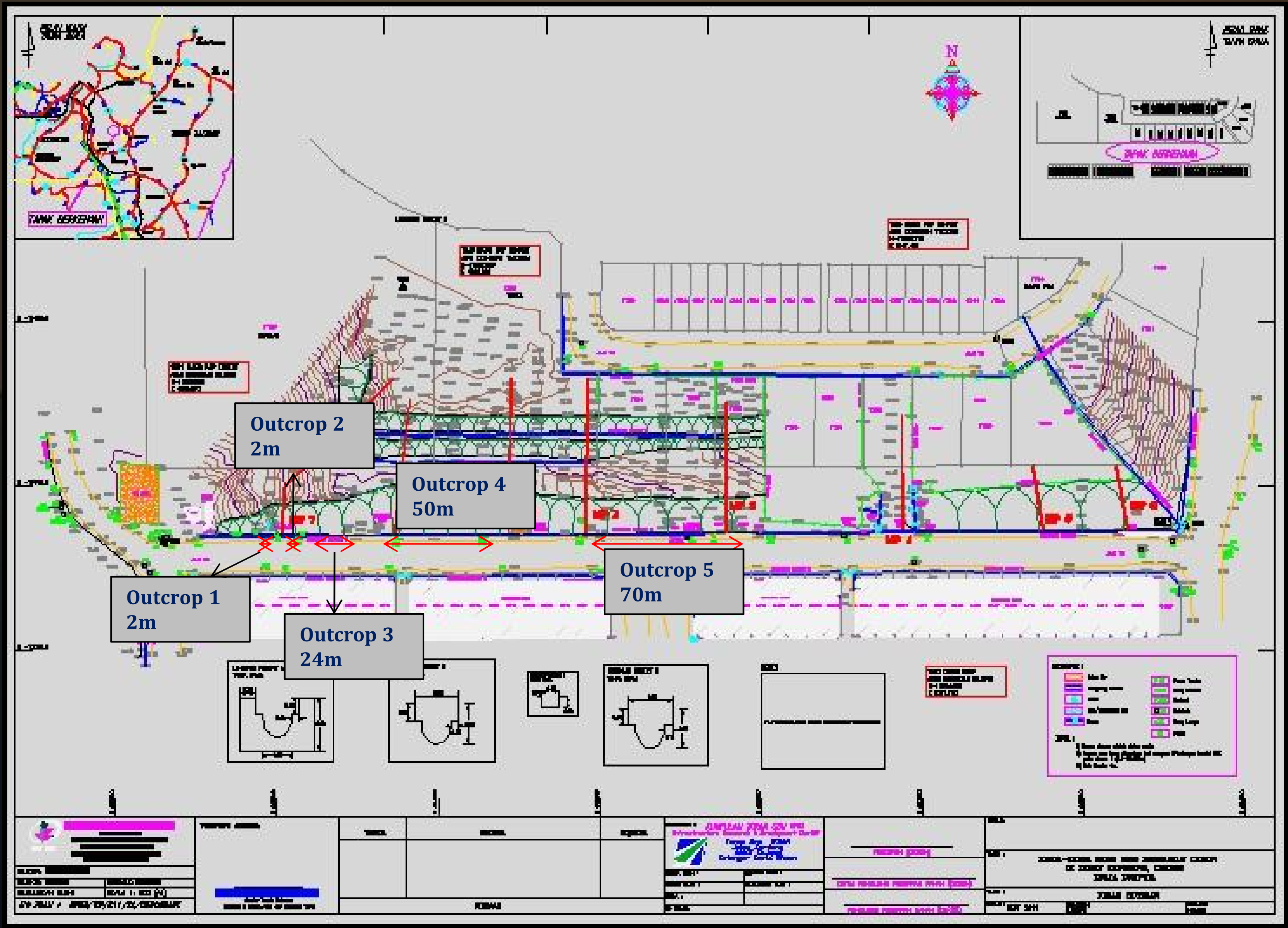




Outcrop 1
Outcrop 3
Erosion seen near outcrop 4
135m
20m
A
CONTINUE UPSLOPE
DRAIN
Br
BD
SLOPE FACE
LEGEND
OLD SCAR FAILURE
EROSION
BROKEN DRAIN
CRACK
BLOCKED DRAIN
ROCK FALL
SEEPAGE
GRANITE
UP ROOTED TREE
JOINT
Outcrop 2
Rock fall
Tree roots penetrated rock outcrop


B
Rock Outcrop 5
220 m
CONTINUE UPSLOPE
GARDEN
SUMP
sump
CASCADE DRAIN
12m
BD
Br
Cr
LEGEND
OLD SCAR FAILURE
ROCK FALL
EROSION
SEEPAGE
BROKEN DRAIN
GRANITE
CRACK
UP ROOTED TREE
BD
BLOCKED DRAIN
JOINT
Evidence of seepage
Rockfall causes the

LAYOUT FOR STEREONET ANALYSIS

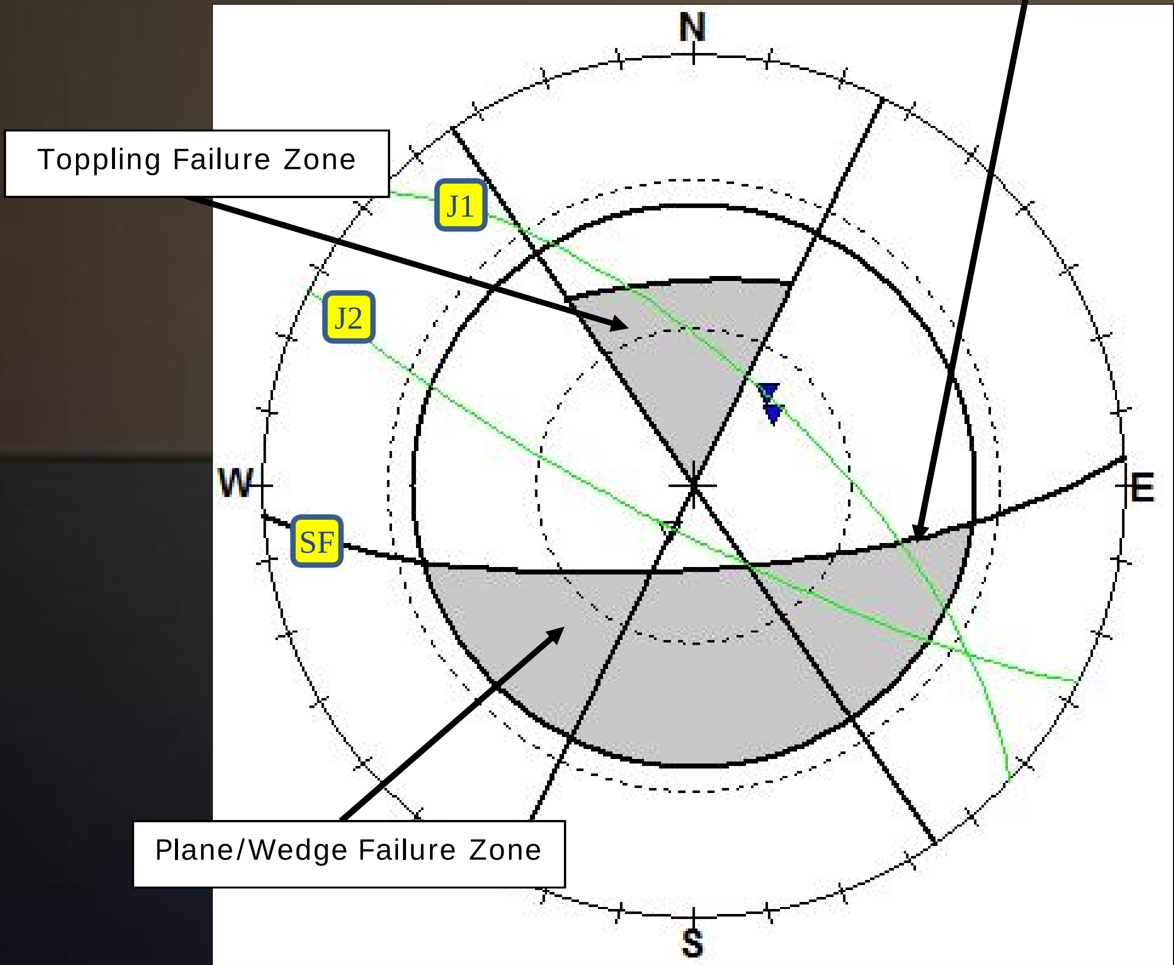


EXPOSED ROCK OUTCROP AT THE FAILURE AREA

Potential Rock Failure Seen on Site

STEREONET PLOT FOR OUTROP 1 (LENGTH: 2M)

Orientation of Slope Face: 56/176



Set of joints:
(J1) 68/043
(J2) 81/207

INTERPRETATION:

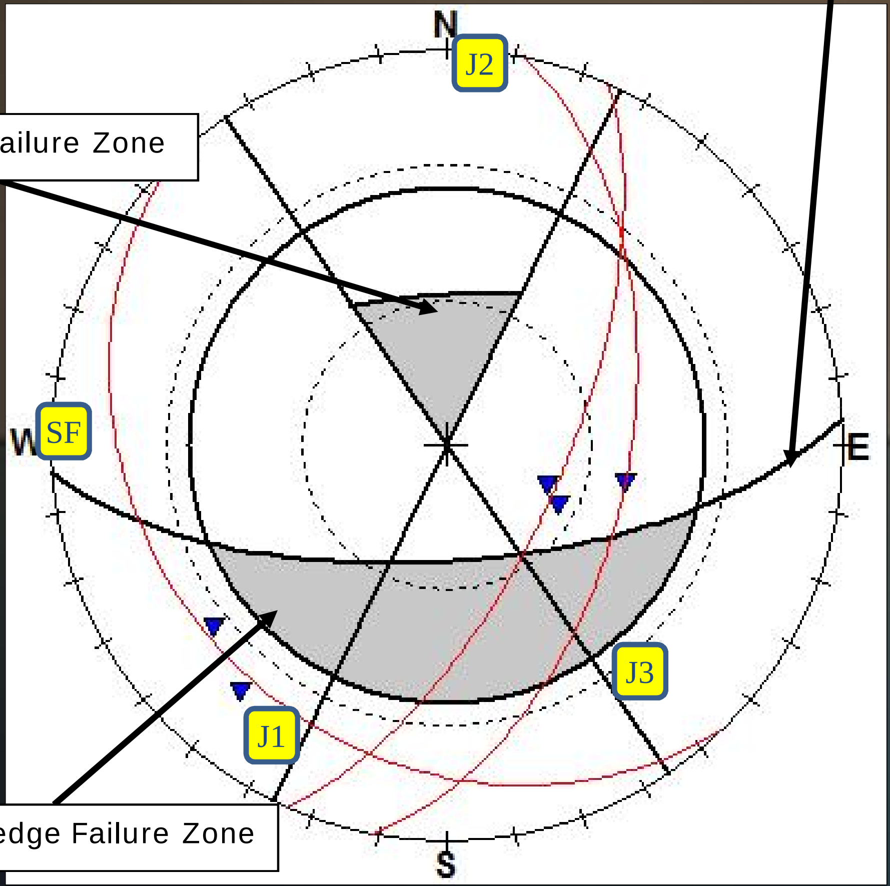
NO POTENTIAL FAILURE

LEGEND:

Joint/shear plane

STEREONET PLOT FOR OUTROP 2 (LENGTH: 2M)

Orientation of Slope Face: 66/176



Toppling Failure Zone

Plane/Wedge Failure Zone

Set of joints:
(J1) 66/114
(J2) 52/101
(J3) 24/226

INTERPRETATION:

NO POTENTIAL FAILURE

LEGEND:

Joint/shear plane

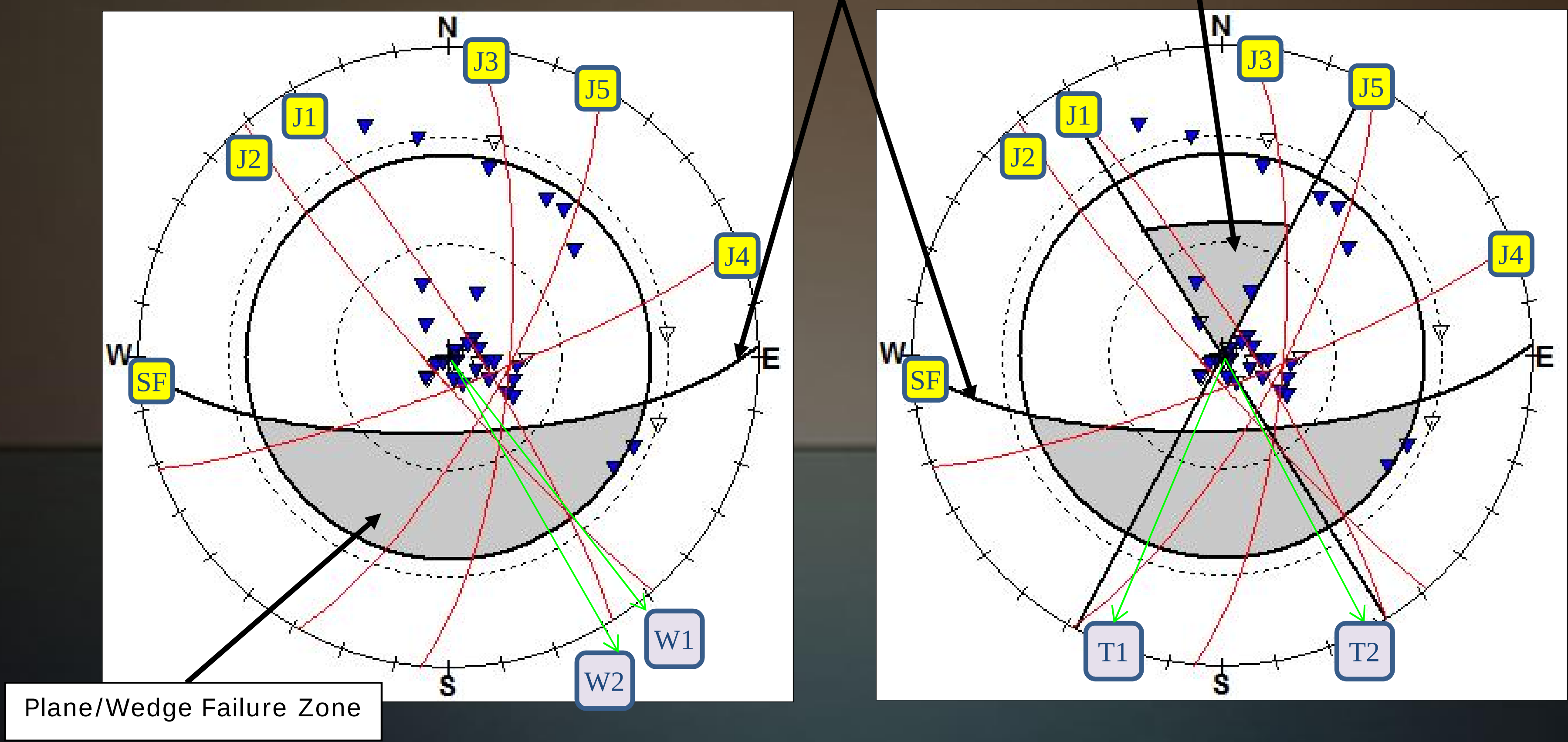
Picture Of Outcrop 3

STEREONET PLOT FOR OUTROP 3

(LENGTH: 24M)

Orientation of Slope Face:
70/178

Toppling Failure Zone



INTERPRETATION:

1. POTENTIAL WEDGE FAILURES
   I. W1: INTERSECT BETWEEN J1 & J2
   II. W2: INTERSECT BETWEEN J2 & J3
2. POTENTIAL TOPPLE FAILURES

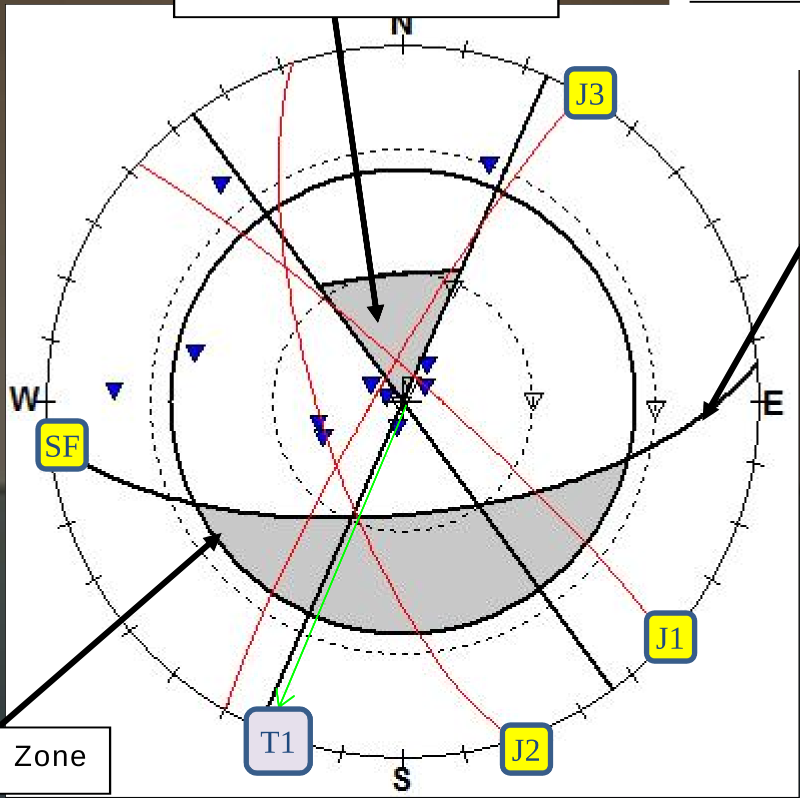
Set of joints:
(J1) 83/058
(J2) 85/229
(J3) 74/095
(J4) 82/159
(J5) 75/119

LEGEND:

Joint/shear plane

STEREONET PLOT FOR OUTROP 4 (LENGTH: 50M)

INTERVAL: 20 – 50M



Orientation of Slope Face: 64/174

Set of joints:
(J1) – 84/042
(J2) – 71/252
(J3) – 84/300

LEGEND:

Joint/shear plane

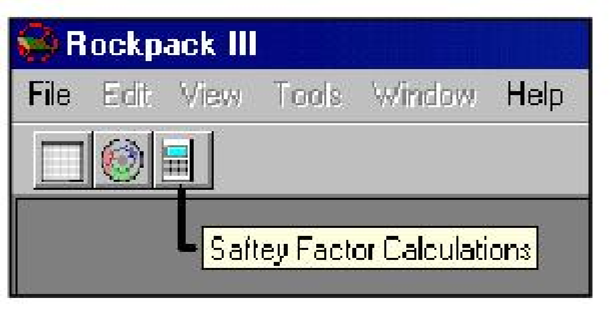
INTERPRETATION:

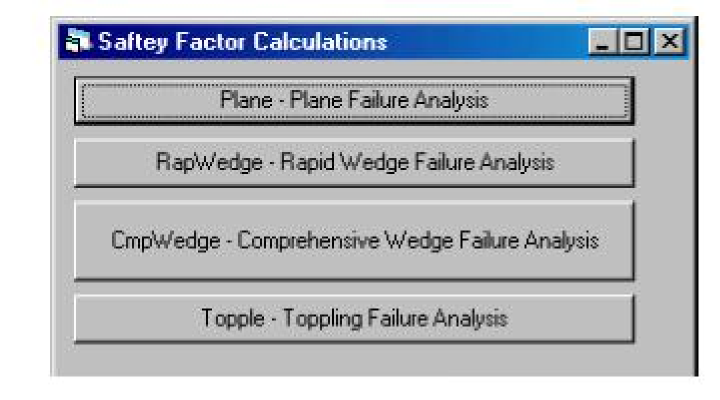
1. NO POTENTIAL WEDGE FAILURE
2. POTENTIAL TOPPLE FAILURE

B.SAFETY FACTOR ANALYSIS

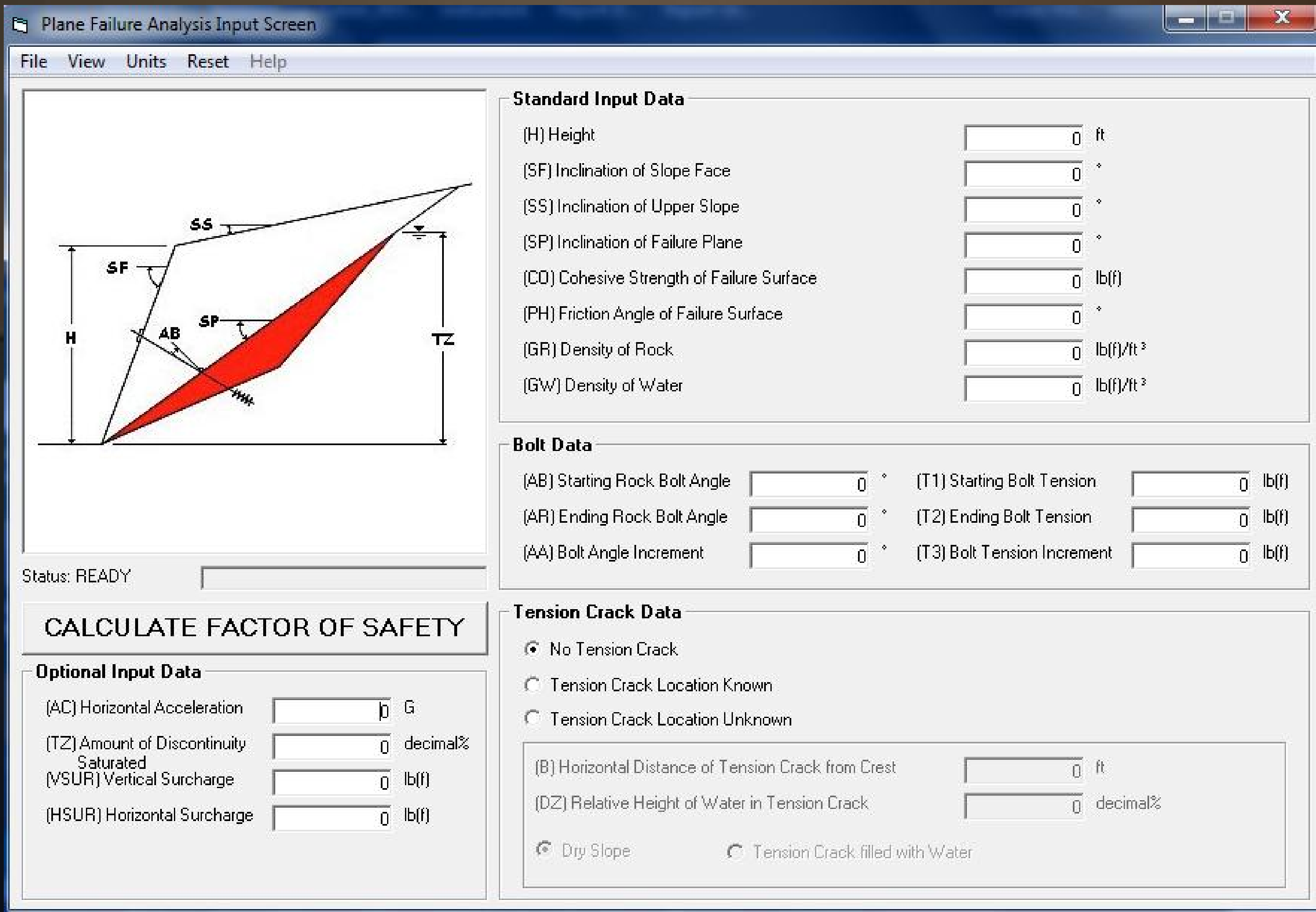
OVERVIEW of SAFETY FACTOR CALCULATION PROGRAMS
(*PLANE, RAPWEDGE, CMPWEDGE and TOPPLE*)

Starting the safety factor programs

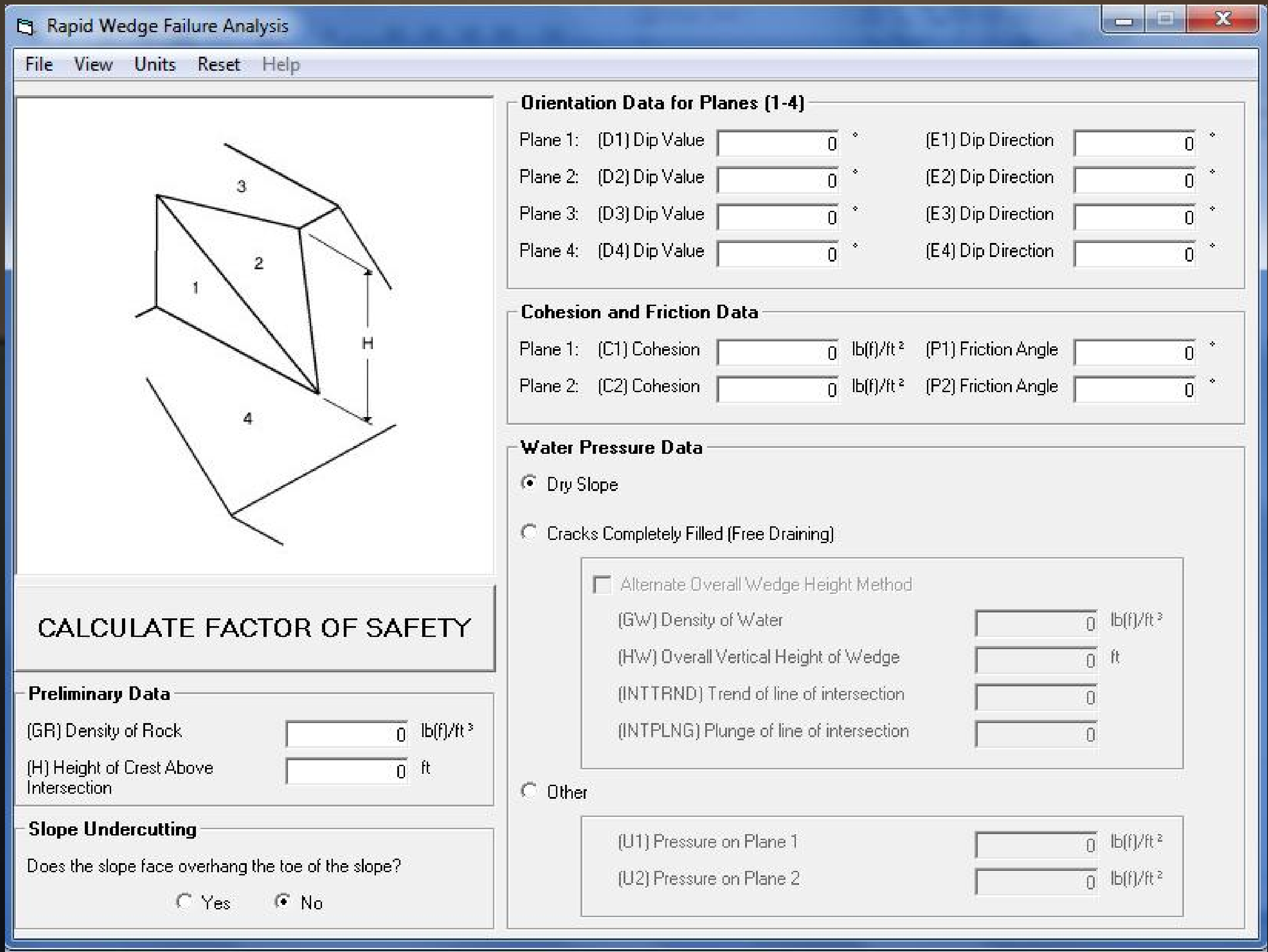




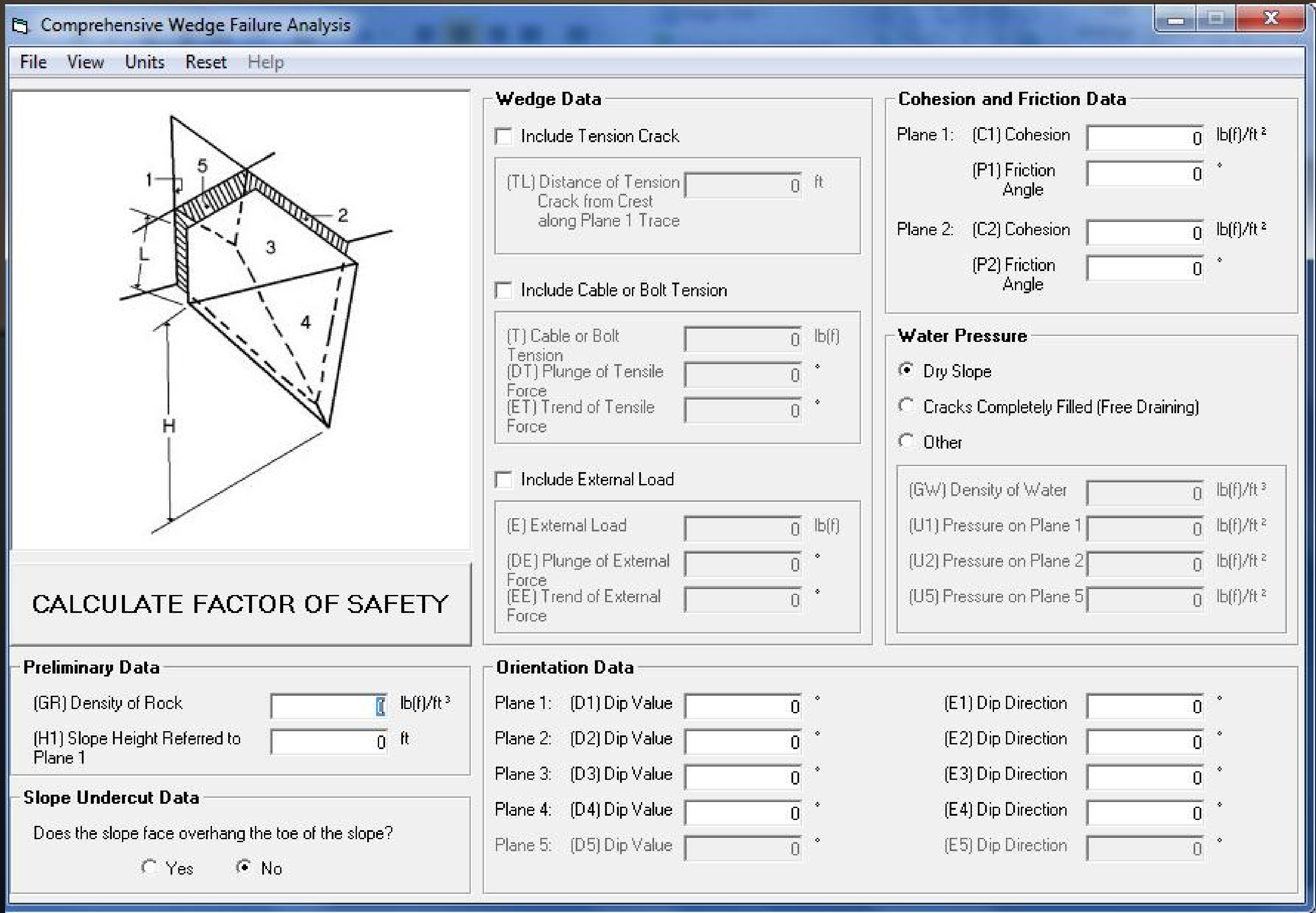
Plane Failure Analysis Input Screen



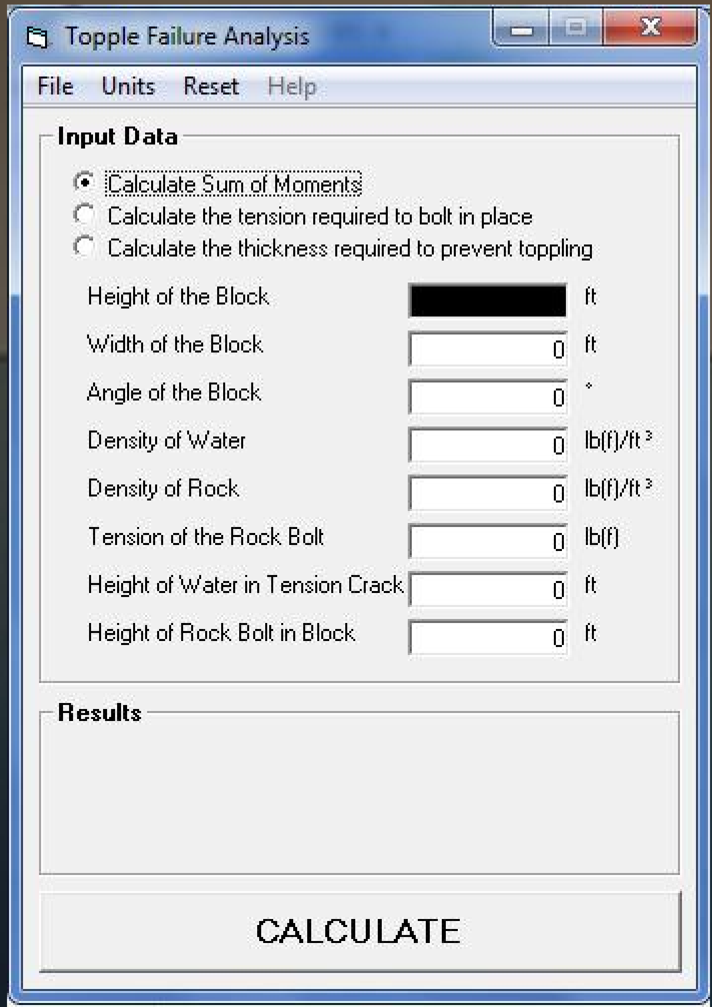
Rapid Wedge Failure Analysis Input Screen



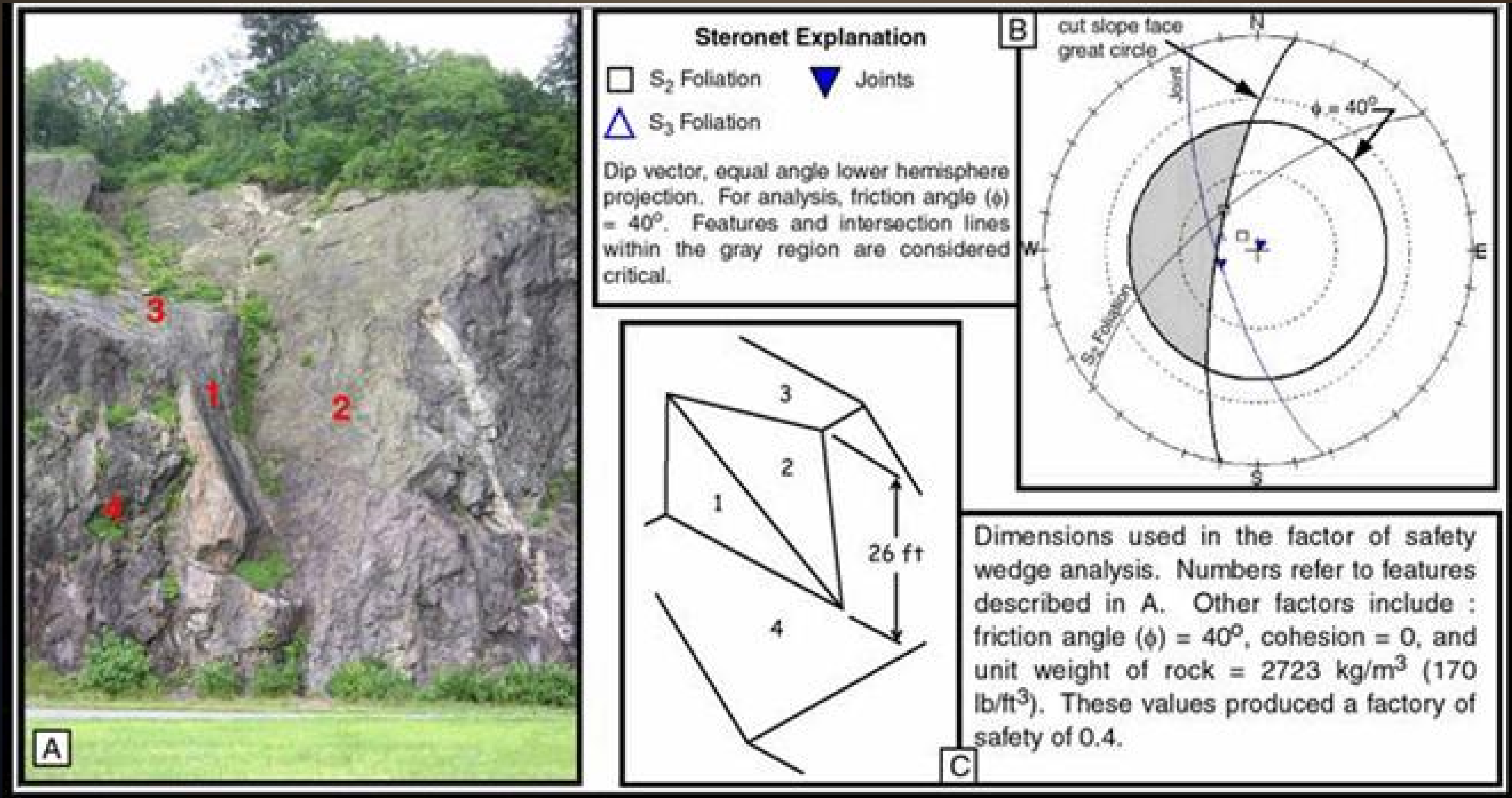
Comprehensive Wedge Failure Analysis Input Screen



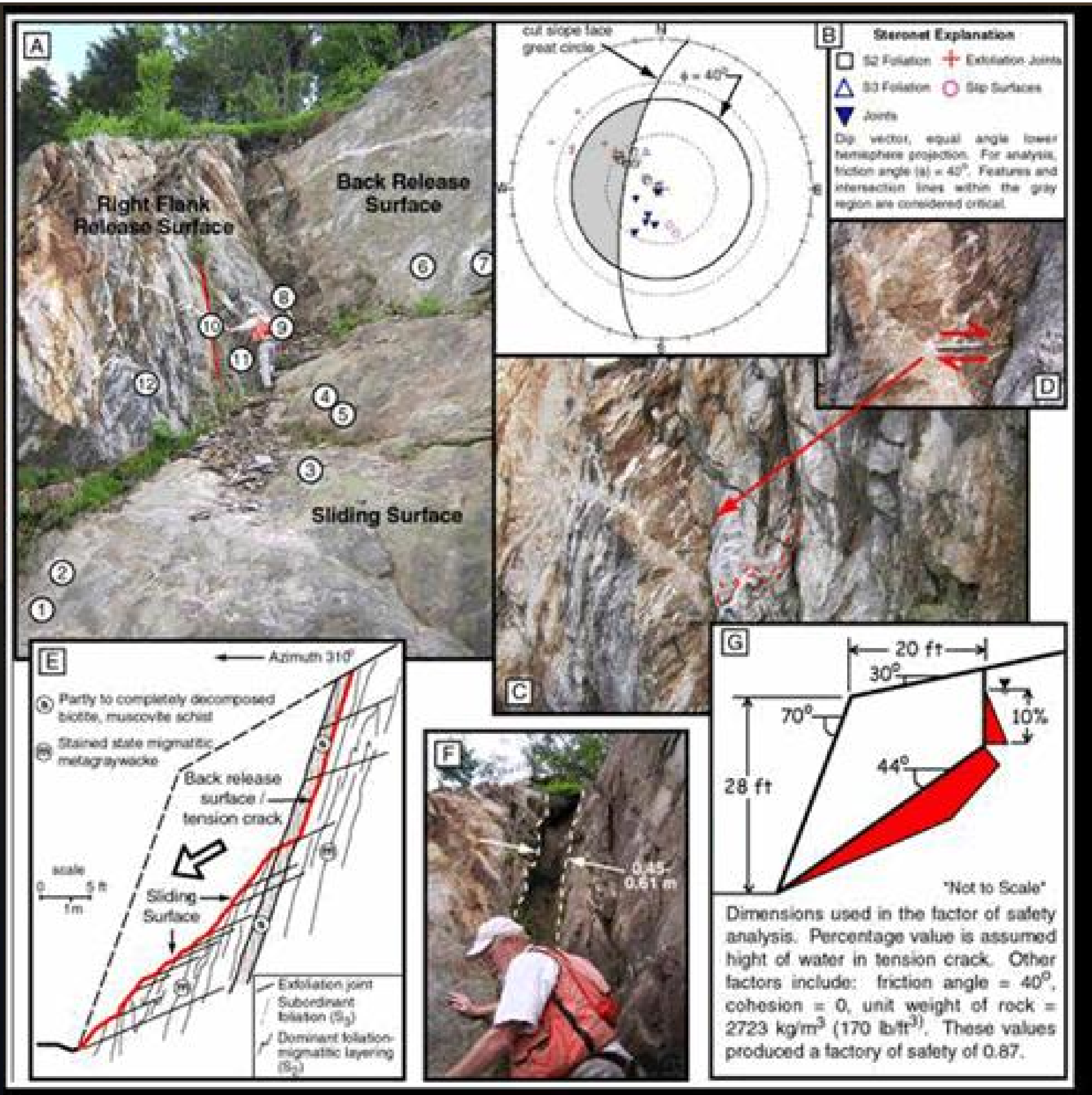
Toppling Failure Analysis Input Screen



EXAMPLE OF WEDGE FAILURE ANALYSIS

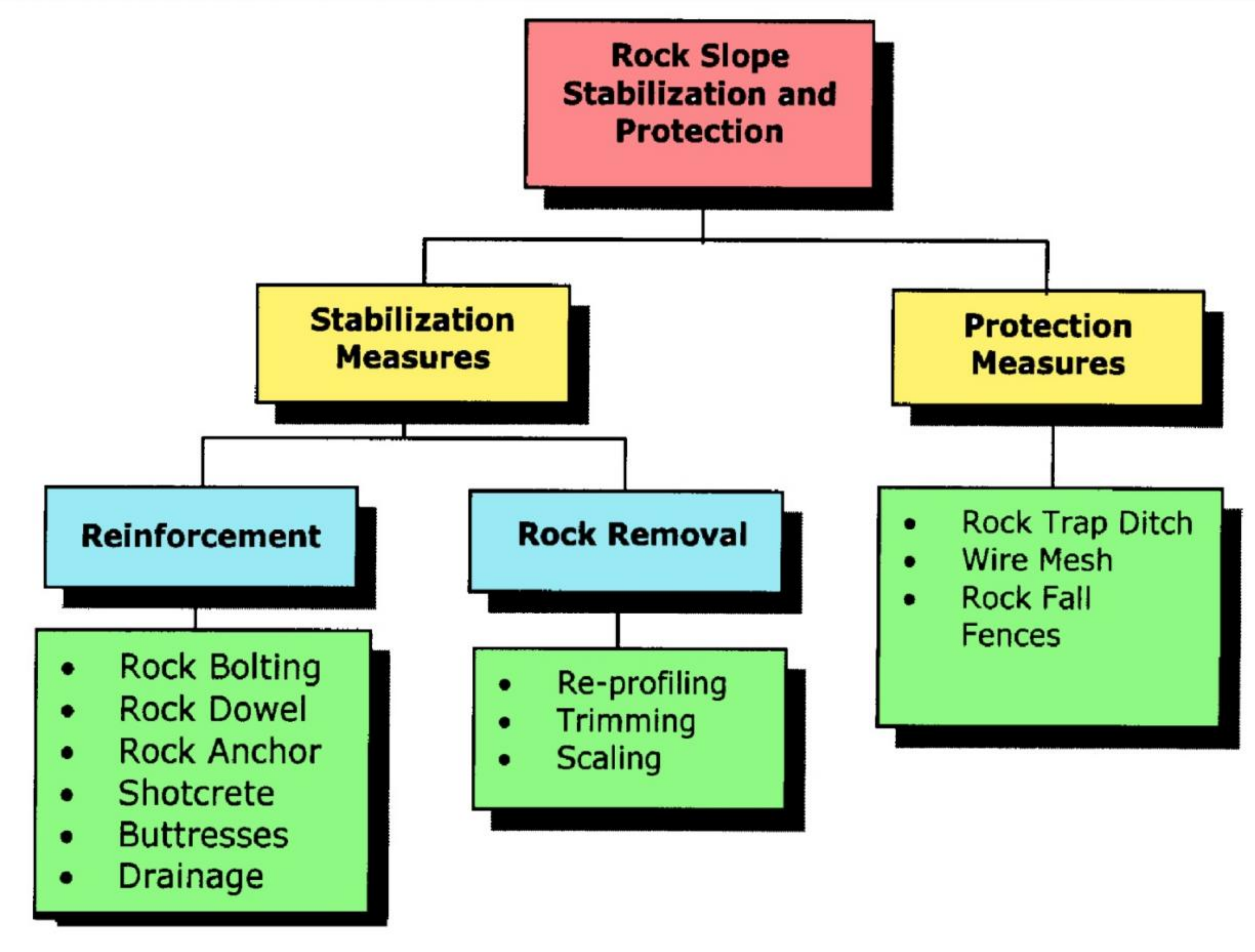


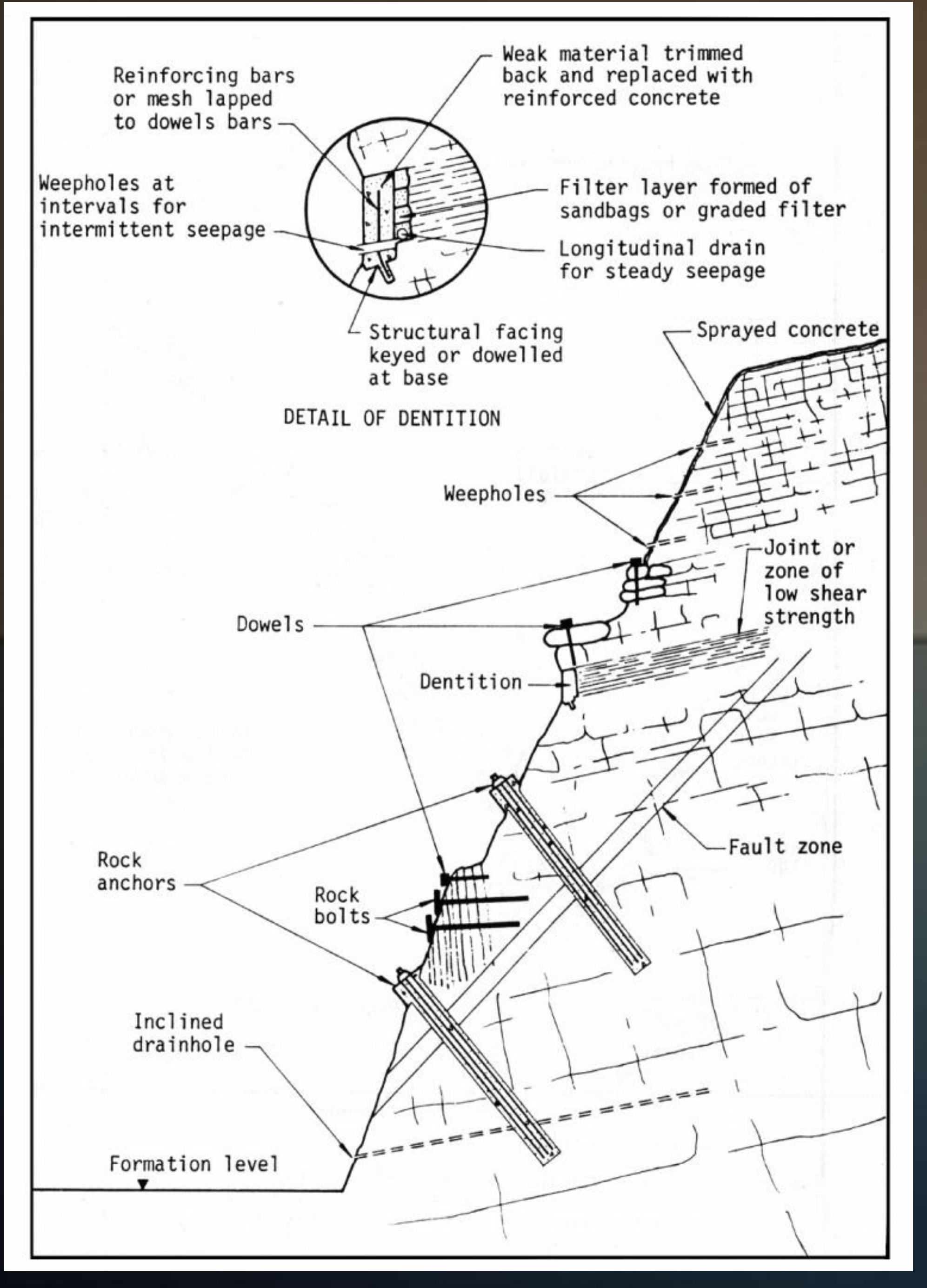
Example of Plane Failure Analysis



4.0 ROCK SLOPE STABILIZATION AND PROTECTION

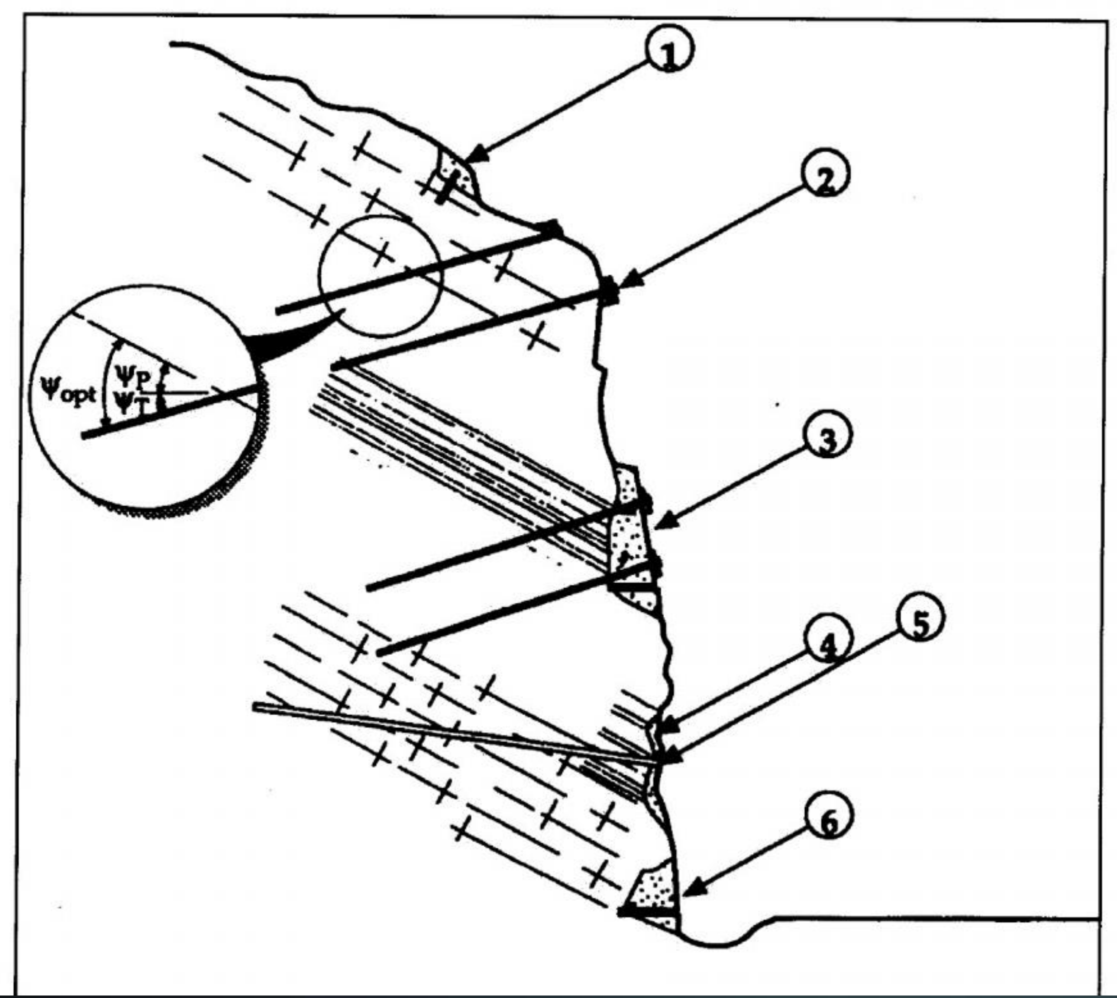
ROCK SLOPE STABILIZATION & PROTECTION MEASURES





VARIOUS METHODS OF STABILISING ROCK SLOPES

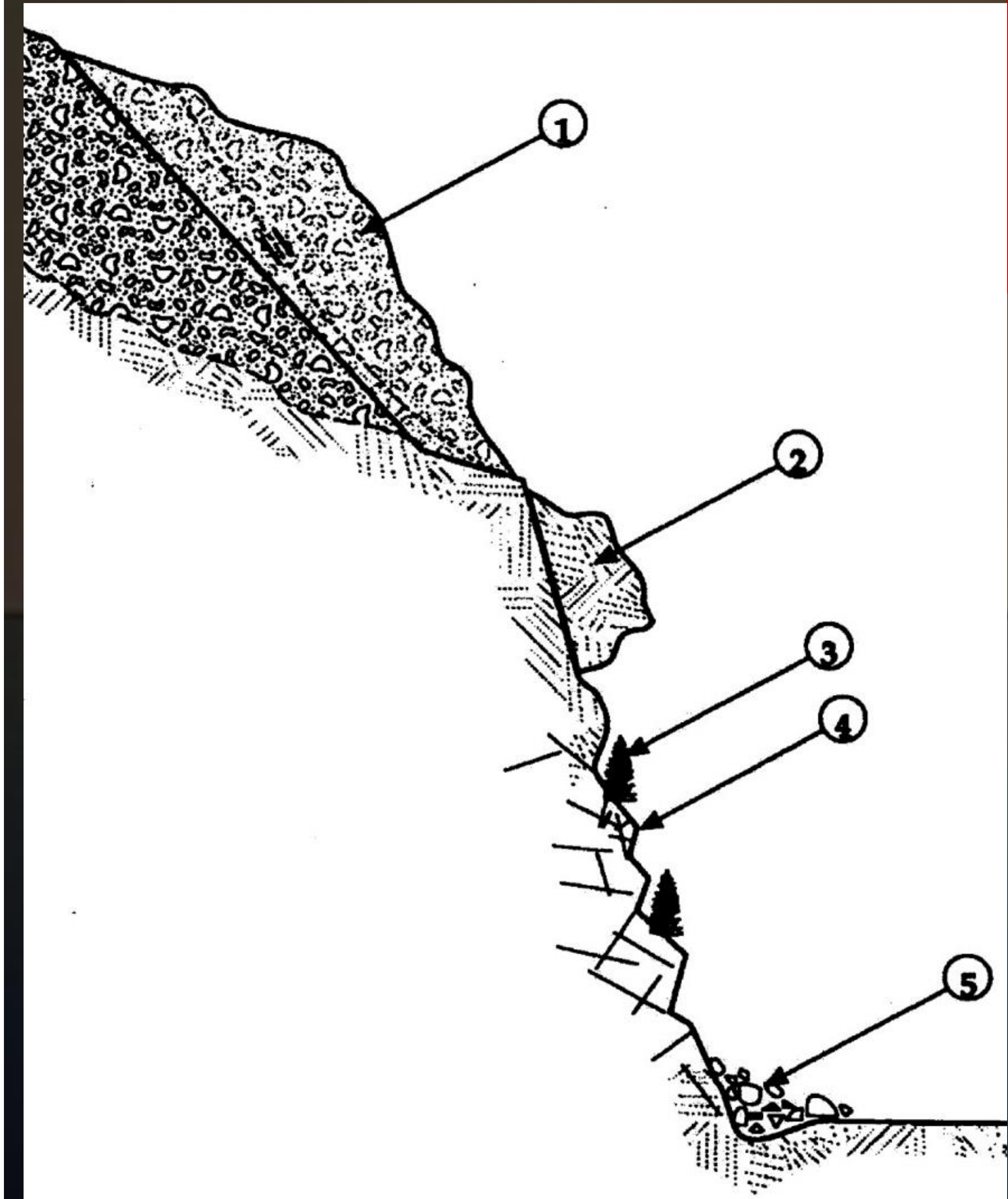
- Sprayed Concrete/Shotcrete
- Dowels
- Rock Bolts
- Rock Anchors / Ground Anchors
- Inclined Drainholes / Horizontal Drains
- Dentition



1. Reinforced concrete dowel to prevent loosening of slab at crest.
2. Tensioned rock anchors to secure sliding failure along crest.
3. Tieback wall to prevent sliding failure on fault zone.
4. Shotcrete to prevent ravelling of zone of fractured rock.
5. Drain hole to reduce water pressure within slope.
6. Concrete butress to support rock above cavity.

REINFORCEMENT METHODS OF STABILISING ROCK SLOPES

(After Keith et al., 1996)

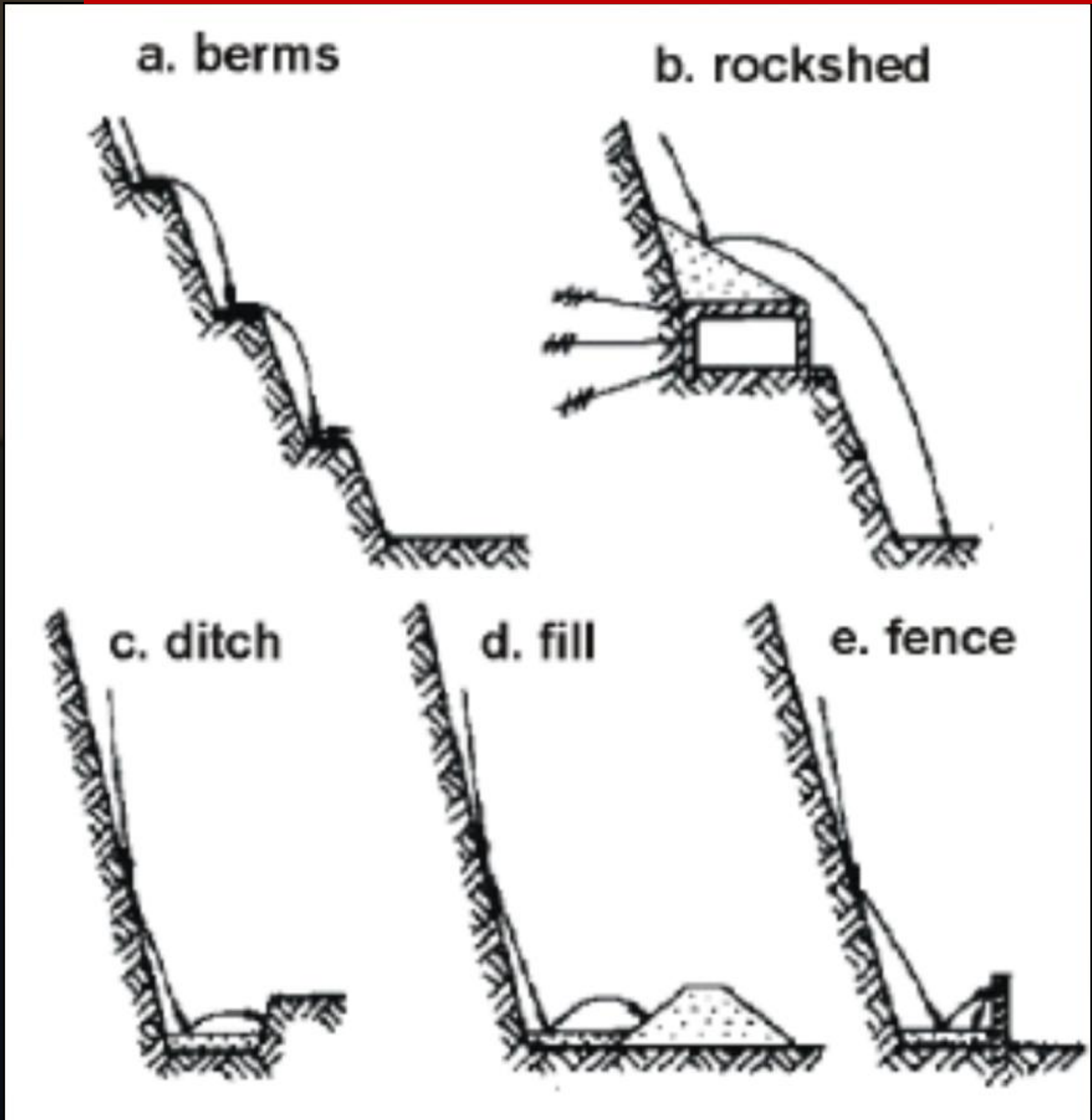


REMOVAL METHODS OF ROCK SLOPES

1. Reprofiling/resloping of unstable weathered material in upper part of slope
2. Removal of rock overhang by trim blasting.
3. Removal of trees with roots growing in cracks
4. Hand scaling of loose blocks in shattered rock
5. Clean ditch or Rock Trap Ditch

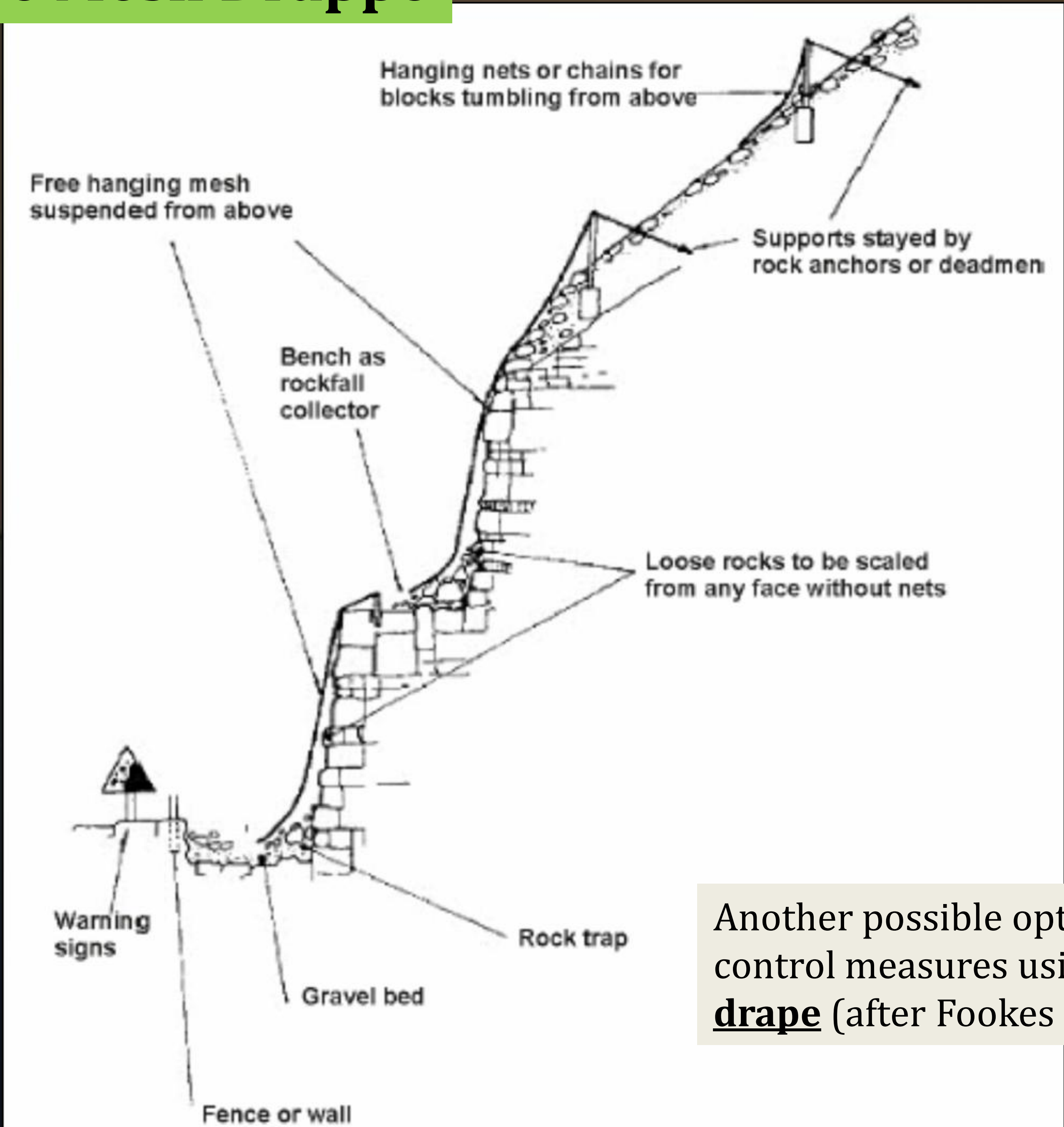
(After Keith et al., 1996)

ROCK SLOPE PROTECTION METHODS



Possible measures to restrain and to reduce damage due to rockfalls (after Spang, 1987)

Wire Mesh Drappe



Another possible option of rockfall control measures using **wire mesh drape** (after Fookes & Sweeney,1976)

ROCK SLOPE STABILISATION (REINFORCEMENT)

- Some common practices in Malaysia -

Wire Mesh Drapery

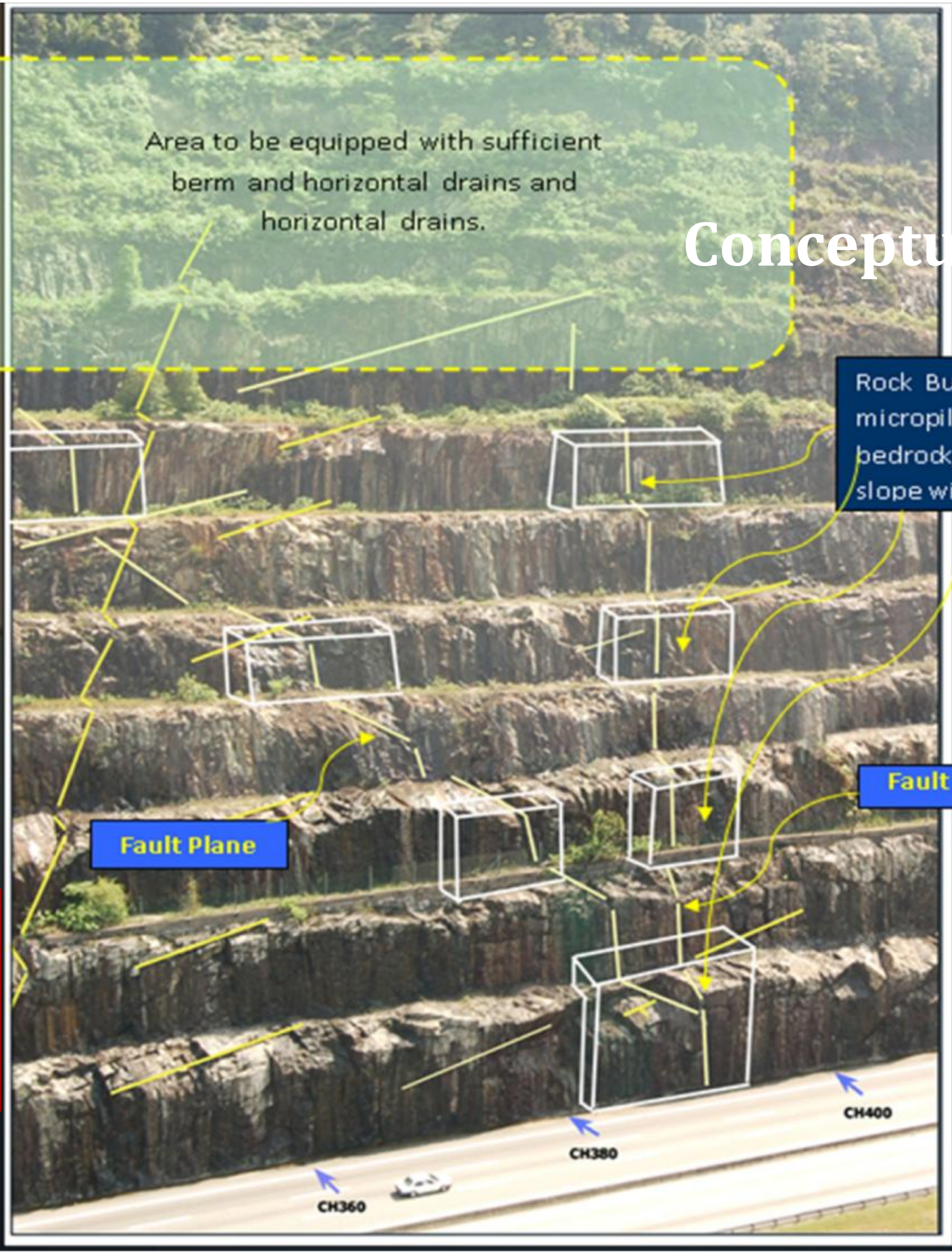
- **Concept:**
  - The design intent of a mesh is to cover a slope and control the rockfall trajectory by restricting the rock's movement;
  - Mesh weight and strength provides an important stabilizing factor. High tensile strength wire mesh
  - Hanging loose on the slope face
  - The rockfall drape shall be capable of being pulled on/out at the bottom to clear rocks retained upslope from the draped slope and for rock removal.
  - The top of the wire mesh drapery shall be secured to a top support cable.

Vegetation

- Geocell + soil improvements to support vegetation growth on poor sub-soil conditions

Conceptual Design

- Proposed rock buttresses to arrest a large scale wedge

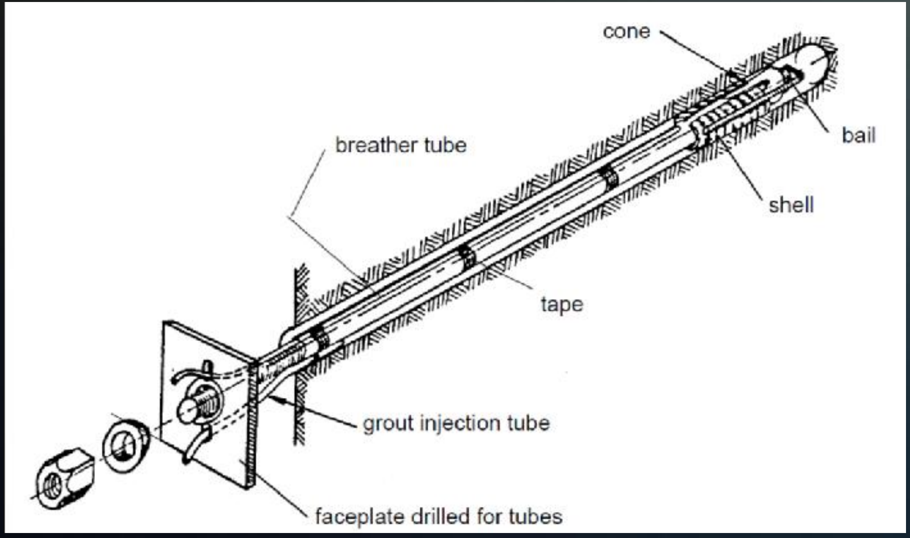


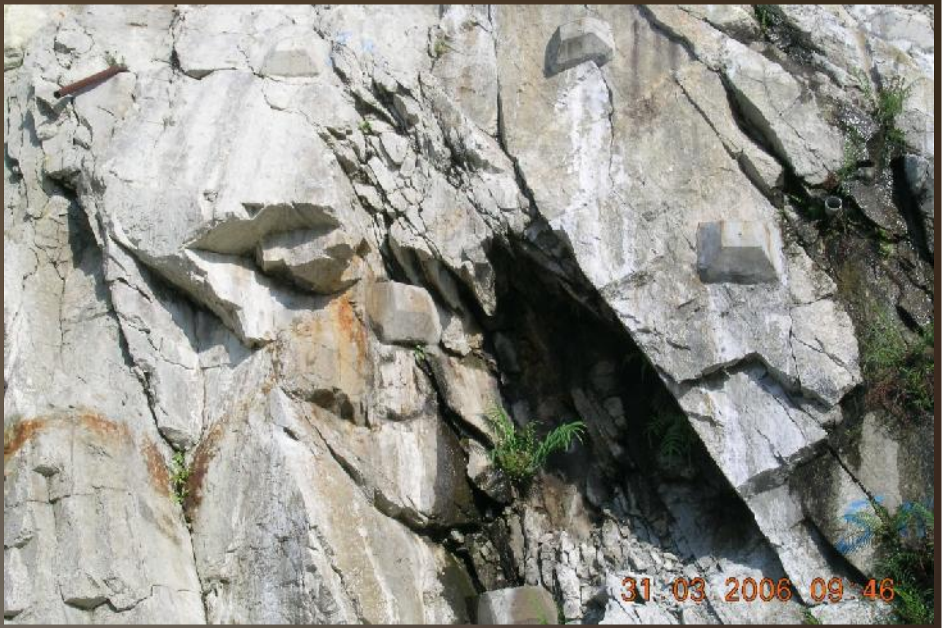
ROCK BUTRESS

IMPLEMENTATION

ROCKBOLTS

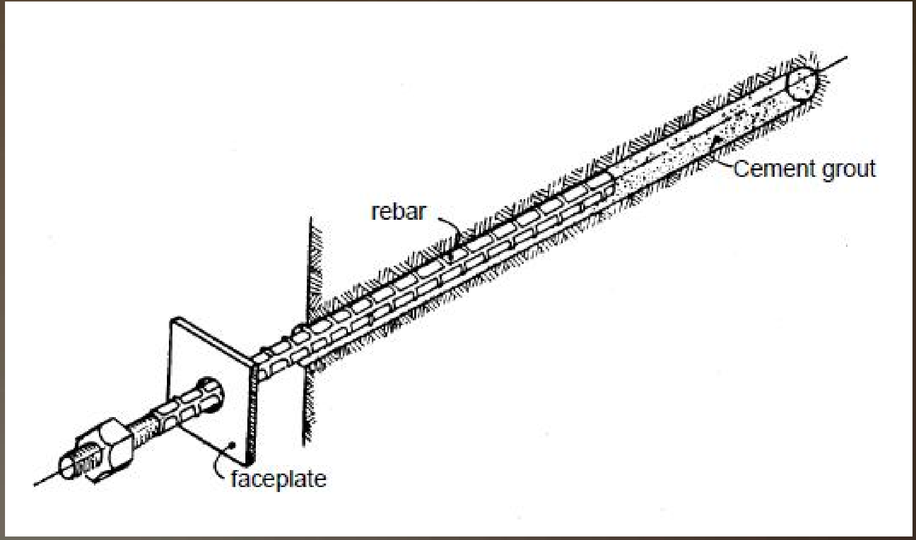
- Rockbolts generally consist of plain steel rods with a mechanical anchor at one end and a face plate and nut at the other.
- They are always tensioned after installation.
- the space between the bolt and the rock can be filled with cement or resin grout.





DOWELS

- Dowels or anchor bars generally consist of deformed steel bars which are grouted into the rock.
- No tensioning!
- In order to be effective, dowels have to be installed before significant movement in the rock mass has taken place.



Grouted dowel using a deformed bar inserted into a grout-filled hole.

ROCK SLOPE STABILISATION
(ROCK REMOVAL)
- Some common practices in Malaysia -

Mechanized Rock Removal/Scaling

Rock Scaling

Rock Scaling

Rock Trimming

ROCK FALL PROTECTION MEASURES

A) BERMS/BENCHING

Lebuhraya Ipoh-Changkat Jering, PLUS.

CATCH BERM

CATCH BERM

A 20m wide catch berm on Bukit Lanjan Rock Slope

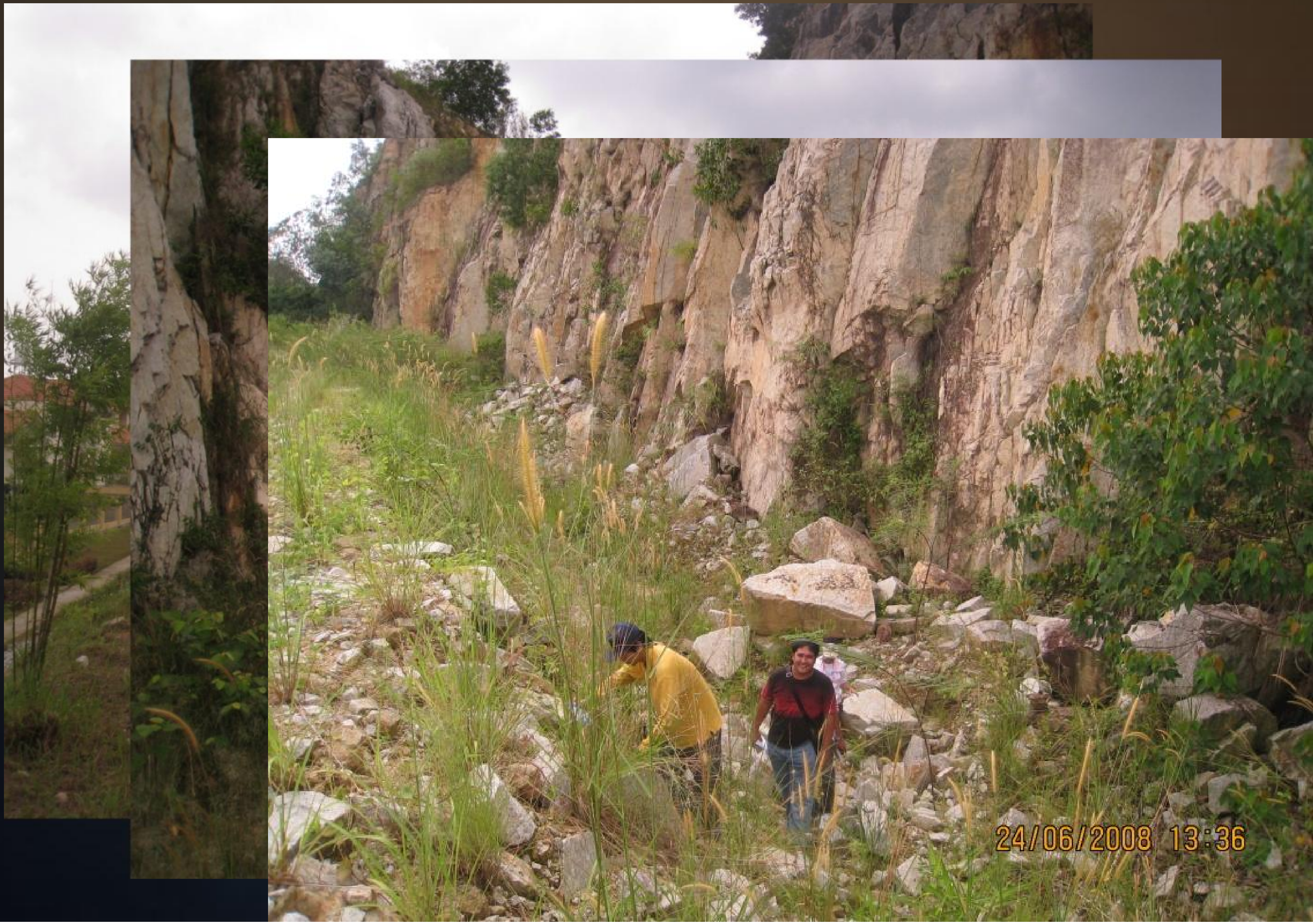
..and it was installed with Geobrugg Rock Fall Fence (after Euroculture Sdn. Bhd., 2005)

Photo 2 : Completed Geobrugg Rock Fall Fence at 20m Wide Berm

B) ROCKSHED

Some examples from Switzerland

C) ROCK TRAP DITCH & FILL – RAWANG PERDANA



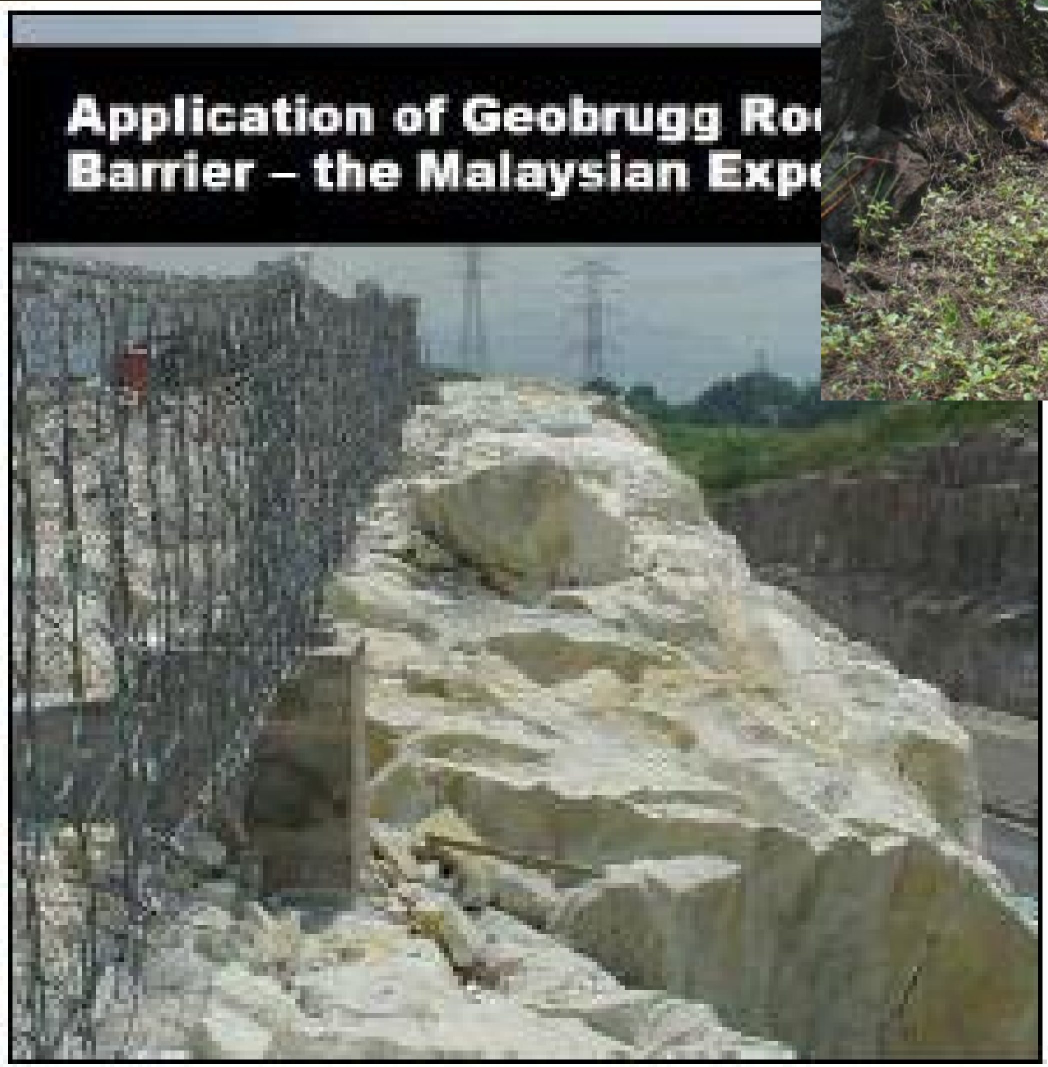
D) ROCK FALL FENCE/BARRIER

Geobrugg ring net shown restraining a boulder. These nets can be designed with energy absorbing capacities of up to 2500 kNm which is equivalent to a 6 tone boulder moving at 20 m per second.

D) ROCK FALL FENCE/BARRIER

Geobrugg energy absorbing ring. When subjected to impact loading the ring deforms plastically and absorbs the energy of the boulder.

D) ROCK FALL FENCE



- An example rockfall fence / barrier installed at:
  - Bukit Lanjan Rock Slope, NKVE Highway.
  - Ipoh-Chkt Jering Highway

D) ROCK FALL BARRIER

Tom Price Iron Ore Mine, West Australia (after Geobrugg, 2006)

EXAMPLE: ROCK FALL FENCE @ GUNUNG PASS

E) WIRE MESH DRAPPE

Top edge with hinged supports and suspension of the TECCO® drape

TECCO® drape in June 2005 after installation; Ramsau Germany (after Geobrugg AG)