Rockslides!

Case Histories, Misconceptions & Public Policy

2003 AEG/GSA Jahns Distinguished Lecture Series

Chester F. Watts (Skip)

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Radford, Virginia

cwatts @ radford.edu

My other Jahns lectures…

"Geology in public policy"

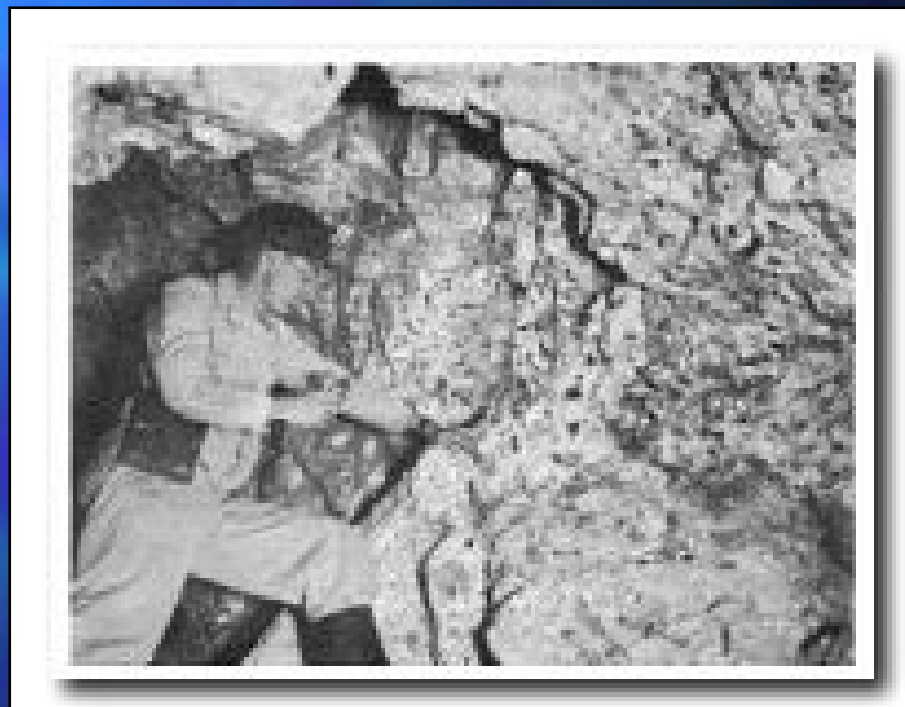
- Fourteen months on the Hill
- Duties of Senate Staff
- Current geoscience issues before Congress
- Tracking policy issues and making a difference

"Military operations in difficult terrain"

- Tactical rockslides
- Hard target defeat

The Association of Engineering Geologists and The Engineering Geology Division of GSA jointly established the Richard H. Jahns Distinguished Lectureship in 1988.

Richard H. Jahns (1915-1983) was an engineering geologist who had a diverse and distinguished career in academia, consulting, and government



Jahns circa 1947. Mineralogist and pegmatite expert, Stanford University, Palo Alto.

The purpose is to commemorate Jahns and to promote student awareness of engineering geology through a series of lectures offered at various locations around the country throughout the year

Limited funding comes from AEG & GSA, and from individual sections who invite the Jahns Lecturer to their area.

Congressional Fellows are individuals funded by professional societies or government agencies to serve as regular staff members to a member of Congress or committee at no cost to Congress

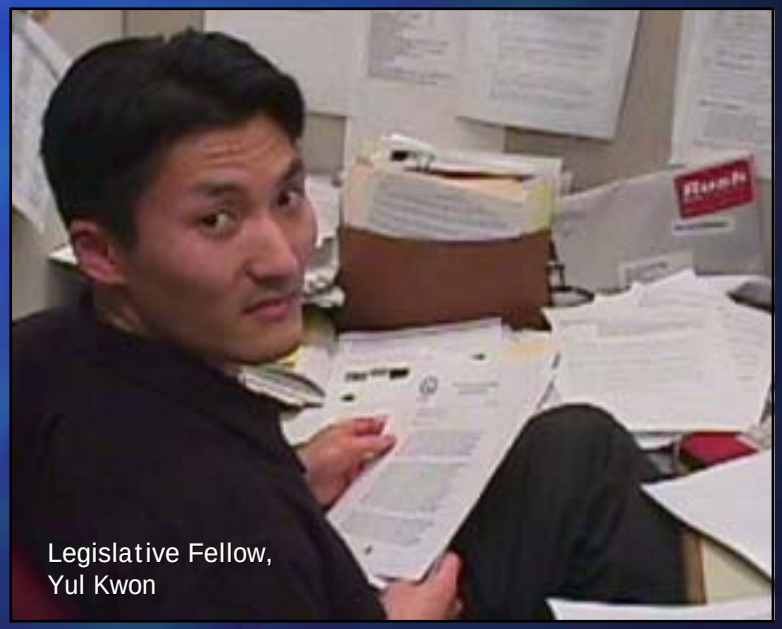
Neither the Fellow nor the funding agency are allowed to have their own agenda

Besides Science Fellows, there are fellows in economics, law, political science, military operations, education and much more!

Geological fellows are funded by:

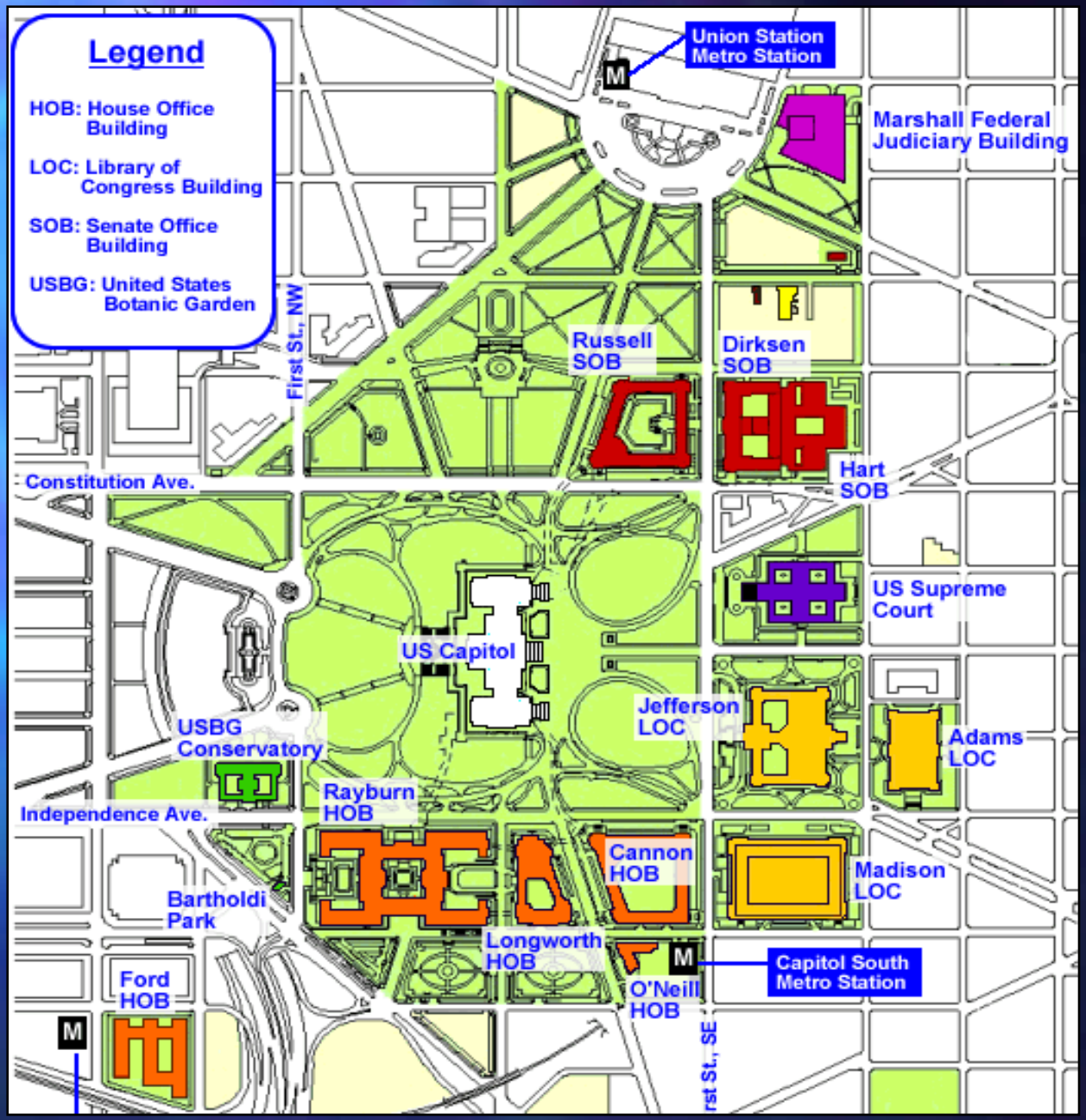
- The American Geological Institute (AGI)
- American Geophysical Union (AGU)
- American Meteorological Society (AMS)
- Soil Science Society of America

There were about 30 science fellows working in various parts of Capitol Hill during my tour



Legislative Fellow,
Yul Kwon

Capitol Hill Map



September 11, 2001: Defining moments for a year on the Hill

Capitol Hill

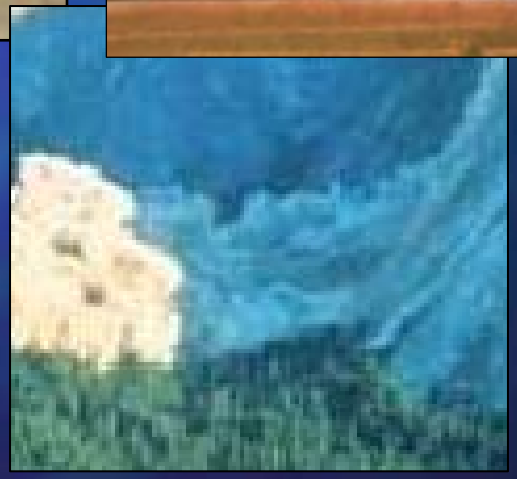

9.11.2001


ANNANDALE


Richmond
Pentagon
South Parking

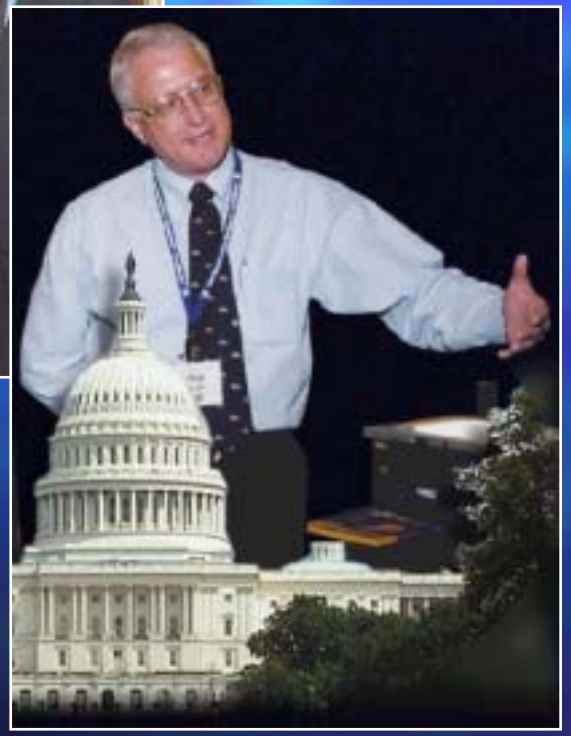

Kenneth L


خاص
بالجزيرة
مسجل
خبر عاجل
أسامة بن لادن
زعيم تنظيم القاعدة



Personal Staff Duties

Office of Senator Joseph Lieberman



1. Attend policy briefings
2. Research assigned policy issues
3. Seek the input of established experts
4. Meet with constituents
5. Meet with lobbyists
6. Brief the senator on issues
7. Write news releases and opinion editorials (op eds) on behalf of the member
8. Arrange and staff events for the member
9. Draft position papers
10. Draft and introduce legislation on behalf of the member

Some of the major national geological issues facing Congress…

1. Drilling for oil in Alaska
2. Disposal of nuclear waste at Yucca Mountain
3. Global climate change
4. National energy policy
5. Funding for USGS
6. Natural hazards / homeland security

Yucca Mountain, Nevada

Rockslides & public policy…


FALLING
ROCK


FLYING
STONES

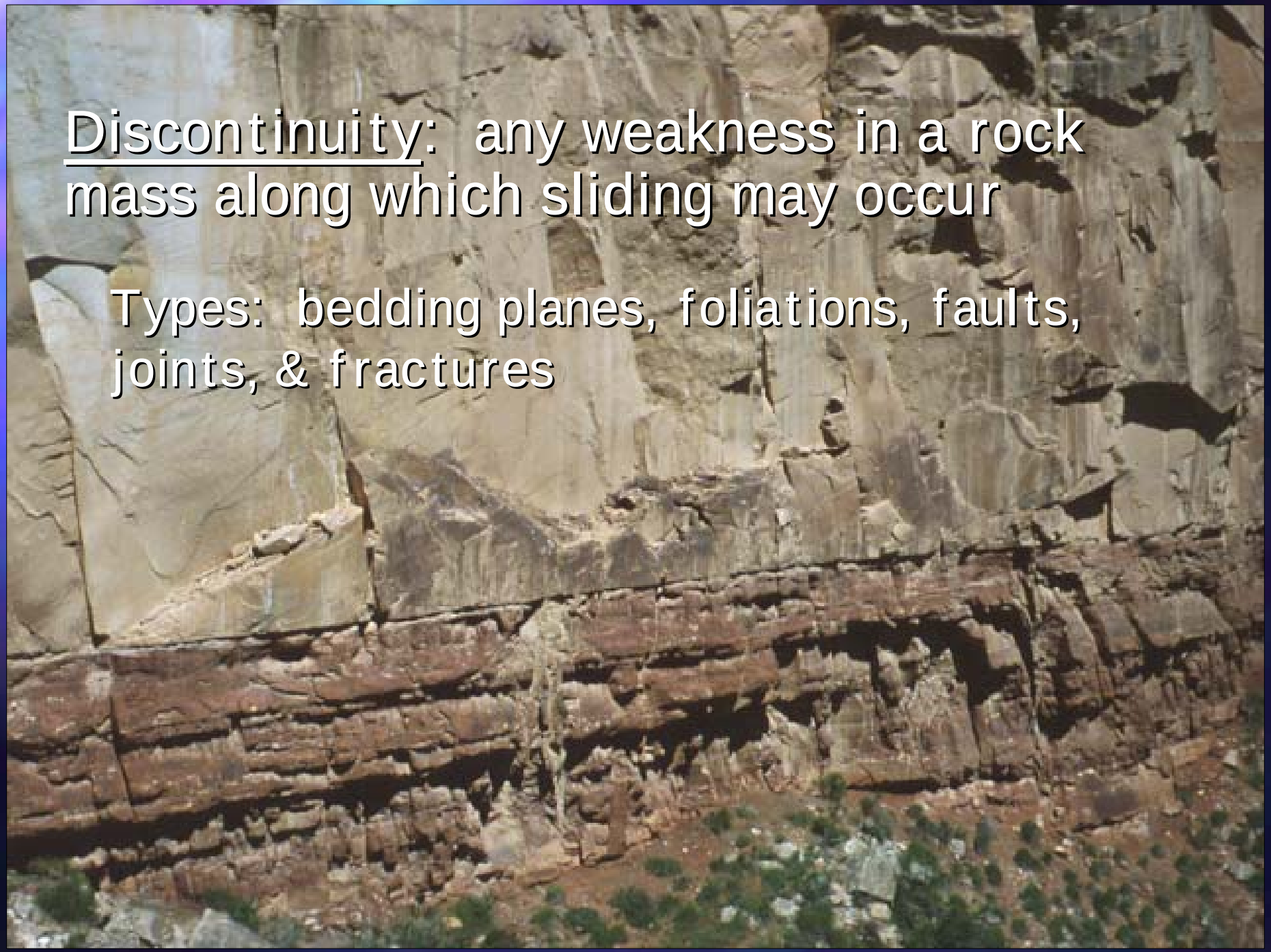

ROCKS


WBL-948

Rock slope stability…

Rock is generally a very strong material

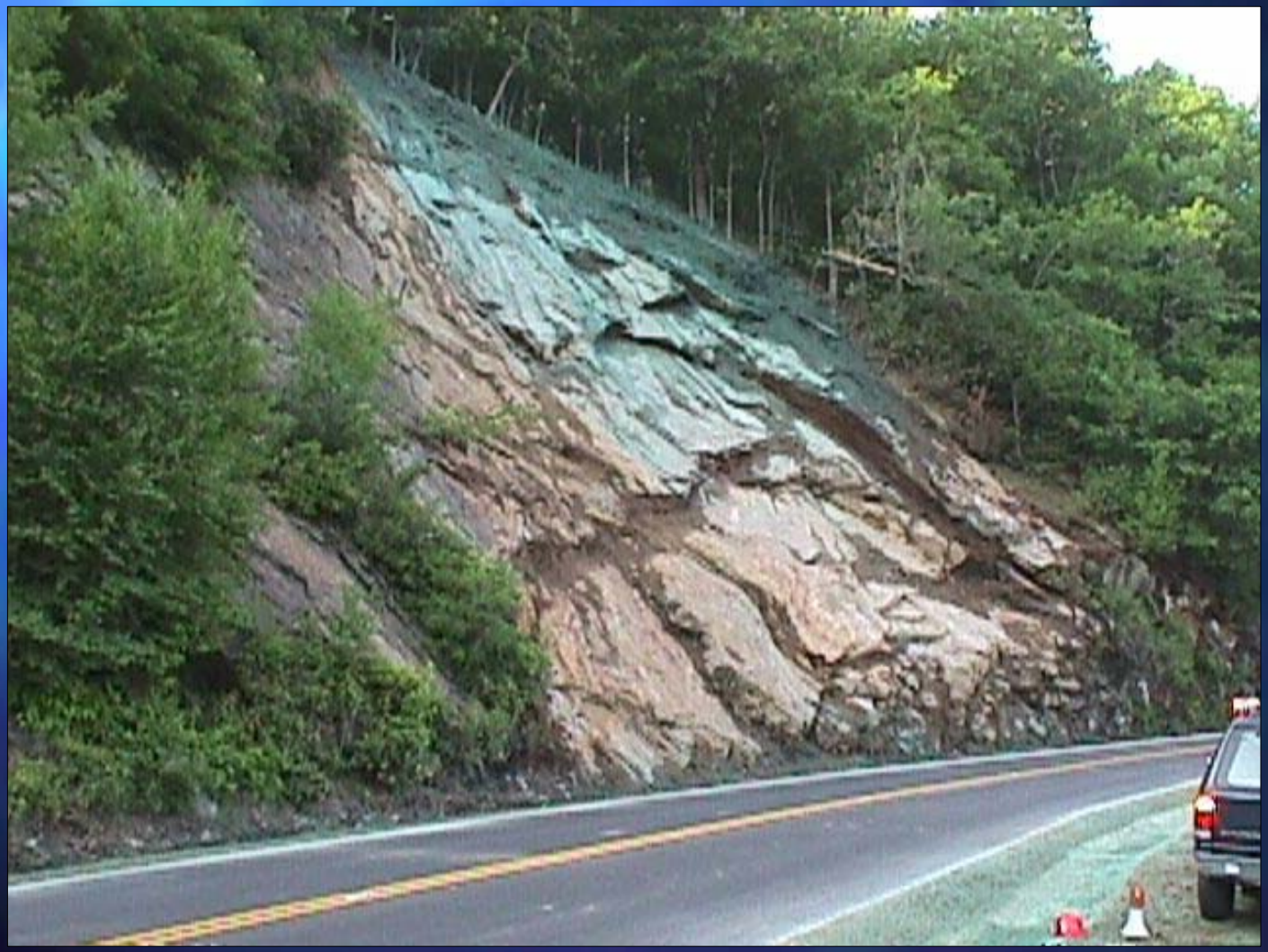
So, stability of rock slopes generally depends on the orientations and physical characteristics of geologic structures, termed *discontinuities*, in the rock mass



Discontinuity: any weakness in a rock mass along which sliding may occur

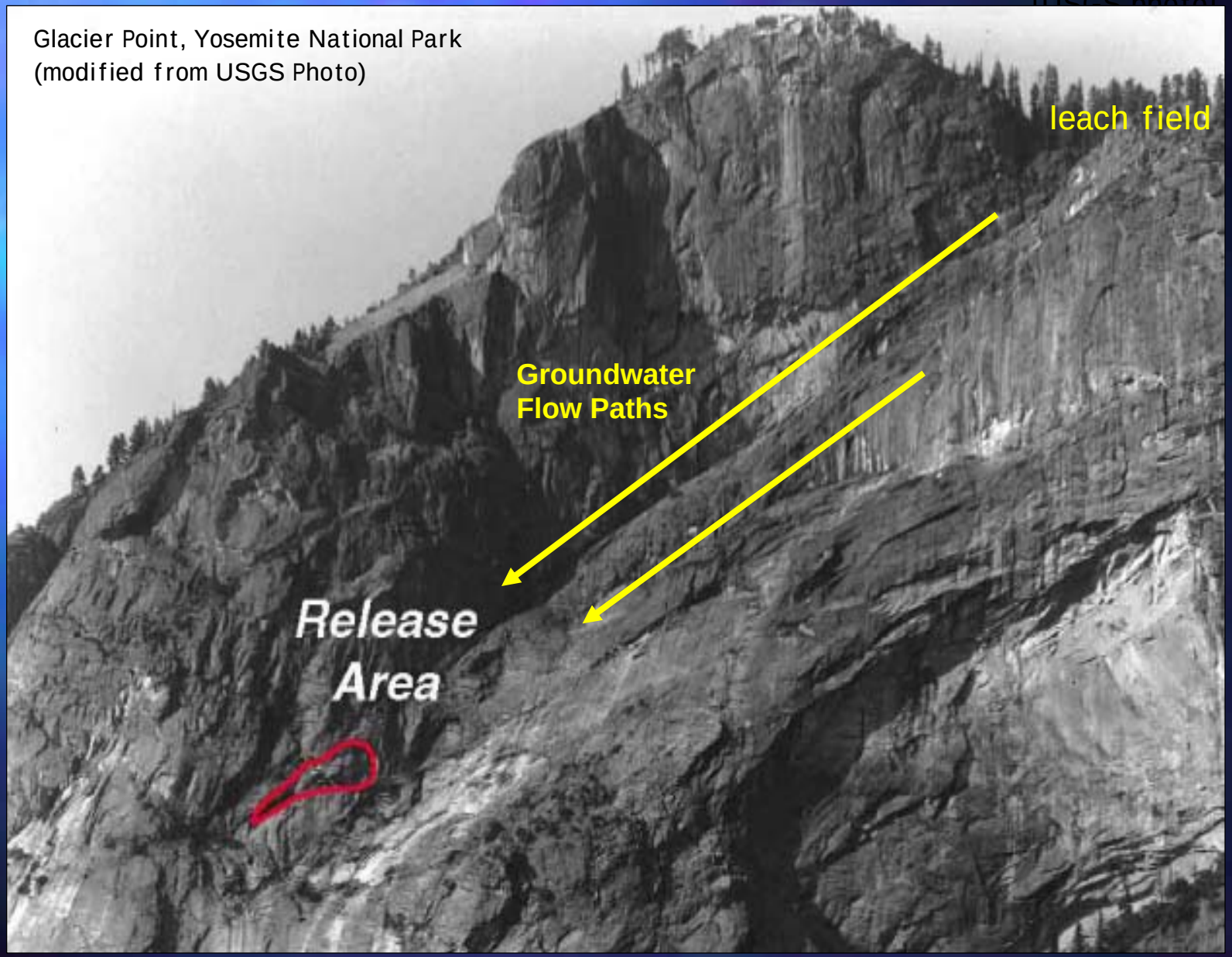
Types: bedding planes, foliations, faults, joints, & fractures

Characteristics: dip, dip direction, structure, roughness, water, continuity, infilling material…



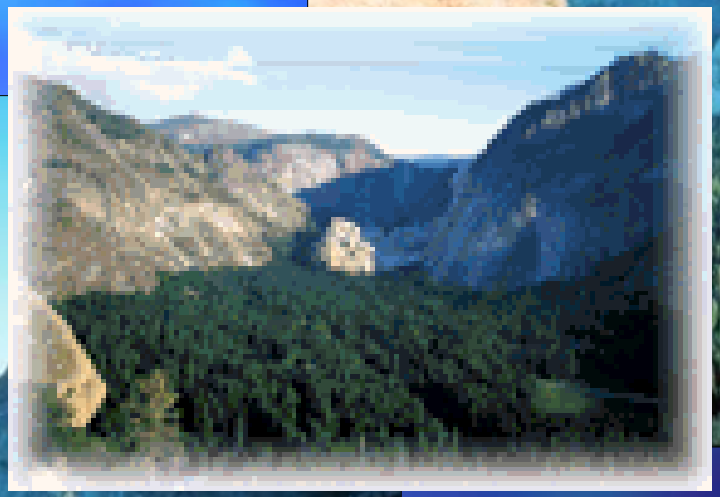
Discontinuities can also act as water conduits

[USGS photo]



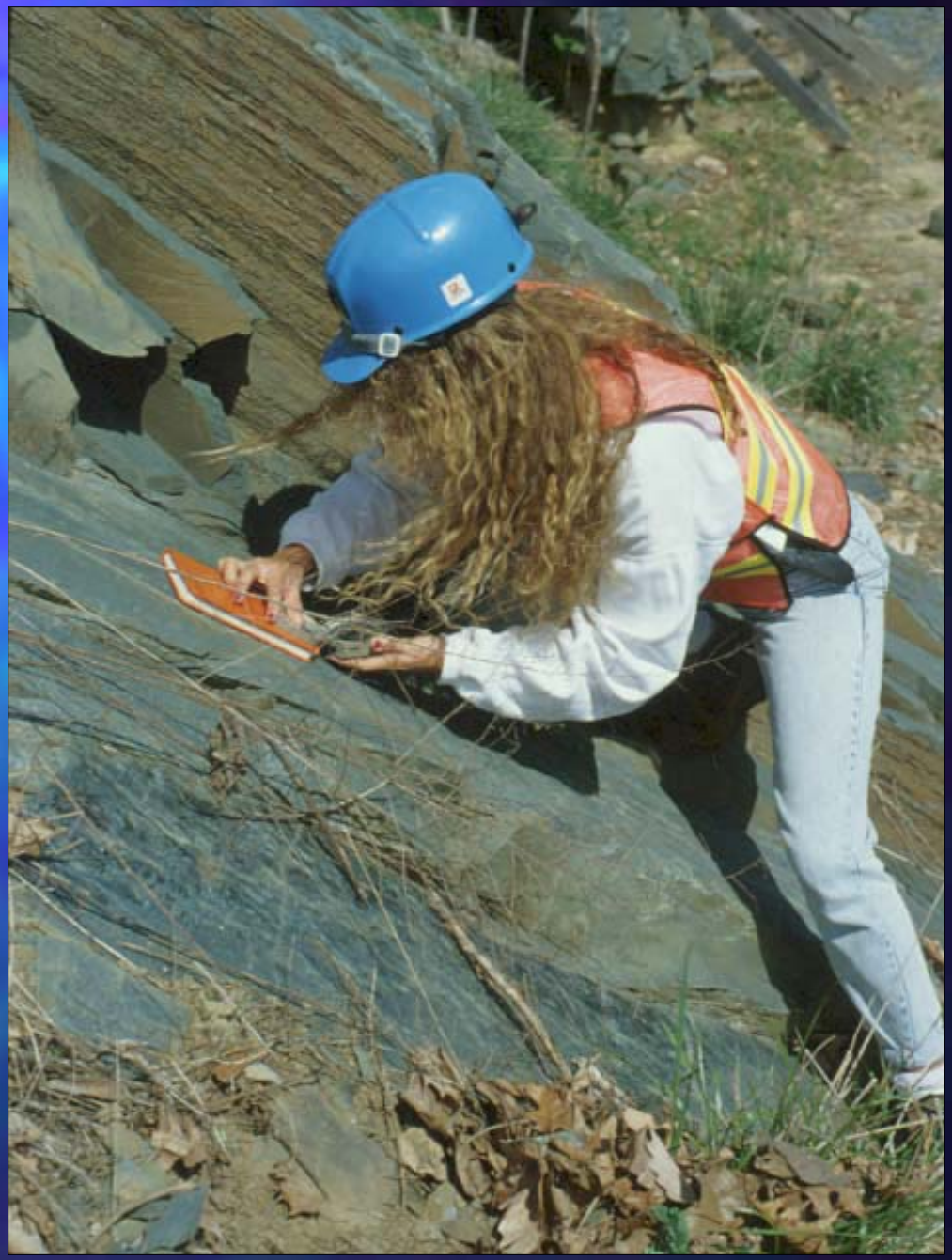
Yosemite rockslides:

The July 10, 1996
Happy Isles event



[photos by David F. Walter]

Discontinuity mapping…



Level compass, release clamp and turn compass until needle points north. Clamp needle.

Use coin to turn adjusting screw to correct magnetic deviation. Zero on scale now reads true north.

Place measuring plate against rock face and level compass, release needle clamp and re-clamp after needle has settled.

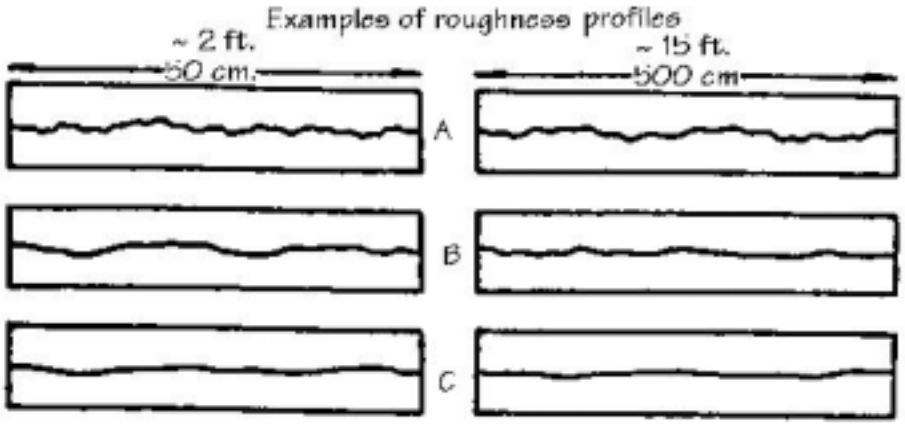
Read dip of plane. In this example, dip is 35 degrees.

Read dip direction of plane. In this case, dip direction is

The difference in magnetic declination in different hemispheres results in the needle jamming if a northern hemisphere compass is used in the southern hemisphere. Manufacturers will supply appropriate instrument if hemisphere is specified.

Rockpack III Data Entry

Data Set	Discontinuity	Traverse Trend	Distance	Dip Direction	Dip	Rock Type	Hardness	Water	Length
1	001	345	005	304	28	2	10	0	0250
1	002	345	010	290	12	2	10	0	0250
1	003	345	000	298	40	2	10	0	0250
1	004	345	000	296	56	2	10	0	0250
1	005	345	000	282	46	2	10	0	0250
1	006	345	000	282	24	2	10	0	0250
1	007	345	000	135	58	2	07	0	1000
1	008	345	000	148	62	2	07	0	1000
1	009	345	000	150	58	2	07	0	1000
1	010	345	000						
1	011	345	000						
1	012	345	000						
1	013	345	000						
1	014	345	000						
1	015	345	000						
1	016	345	000						
1	017	345	000						

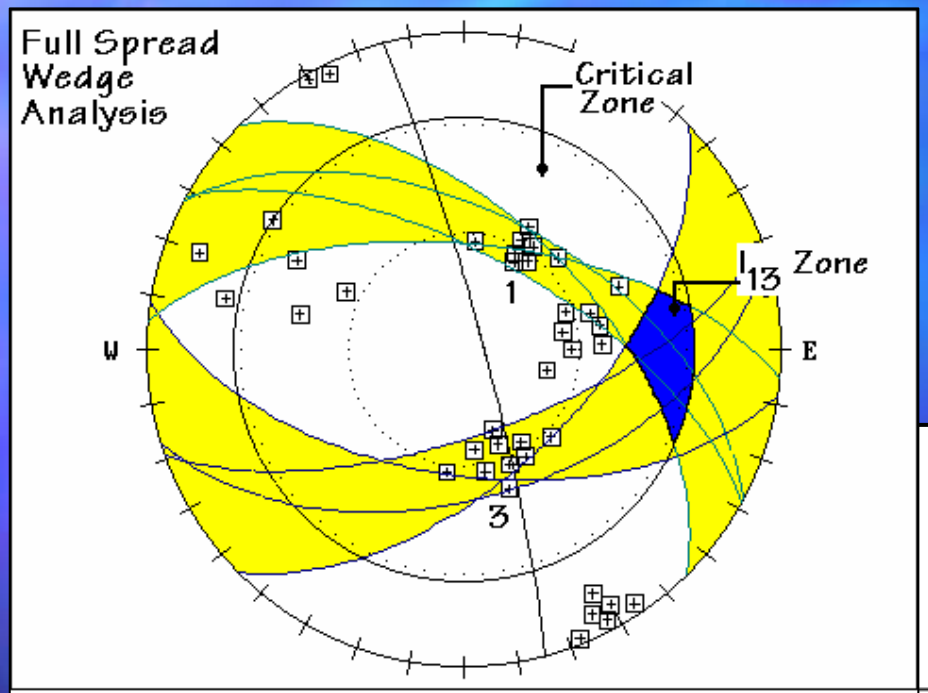


A. Rough undulating - tension joints, rough sheeting, rough bedding. JRC = 20

B. Smooth undulating - smooth sheeting, non - planar foliation, undulating bedding. JRC = 10

C. Smooth nearly planar - planar shear joints, planar foliation, planar bedding. JRC = 5

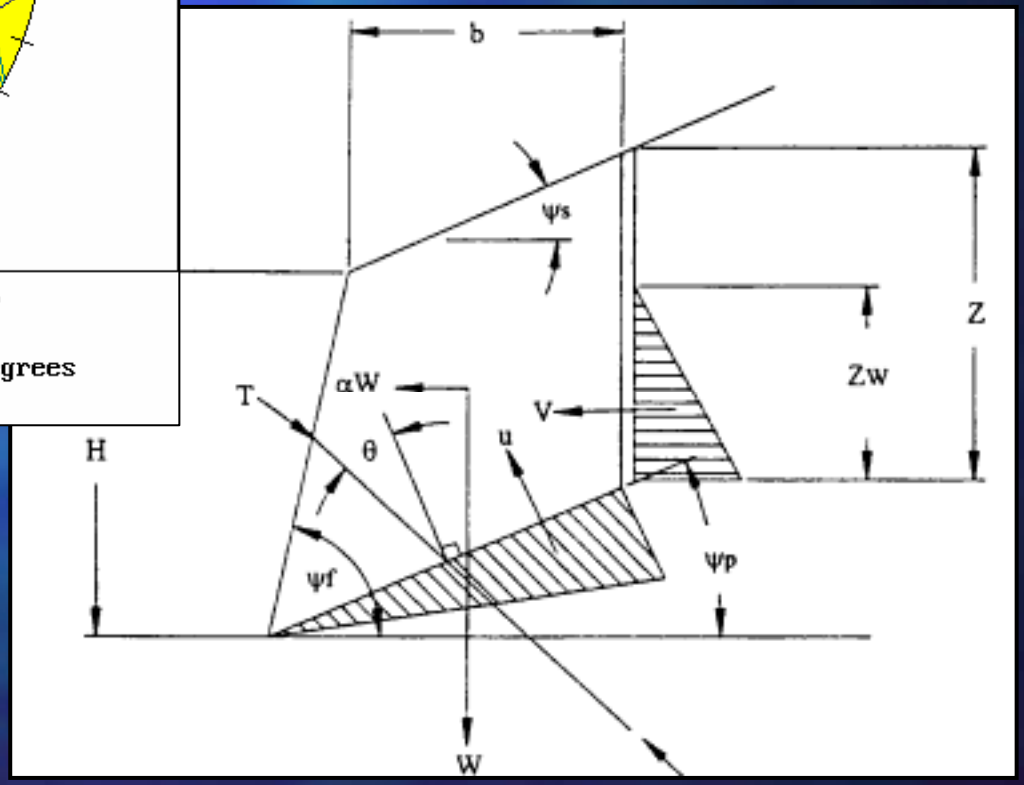
ANALYTICAL TECHNIQUES



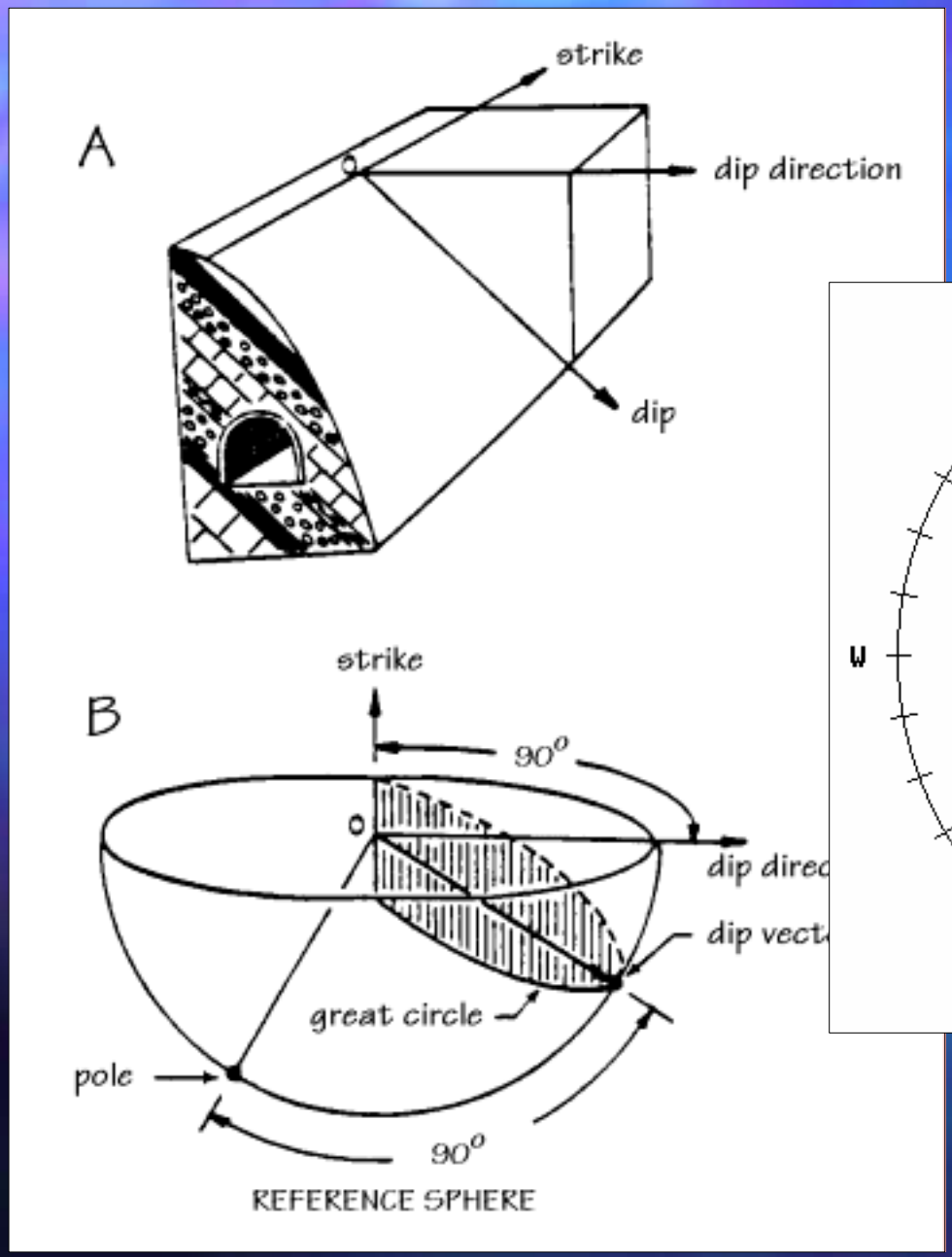
MARKLAND TEST PLOT: c:\rkpk2-04\data\problem.DAT
Friction Angle = 28 degrees
Slope dip direction = 75 degrees, Dip = 85 degrees
Number of Stations = 40

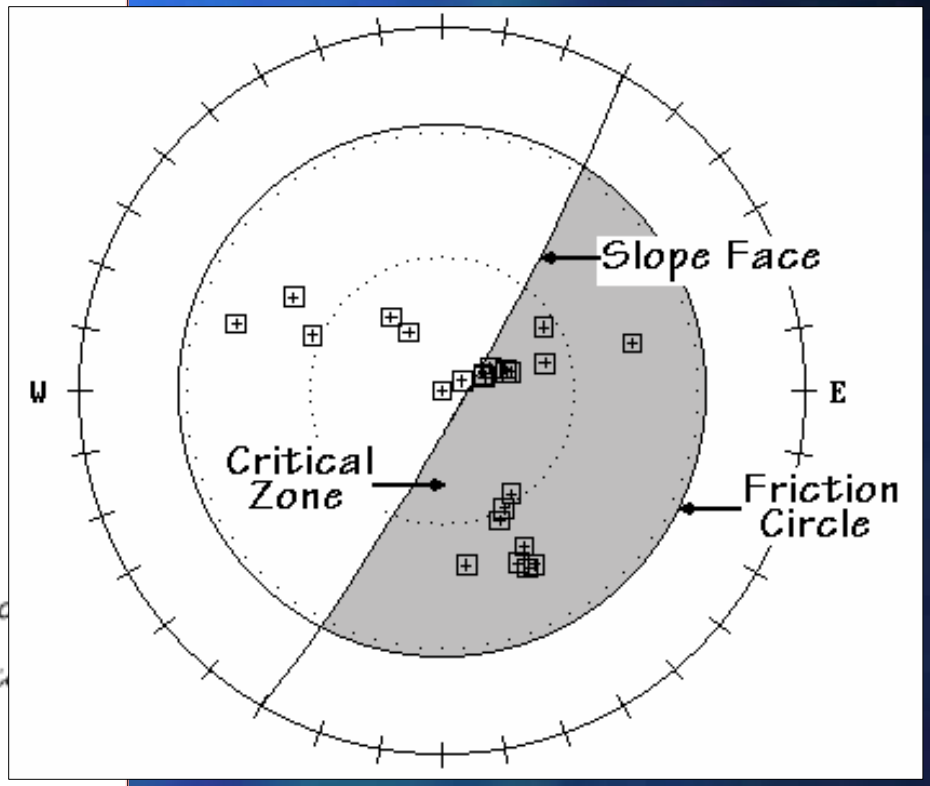
Stereonet analyses

Safety factor calculations



STEREONET ANALYSES





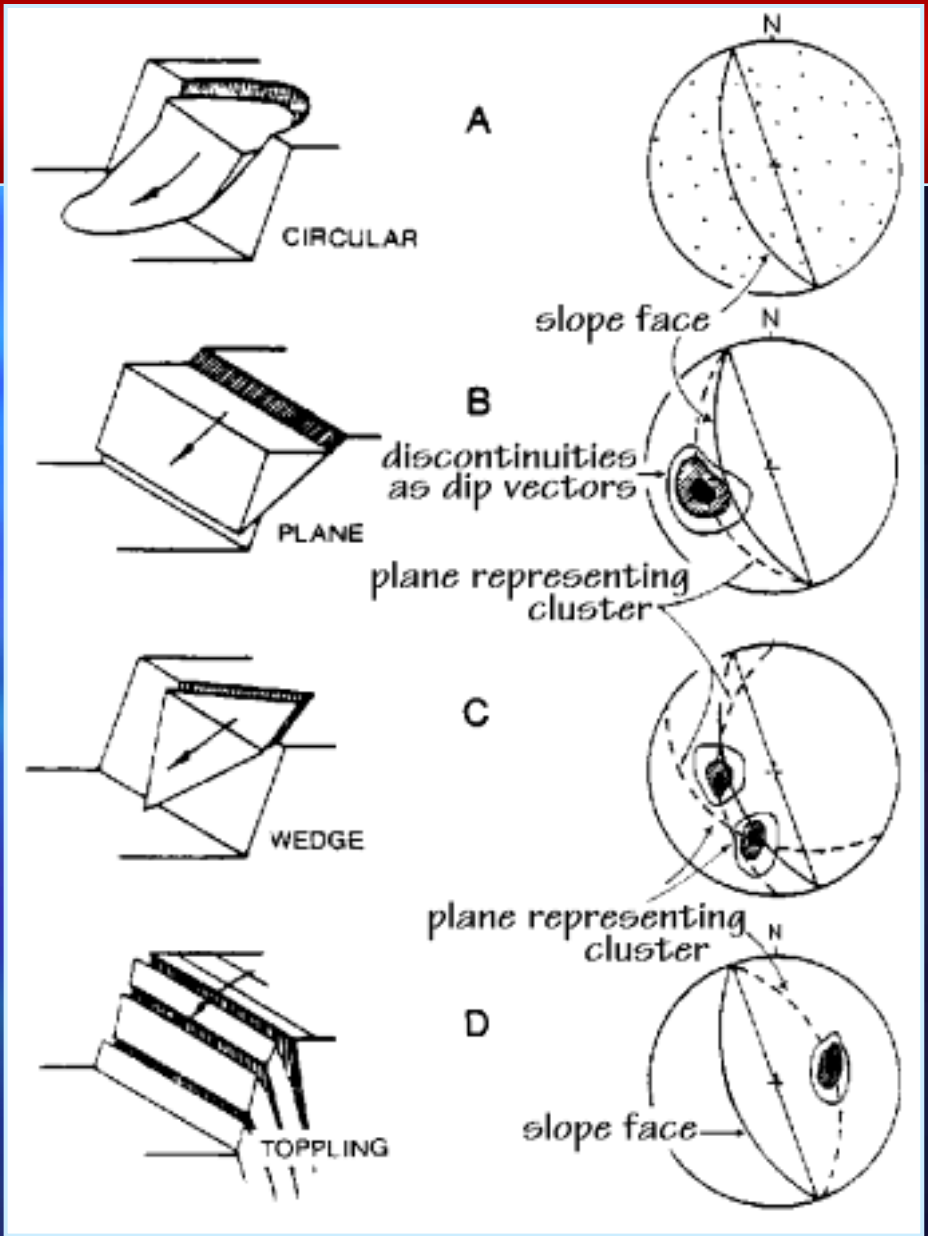
Markland's Test

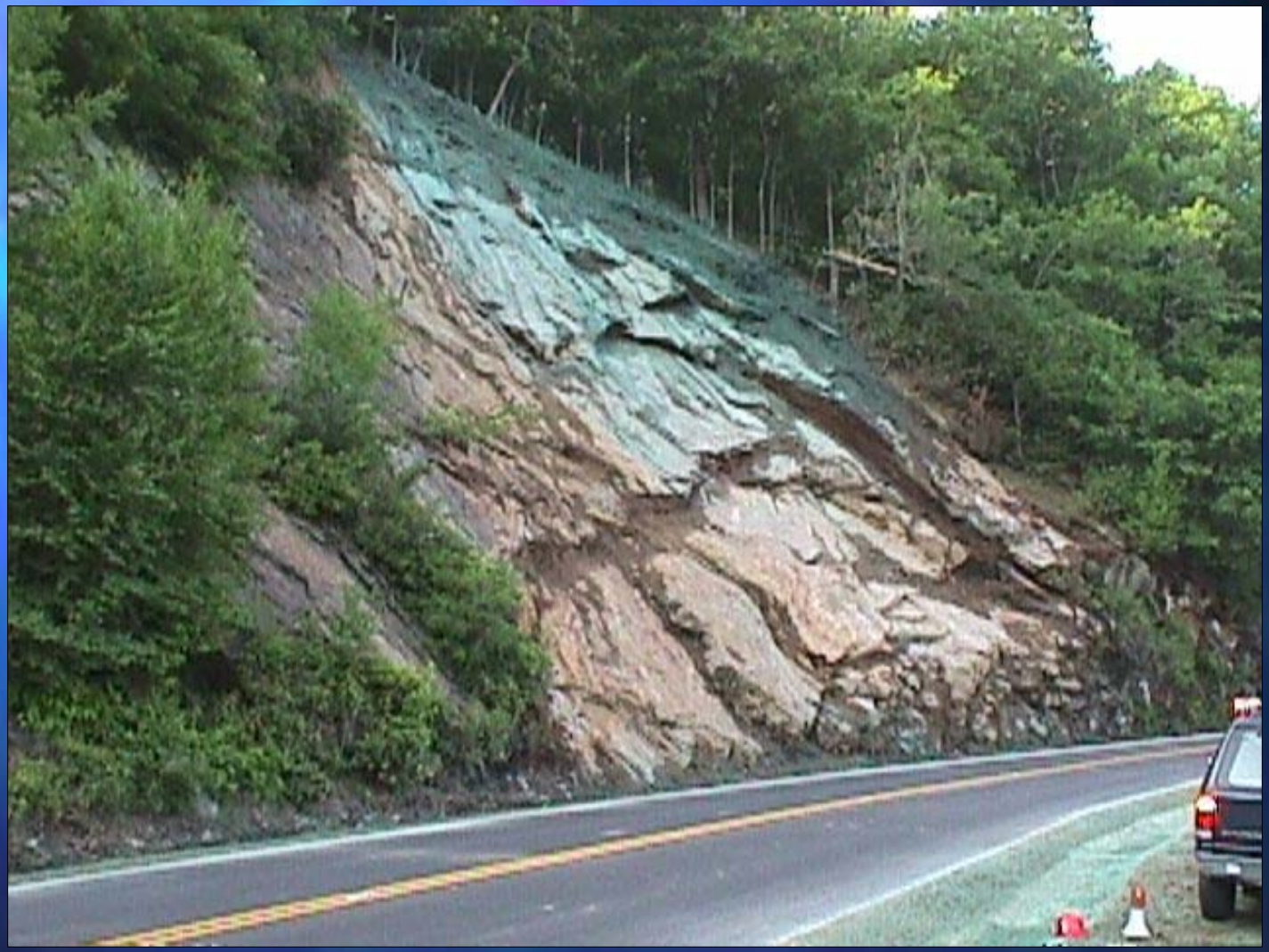
Rockslides

Failure Types

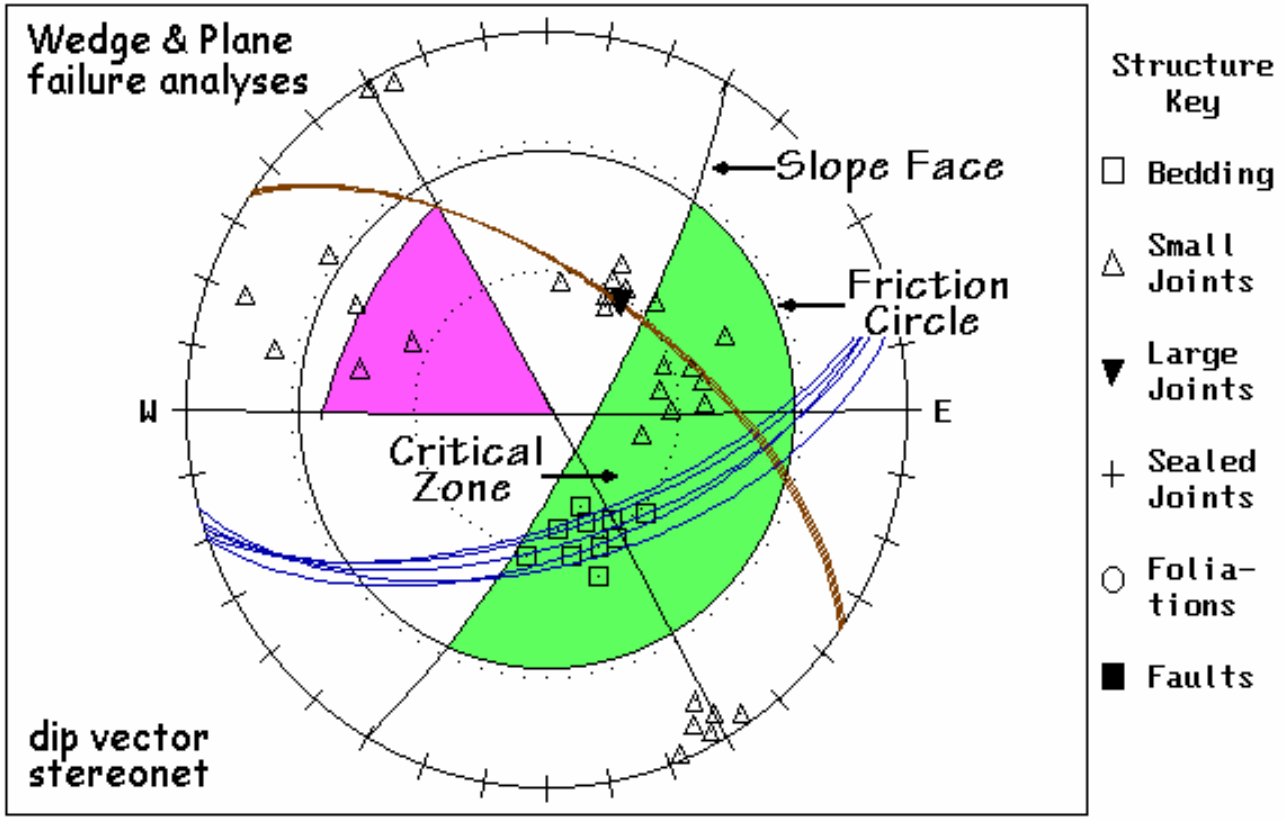
- Circular
- Planar
- Wedge
- Toppling

Different types of slope failures plot differently on dip-vector stereonets. Some examples are shown here.





Wedge failure analysis



MARKLAND TEST PLOT: c:\rkpk2-04\data\Problem2.DAT
Friction Angle = 32 degrees
Slope dip direction = 120 degrees, Dip = 80 degrees
Number of Stations = 40

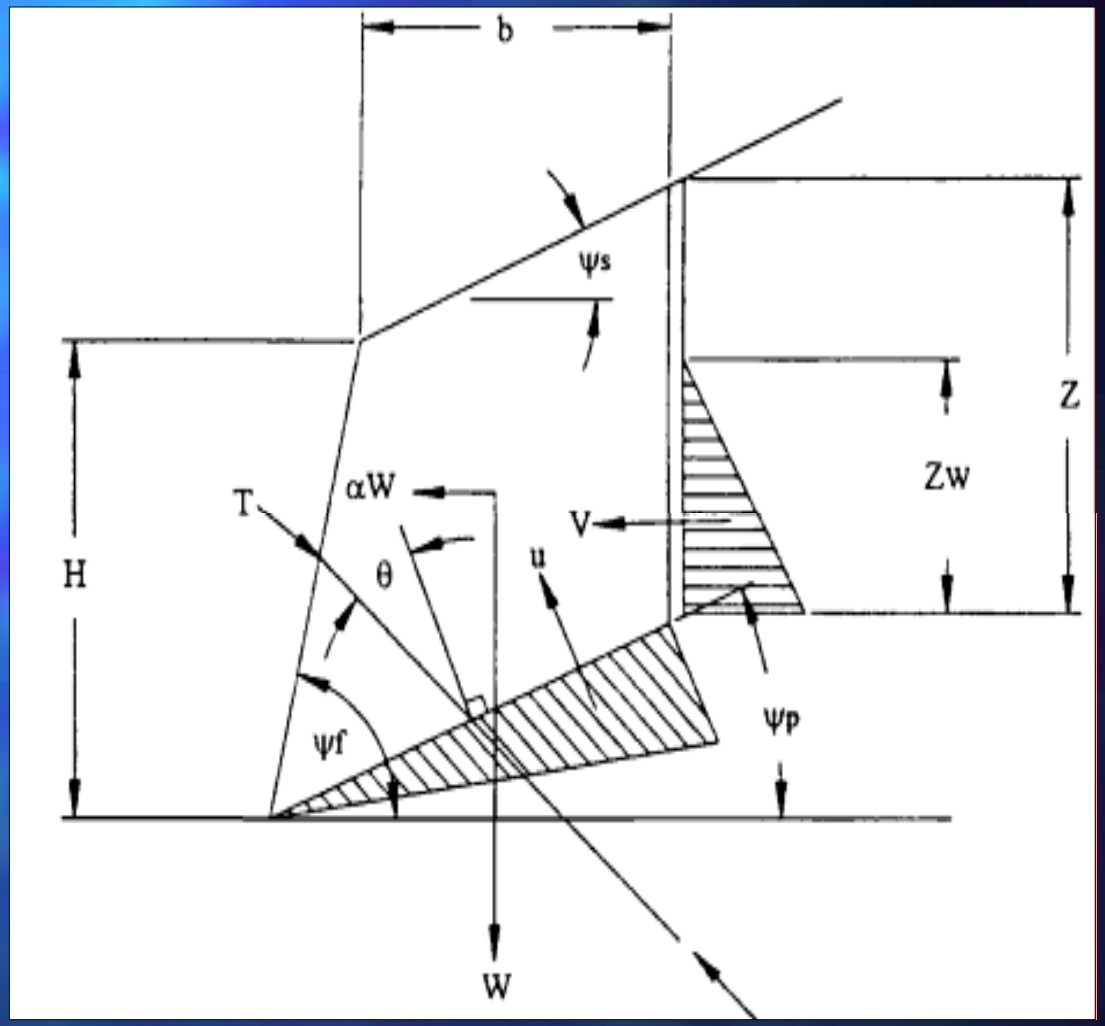
Sample stereonet

The green area is the critical zone for *plane* and *wedge* failures.

The pink area is the critical zone for *toppling* failures.

Safety factor calculations...

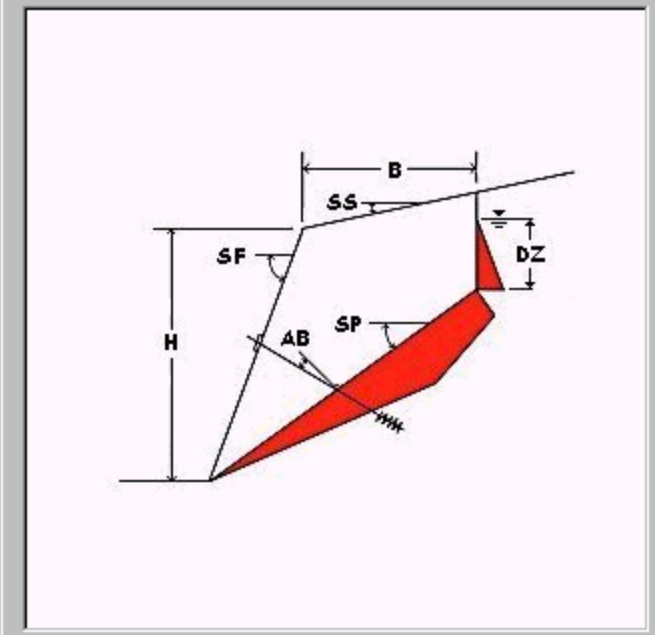
- limiting equilibrium
- watch those water pressures
  (especially in tension cracks)
- cause v. trigger in rockslides



Chapters 8 & 9, ROCKPACK III User's Manual & Appendix B

Plane Failure Analysis Input Screen

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	0	ft
(SF) Inclination of Slope Face	0	°
(SS) Inclination of Upper Slope	0	°
(SP) Inclination of Failure Plane	0	°
(CO) Cohesive Strength of Failure Surface	0	lb(f)
(PH) Friction Angle of Failure Surface	0	°
(GR) Density of Rock	0	lb(f)/ft³
(GW) Density of Water	0	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

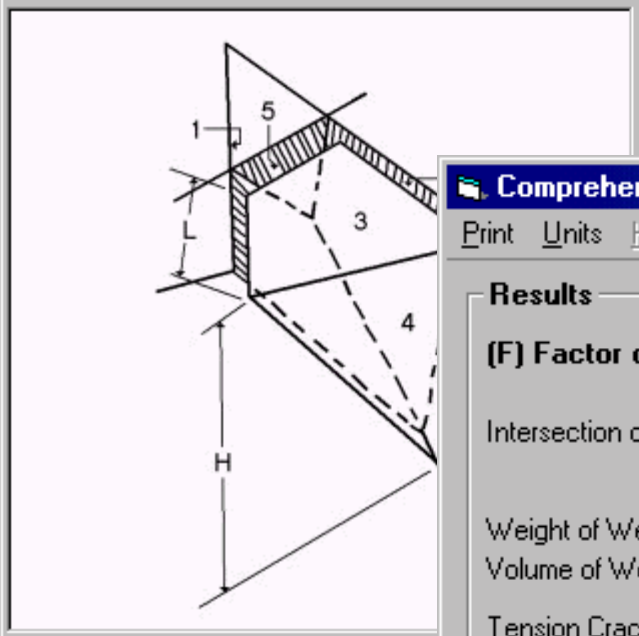
- ○ No Tension Crack
- ◉ Tension Crack Location Known
- ○ Tension Crack Location Unknown

(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

Comprehensive Wedge Failure Analysis - C:\Rockpack\Data\Test2.cmp

File View Units Reset Help



Wedge Data

☑ Include Tension Crack

(TL) Distance of Tension Crack from Crest: 40 ft

Cohesion and Friction Data

Plane 1: (C1) Cohesion 500 lb(f)/ft²

(P1) Friction Angle 20 °

CALCULATE FACTOR OF

Preliminary Data

(GR) Density of Rock

(H1) Slope Height Referred to Plane 1

Slope Undercut Data

Does the slope face overhang the toe of the

○ Yes ◉ No

Comprehensive Wedge Failure Analysis Output Screen

Print Units Help

Results

(F) Factor of Safety = 1.14 CONTACT MAINTAINED ON BOTH PLANES

Intersection of Planes 1 & 2 : Plunge = 31.2 °
Trend = 157.73 °

Weight of Wedge = 28272195.3 lb(f)
Volume of Wedge = 176701.22 ft³

Tension Crack Exists :
Maximum Free Draining Pressure on Both Planes = 0 lb(f)/ft²
Water Pressure on Planes 1,2,& 5 = 1082.53 lb(f)/ft²
(V) Normal Force from Water on Tension Crack = 1998935.61 lb(f)
(U1) Water Pressure on Plane 1 = 0 lb(f)/ft²
(U2) Water Pressure on Plane 2 = 0 lb(f)/ft²
(U5) Water Pressure on Plane 5 = 0 lb(f)/ft²

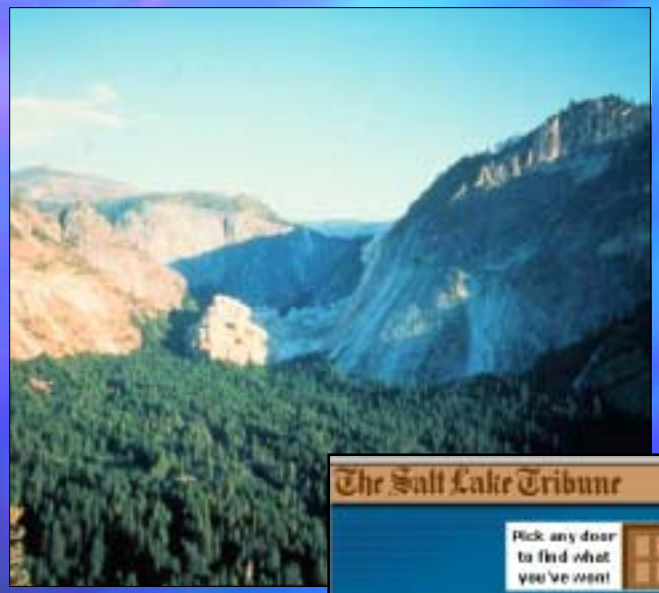
(N1) Effective Normal Force on Plane 1 = 15183813.34 lb(f)
(N2) Effective Normal Force on Plane 2 = 5802572.16 lb(f)

(A1) Plane 1 Area = 5565.01 ft²
(A2) Plane 2 Area = 6428.13 ft²

(H5) Tension Crack Height Along Planes 1 & 5 Intersection = 87.52 ft
(A5) Tension Crack Face Area = 1846.54 ft²

Resisting Forces = 18087200.81 lb(f)
Driving Forces = 15884016.43 lb(f)

SPECIFIC CASE HISTORIES



The Salt Lake Tribune

Utah's Independent

Pick any door to find what you've won!

FRONT | WORLD | STATE | BUSINESS | SPORTS | OPINION

Geologist Says Restrooms Causing Yosemite Rock Slides; It's 'Crap,' Says Park Service

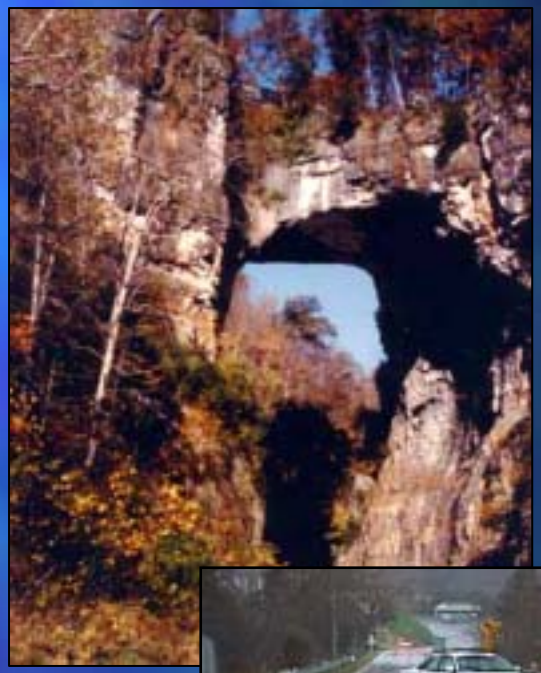
BY CHRISTOPHER SMITH
and LEE SIEGEL

© 1999, THE SALT LAKE TRIBUNE

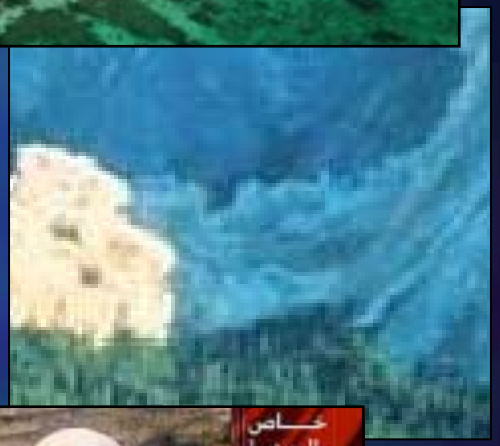
The National Park Service is dismissing a geologist's contention that two deadly rock slides at Yosemite National Park may have been triggered by septic systems draining from park restrooms.

Last month during the annual meeting of the Association of Engineering Geologists in Salt Lake City, Chester "Skip" Watts, director of Radford (Va.) University's Institute for Engineering Geosciences, delivered a scientific paper that found so-called "rockfalls" in 1996 and last June from the towering face of Yosemite's Glacier Point in northern California were possibly caused by the discharge of sewage on the slope above where the huge granite slabs sloughed off.

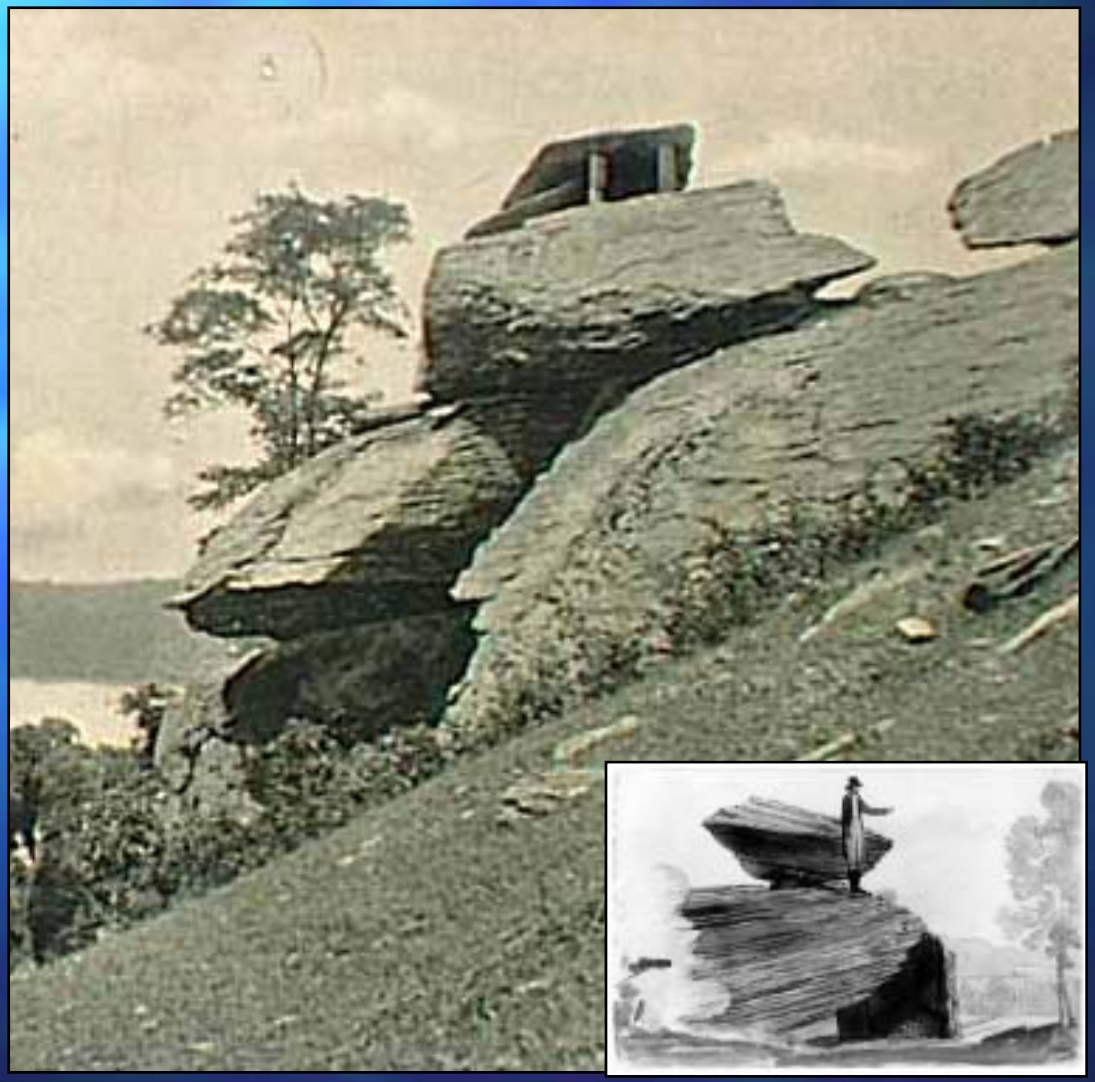
Watts also has presented the findings personally to Park Service



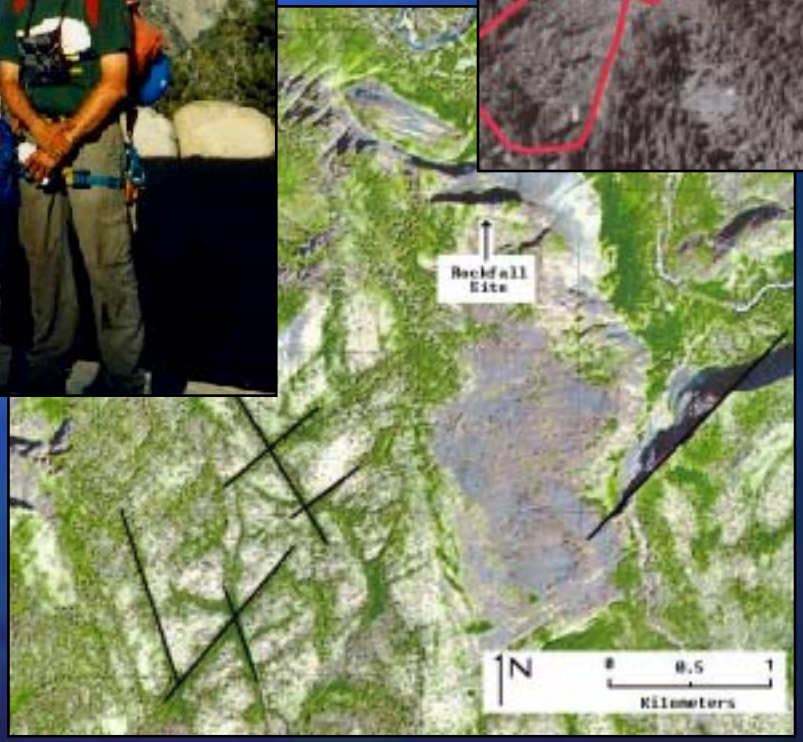
SPECIFIC CASE HISTORIES



SPECIFIC CASE HISTORIES



Yosemite Rockfall Studies…



1996 slide, USGS photos

There is a long history of rock falls throughout some portions of the park, but not from Glacier Point

The July 10, 1996
Happy Isles event

[photos by David F. Walter]

Happy Isles effects…

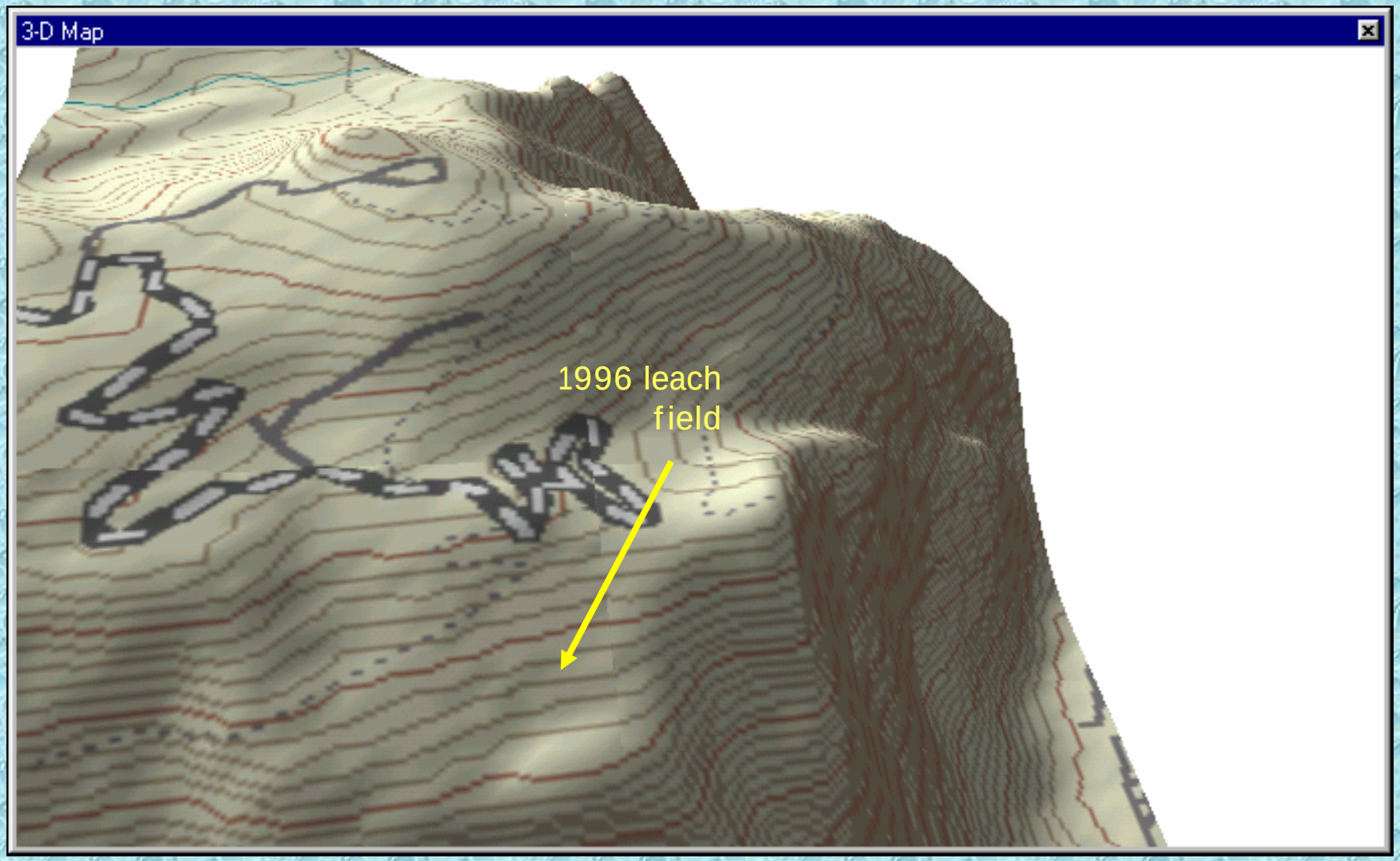
USGS photos

Wastewater management above the slide area…

1996 leach field area (in August 1997)

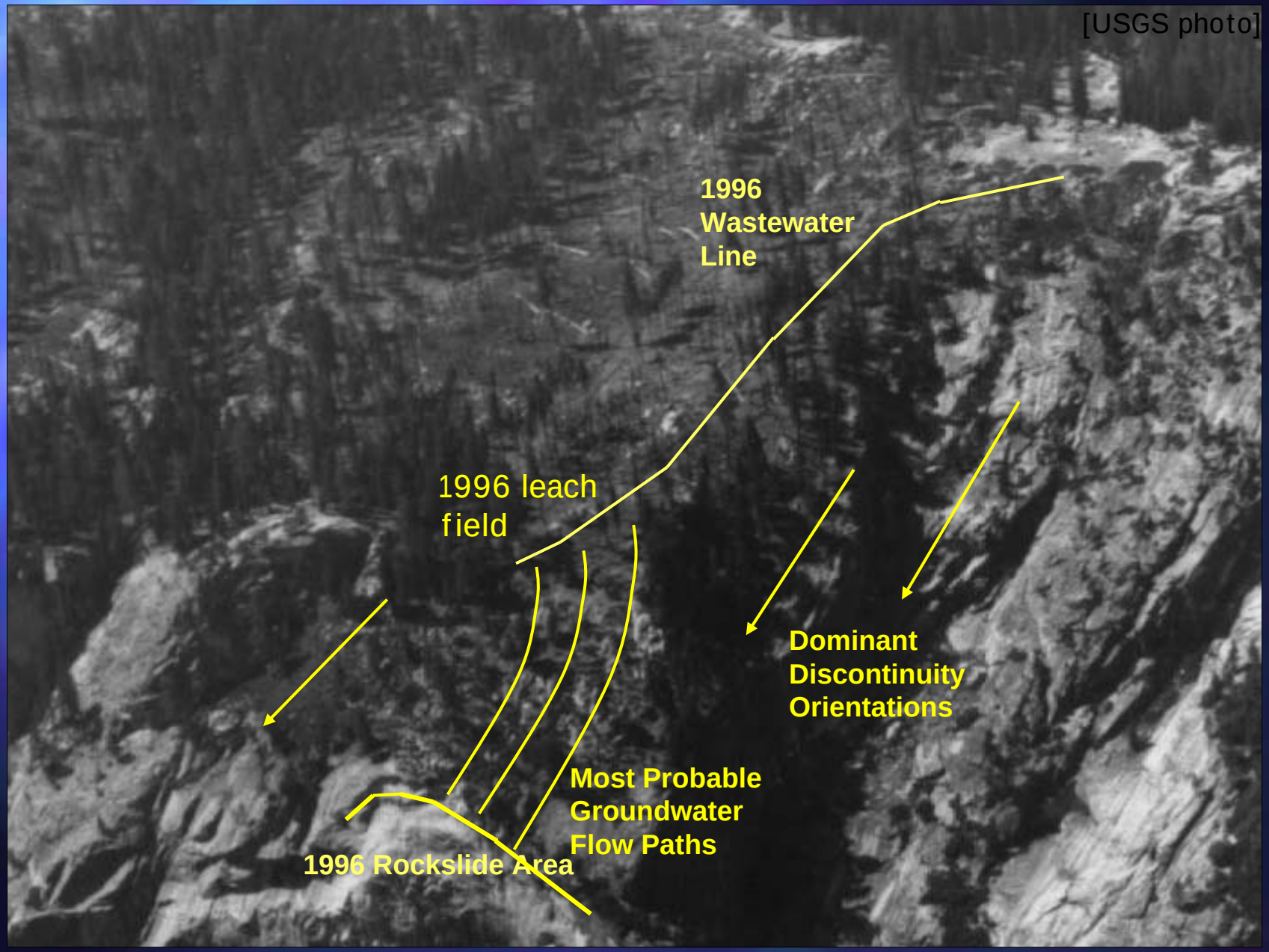
Three seepage points at the release area, 1996

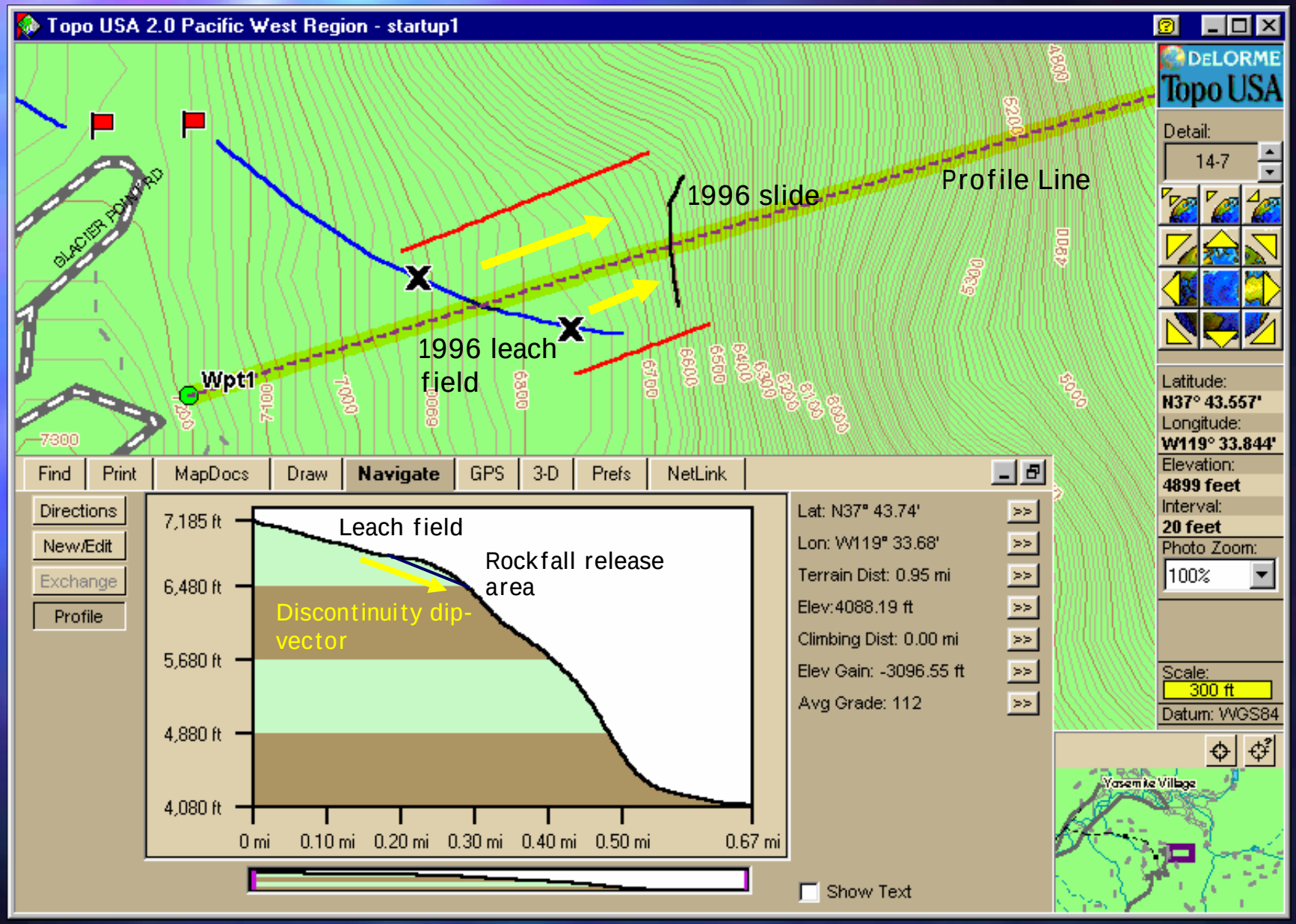
[USGS photo]



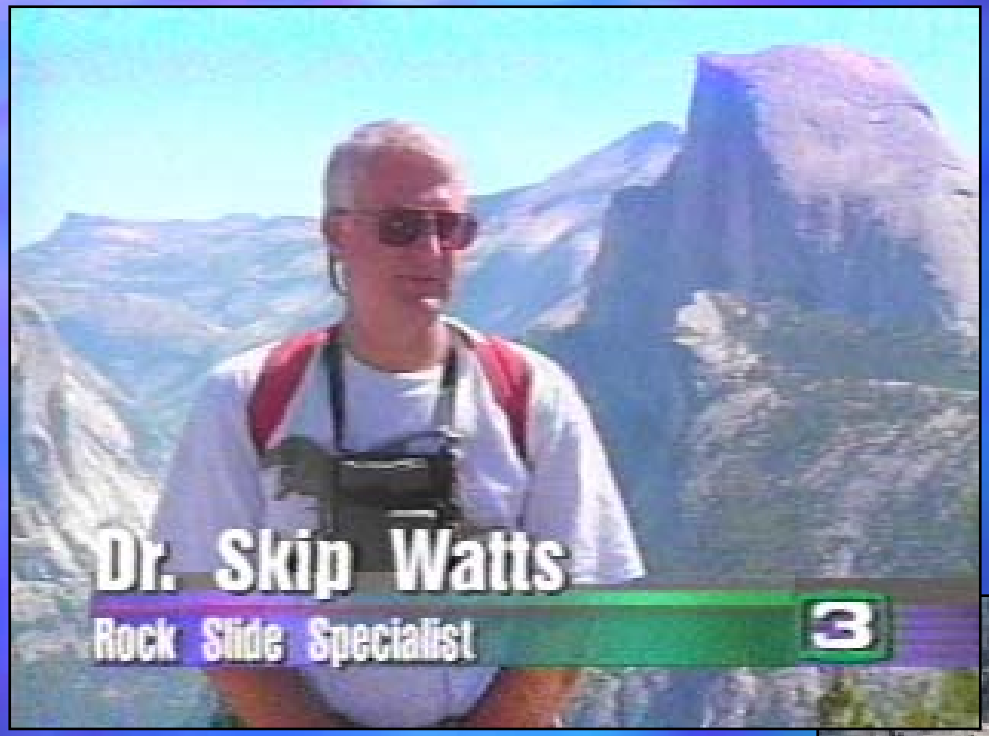
Glacier Point, Computer-generated 3D View
(looking west)

TopoUSA by Delorme


[USGS photo]
1996
Wastewater
Line
1996 leach
field
Dominant
Discontinuity
Orientations
Most Probable
Groundwater
Flow Paths
1996 Rockslide Area



Flow path to Happy Isles 1996 rockfall source area



Our study became a high profile, “attractive nuisance”...

... and with time, Dan Gilliam completed his thesis

But then there were more…

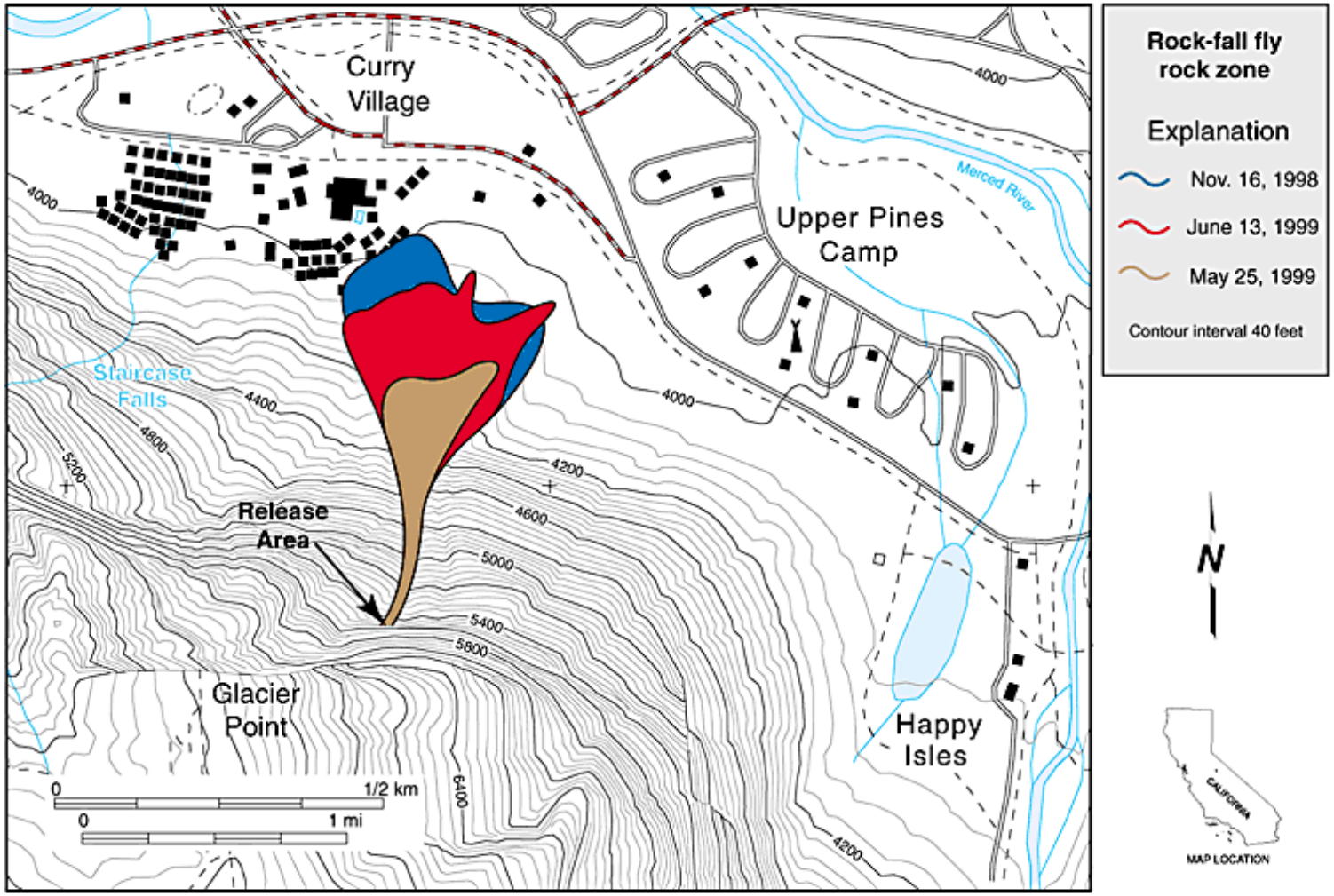
In 1998, activity shifted from the Happy Isles area of Glacier Point to the Curry Village area

Not active in historic time until --

- November 16, 1998
- May 25, 1999
- June 13 through July 14, 1999
- and many more since then

[Photo by Lloyd DeForest]

Effects of Curry Village area slides...

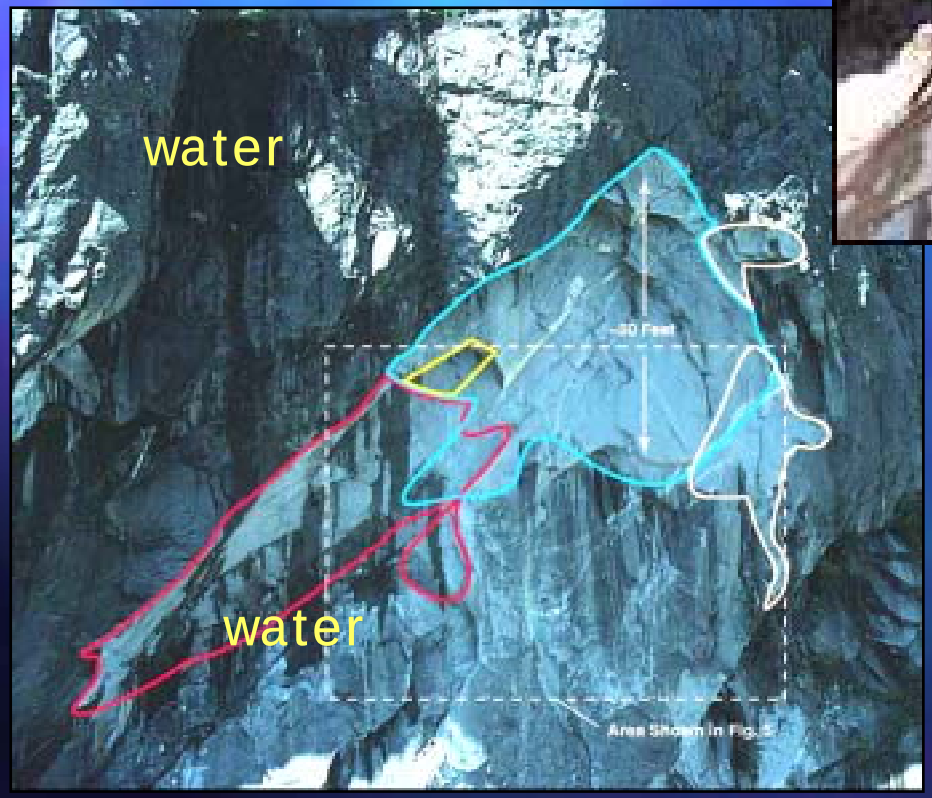


Recent Rock-falls Near Curry Village in Yosemite Valley

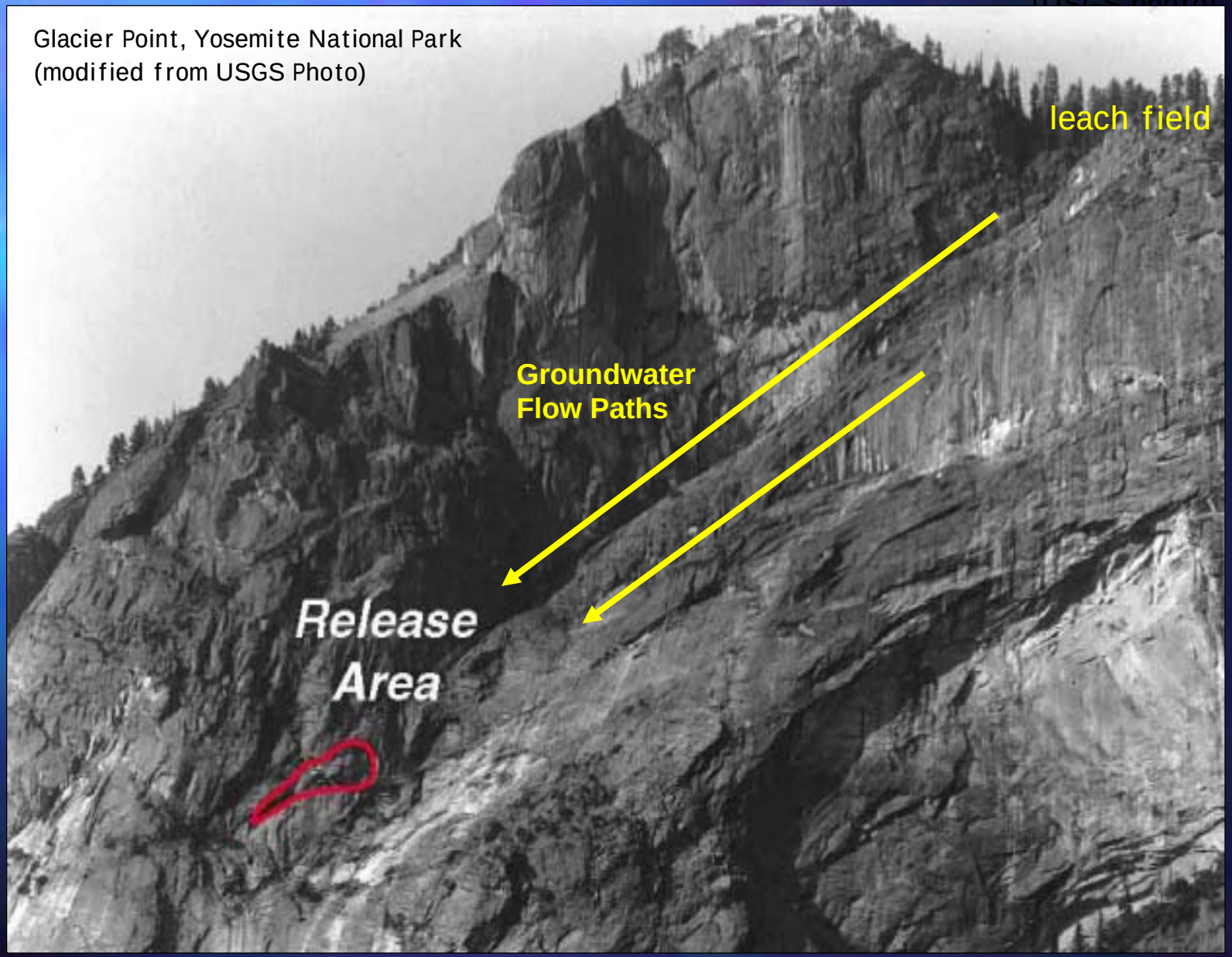
from USGS Open-file Report 99-385

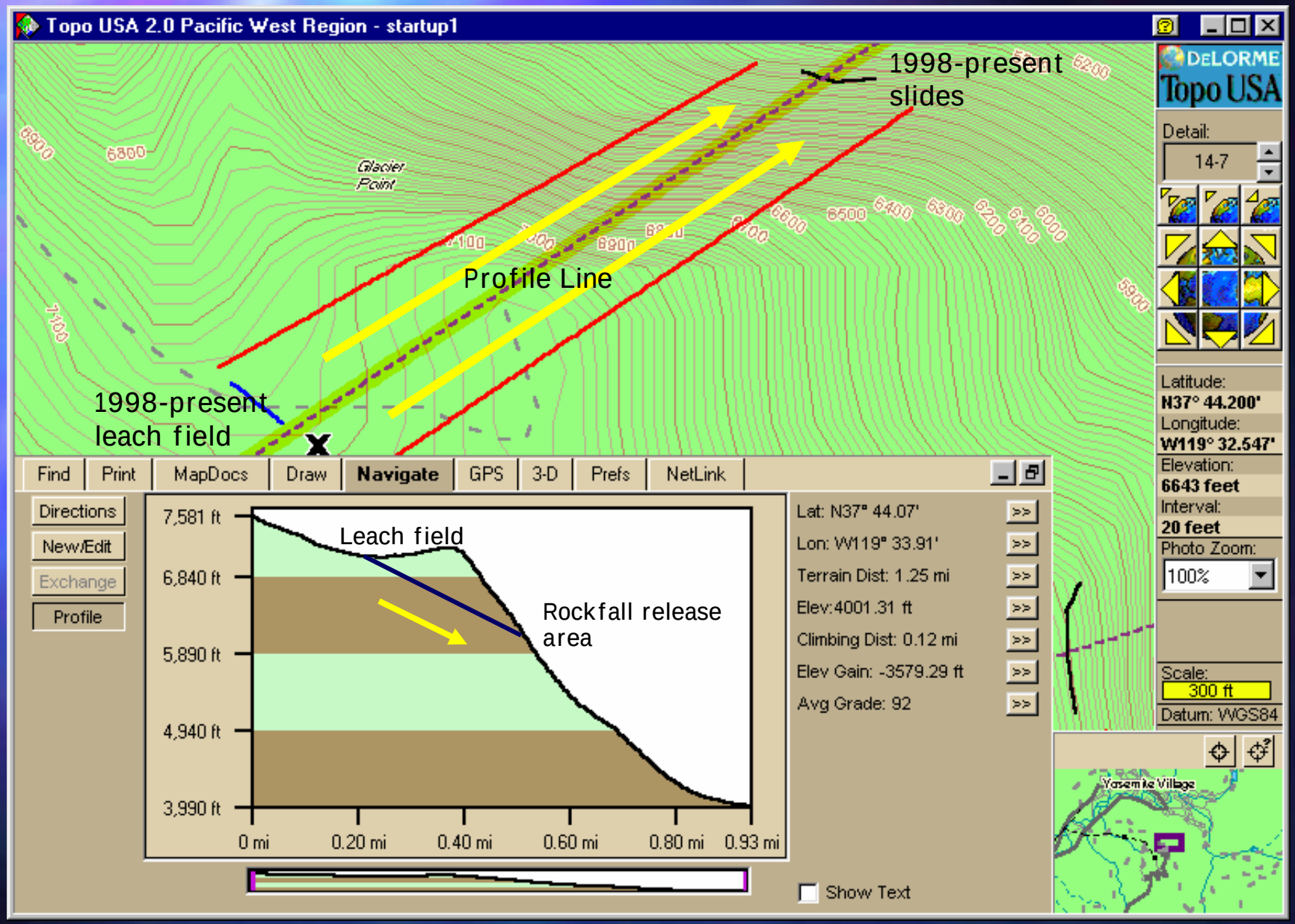
Water seepage is visible in these photographs of the Curry Village rockslide area

note helicopter for scale

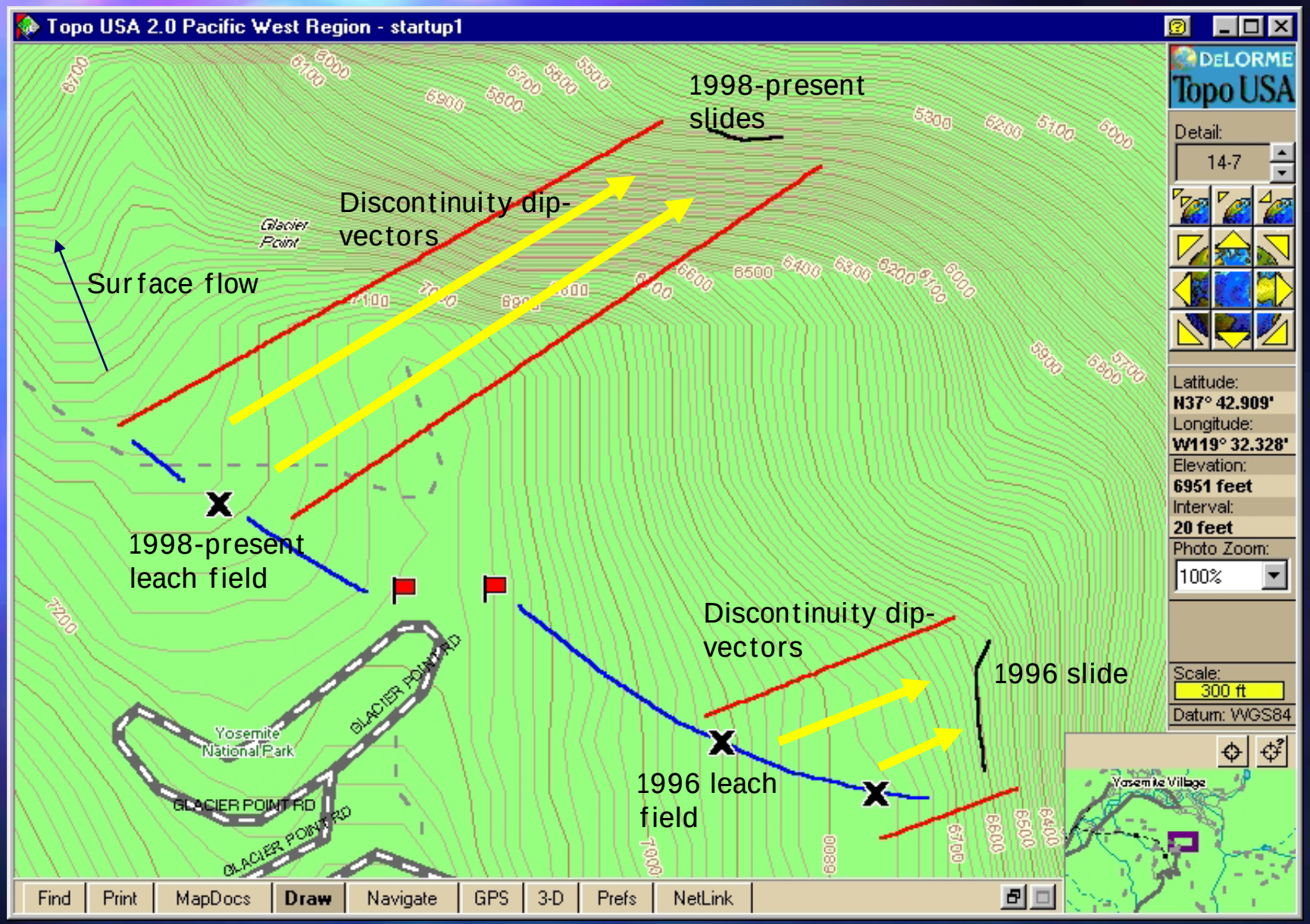


modified USGS diagram


Glacier Point, Yosemite National Park
(modified from USGS Photo)
leach field
Groundwater
Flow Paths
Release
Area



Flow path to Curry Village 1998-present rockfall source area



Structural flow path analyses: dominant discontinuity dip-vectors indicate most probable flow from septic leach fields to slide sites

The Salt Lake Tribune
Utah's Independent Voice Since 1871

Geologist Says Restrooms Causing Yosemite Rock Slides; It's 'Crap,' Says Park Service

Tuesday, November 2, 1999

BY CHRISTOPHER SMITH
and LEE SIEGEL

The National Park Service is dismissing a geologist's contention that two deadly rock slides at Yosemite National Park may have been triggered by septic systems draining from park restrooms.

Last month during the annual meeting of the Association of Engineering Geologists in Salt Lake City, Chester "Skip" Watts, director of Radford (Va.) University's Institute for Engineering Geosciences, delivered a scientific paper that found so-called "rockfalls" in 1996 and last June from the towering face of Yosemite's Glacier Point in northern California were possibly caused by the discharge of sewage on the slope above where the huge granite slabs sloughed off.

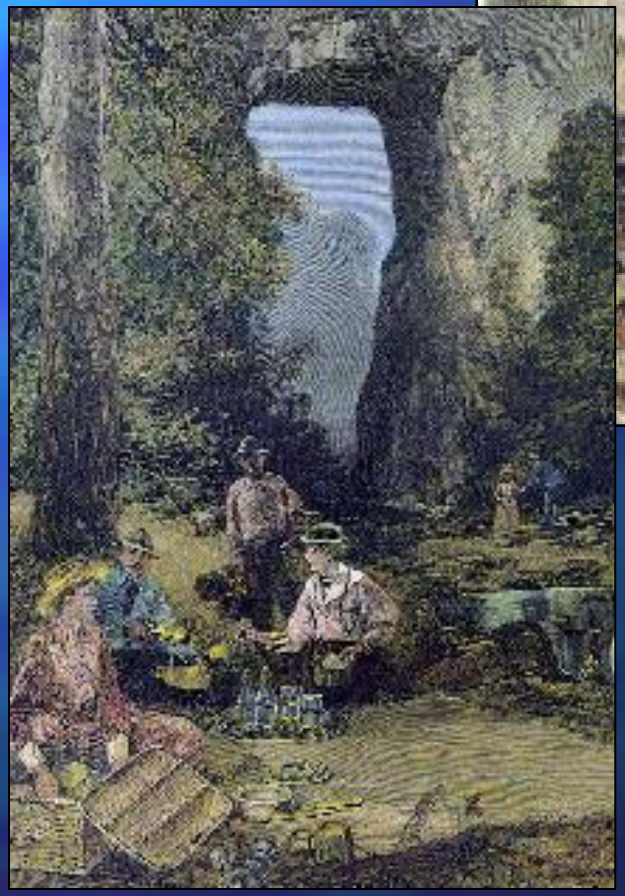
Watts also has presented the findings personally to Park Service

Natural Bridge of Virginia

- 215’ tall, spanning a canyon 90’ wide
- approximately 55’ thick
- only known natural arch in the world to have a highway across it - U.S. Rt 11

historical interest...

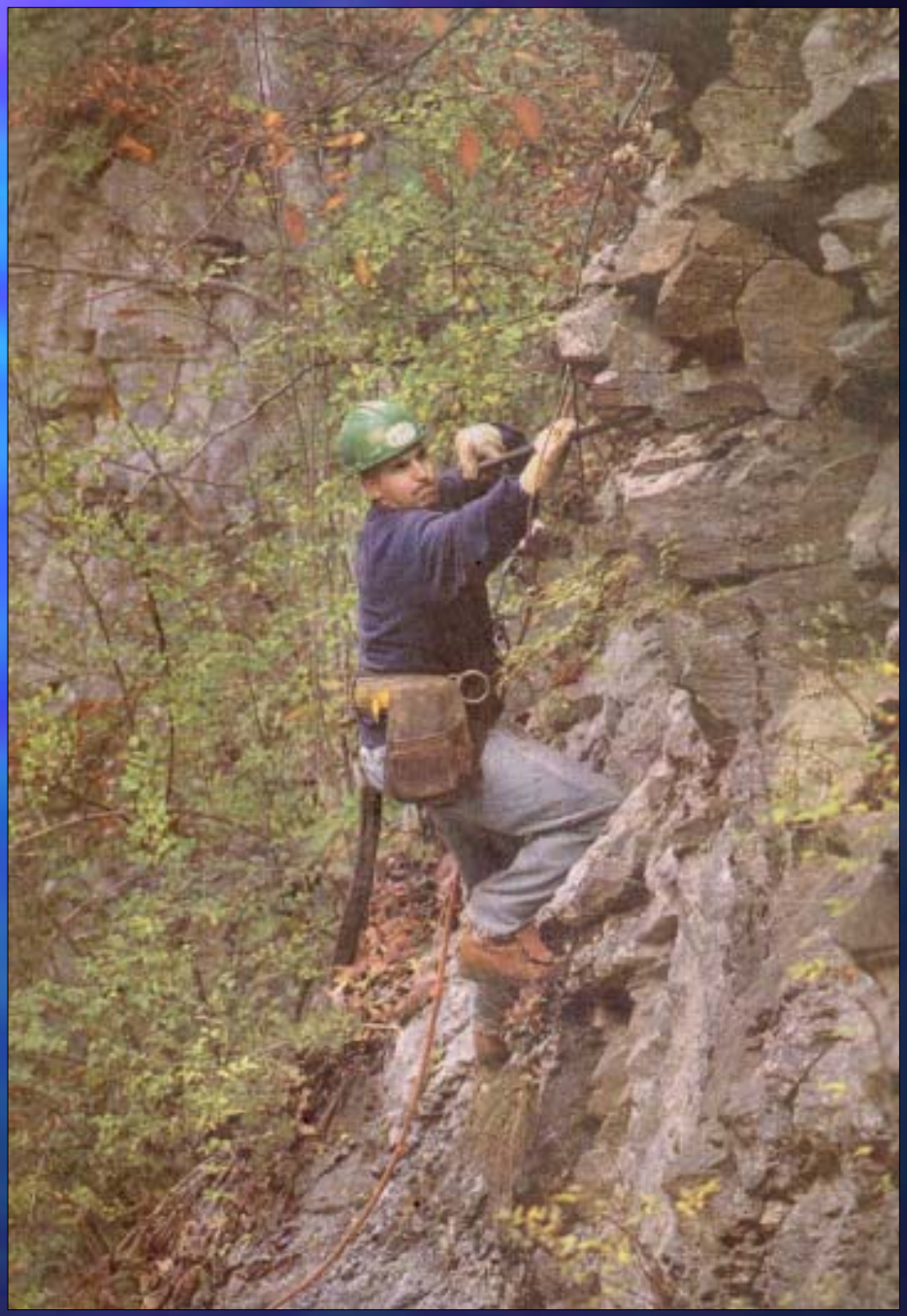
- Purchased by Thomas Jefferson in 1774 from King George III
- Held by heirs until 1833
- Present owner purchased it in 1984



Saturday
October 23, 1999

A slab of rock approximately 6’ long, 2’ feet thick, and 3’ wide falls from the ceiling of the natural arch, killing a tourist

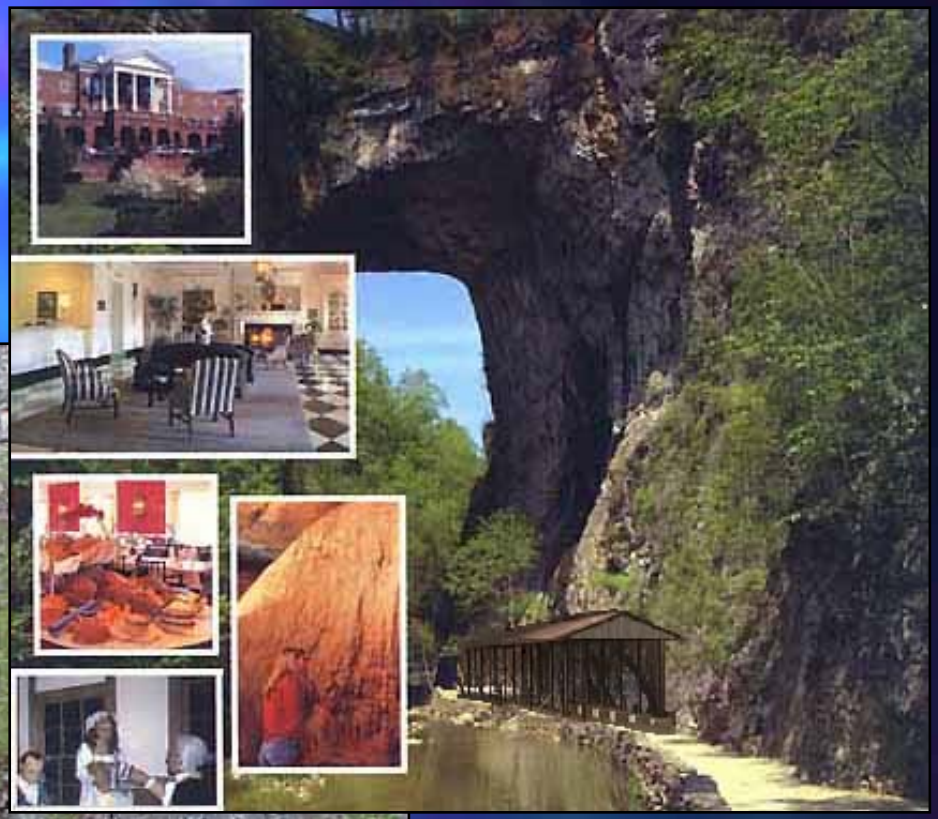
Scaling…



Rock bolts...

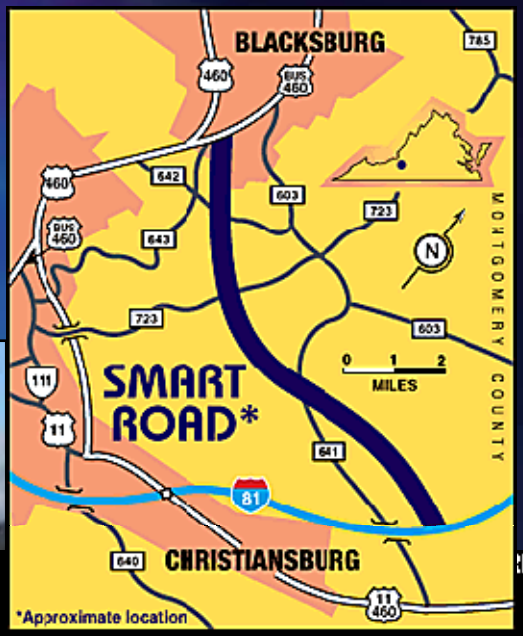

RTE. 130 EAST
KEEP RIGHT
CHEVROLET
300

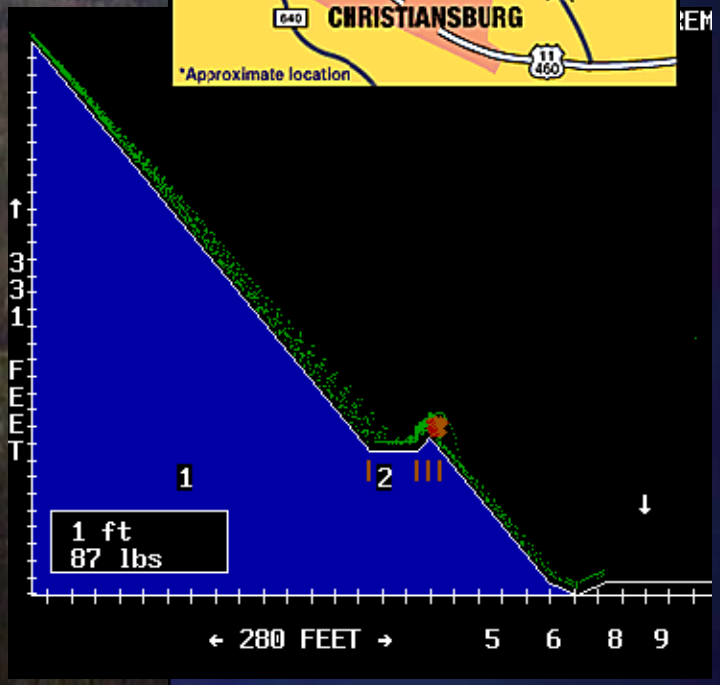

RTE. 130 EAST
KEEP RIGHT



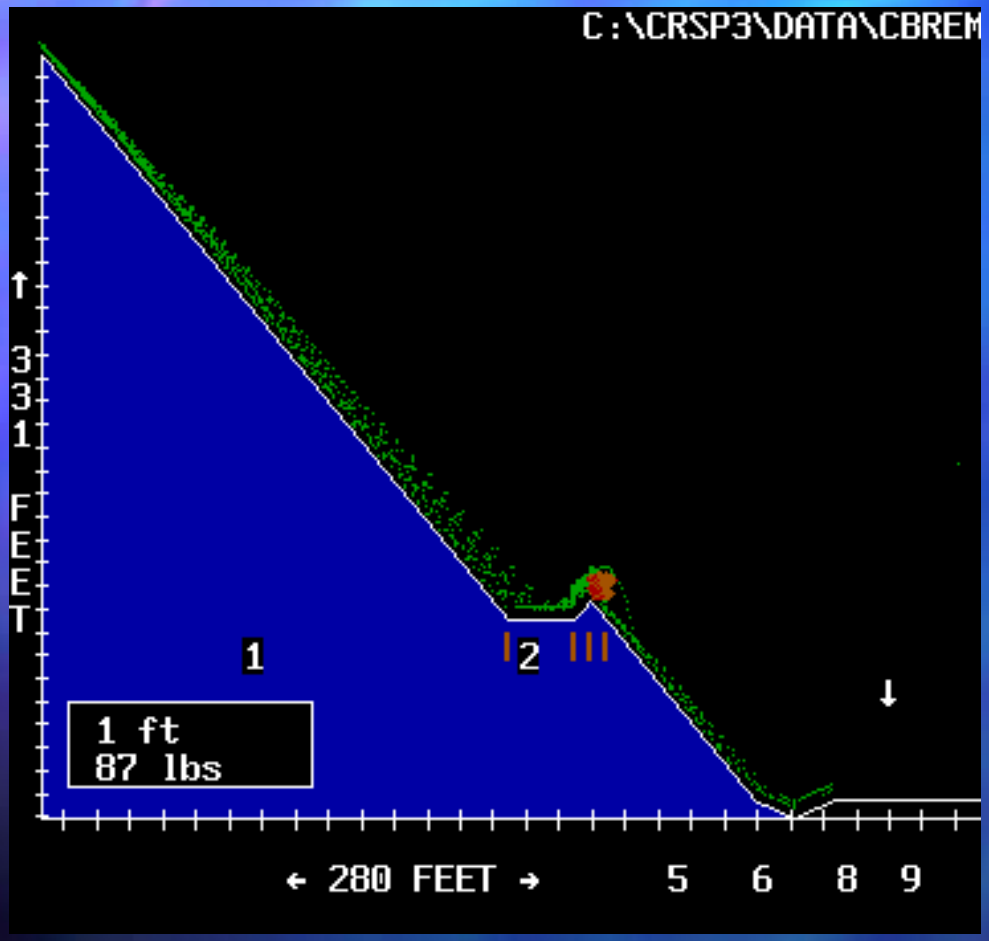
VDOT We Keep Virginia Moving

The Smart Road





Rockslides vs rockfalls...



Colorado Rockfall Simulation Program
CRSP

The design dilemma:

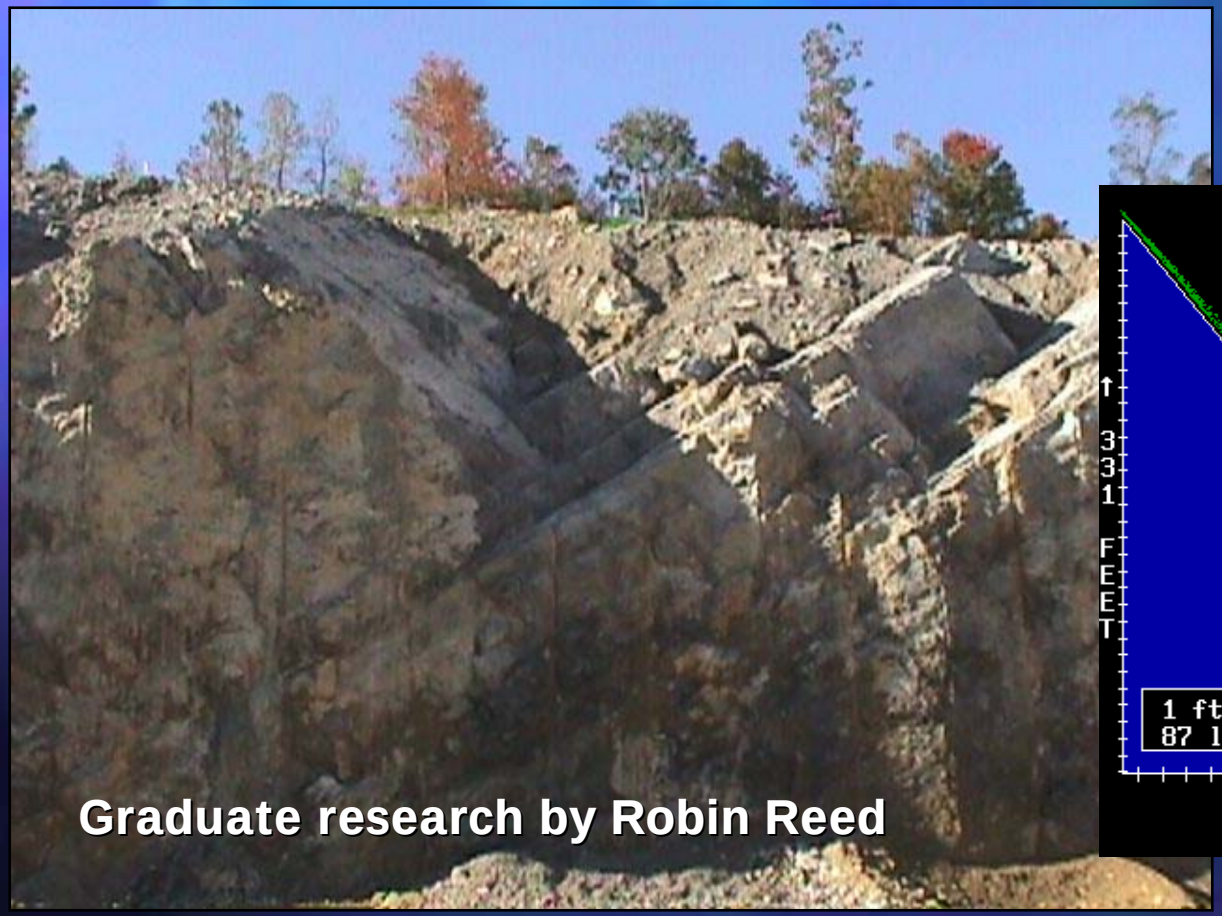
- vertical slopes are <u>not</u> usually the best, thanks to discontinuities

- work with the geologic structures first to eliminate rockslides

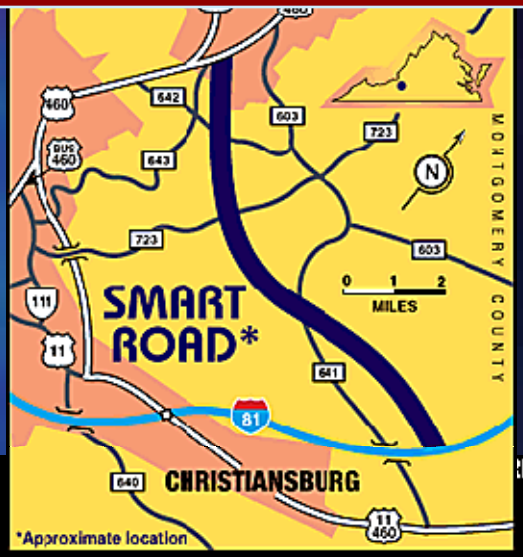
- then mitigate falling and rolling rock with barriers & mesh

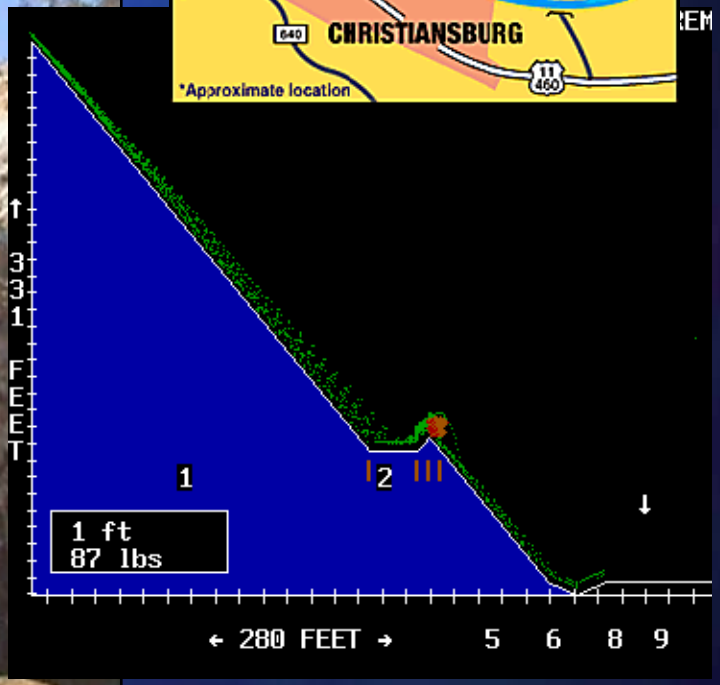
Rock slope case histories...

Va Dept of Transportation - HiTech Smart Road

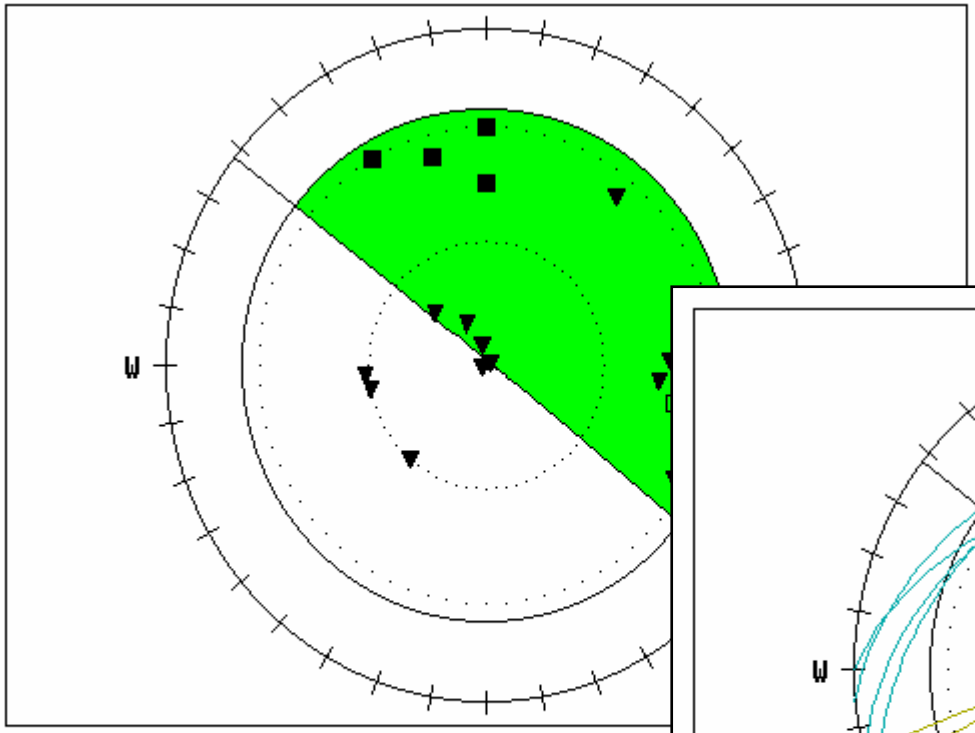


Graduate research by Robin Reed

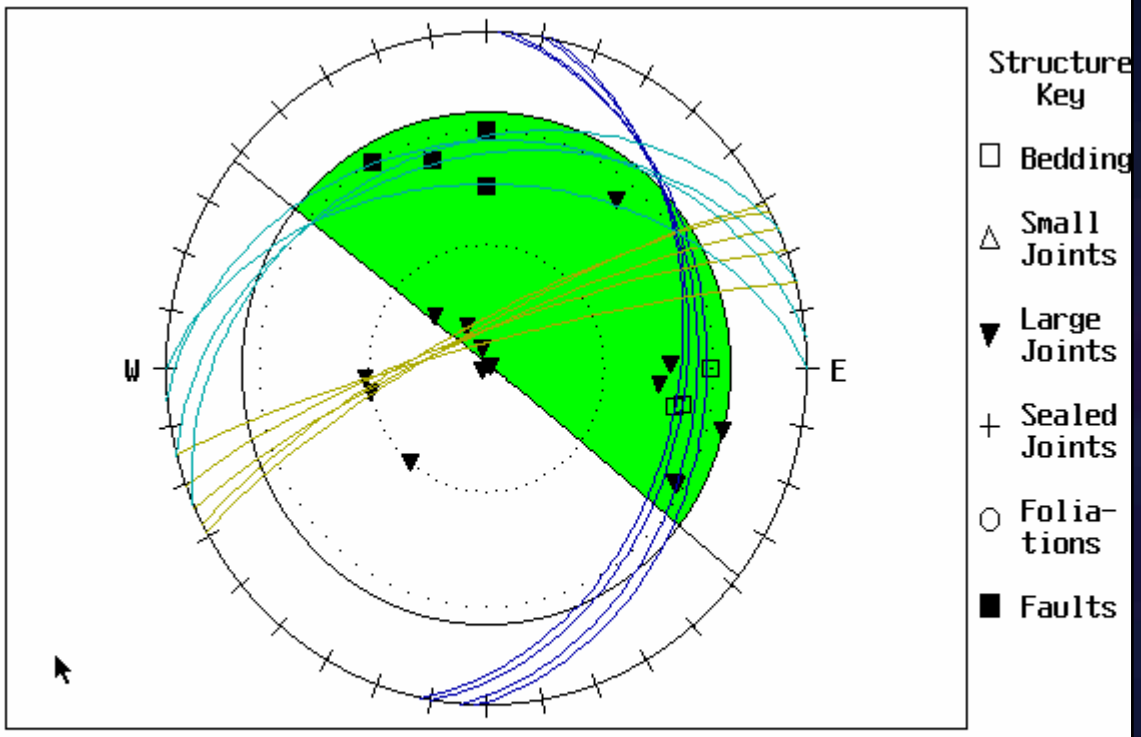




VDOT We Keep Virginia Moving



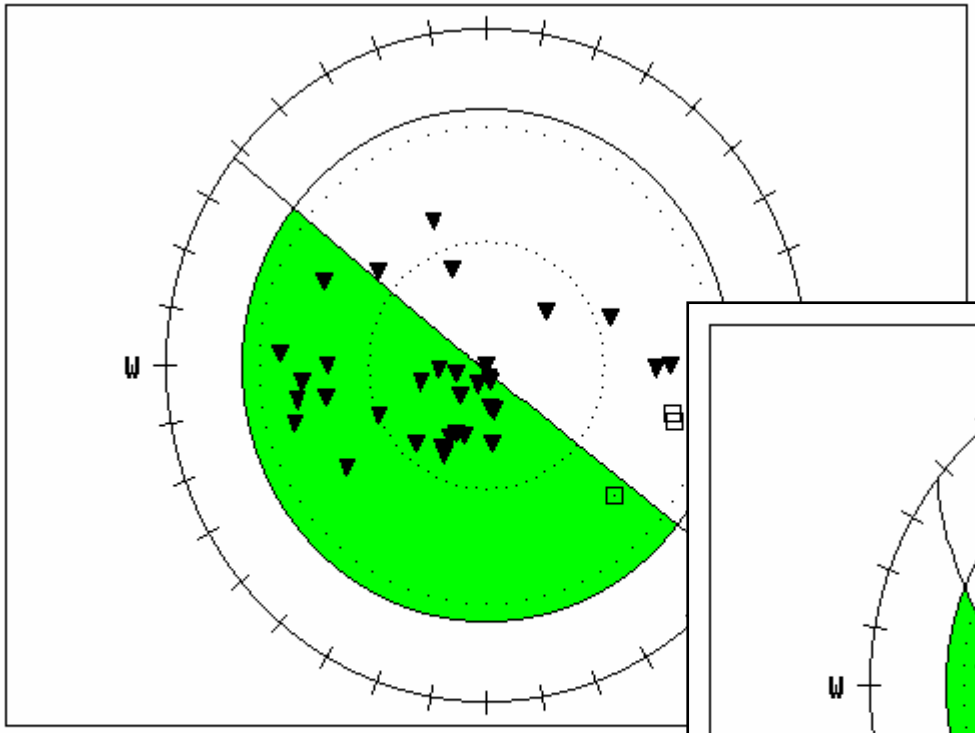
MARKLAND TEST PLOT: c:\rkpk2-04\data\a207
Friction Angle = 25 degrees
Slope dip direction = 38 degrees, Dip =
Number of Stations = 21



MARKLAND TEST PLOT: c:\rkpk2-04\data\a20714.DAT
Friction Angle = 25 degrees
Slope dip direction = 38 degrees, Dip = 90 degrees
Number of Stations = 21


KOBELCO

VDOT We Keep Virginia Moving



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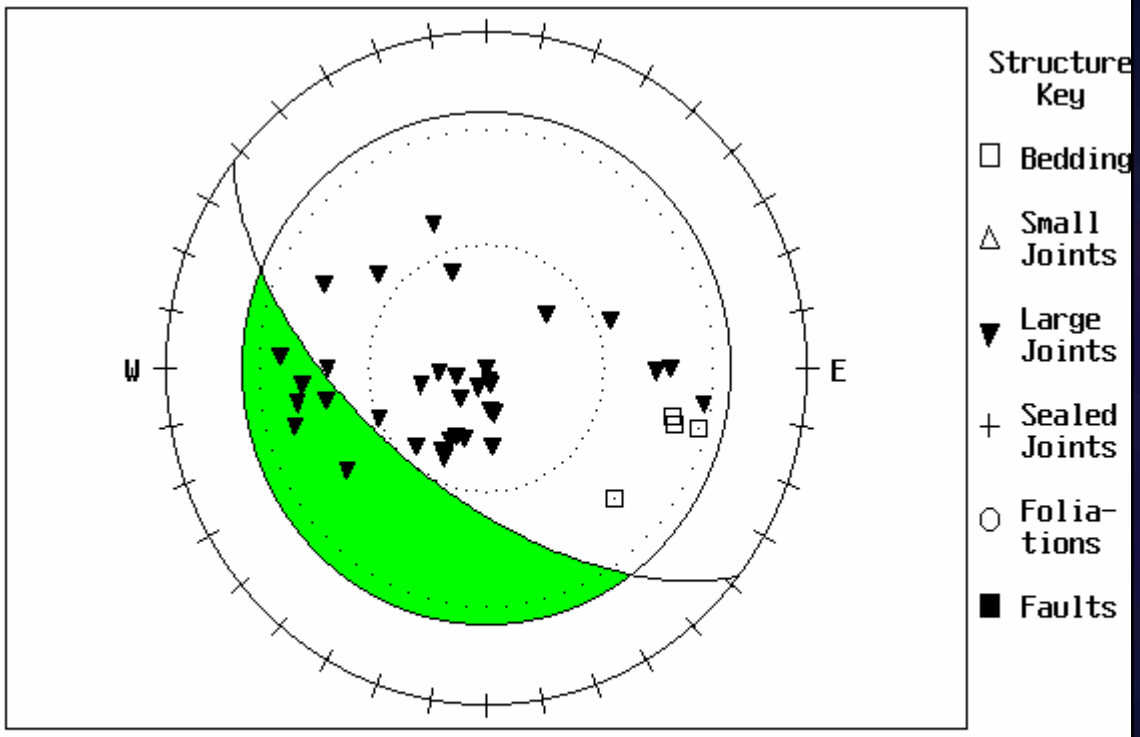
Slope dip direction = 218 degrees, Dip =
Number of Stations = 38



MARKLAND TEST PLOT: c:\rkpk2-04\data\a1&30714.DAT
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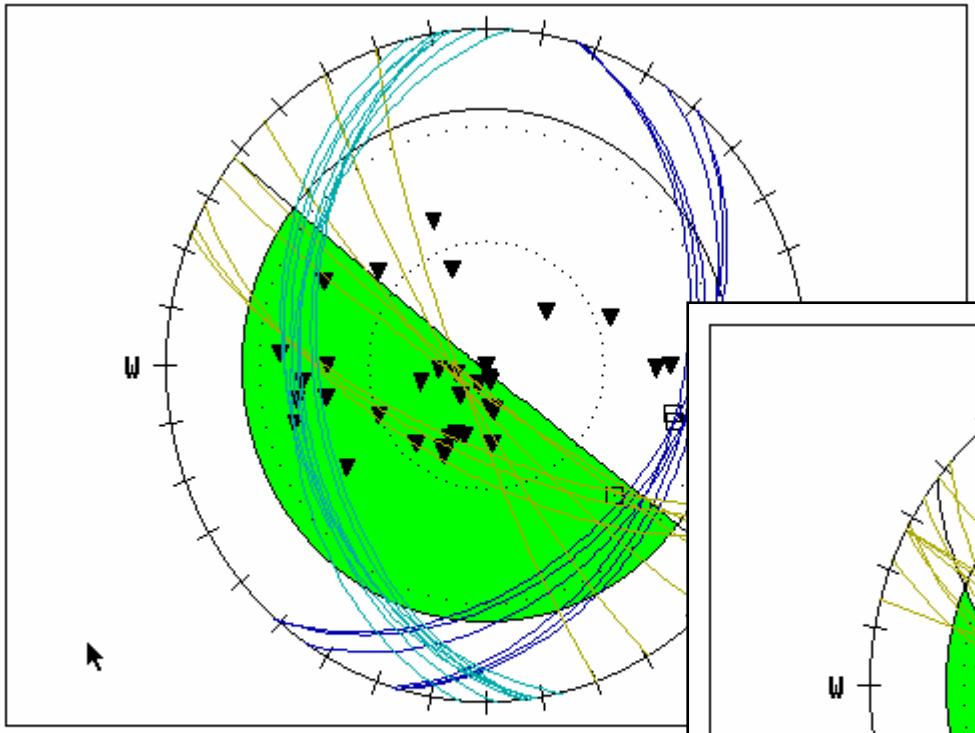
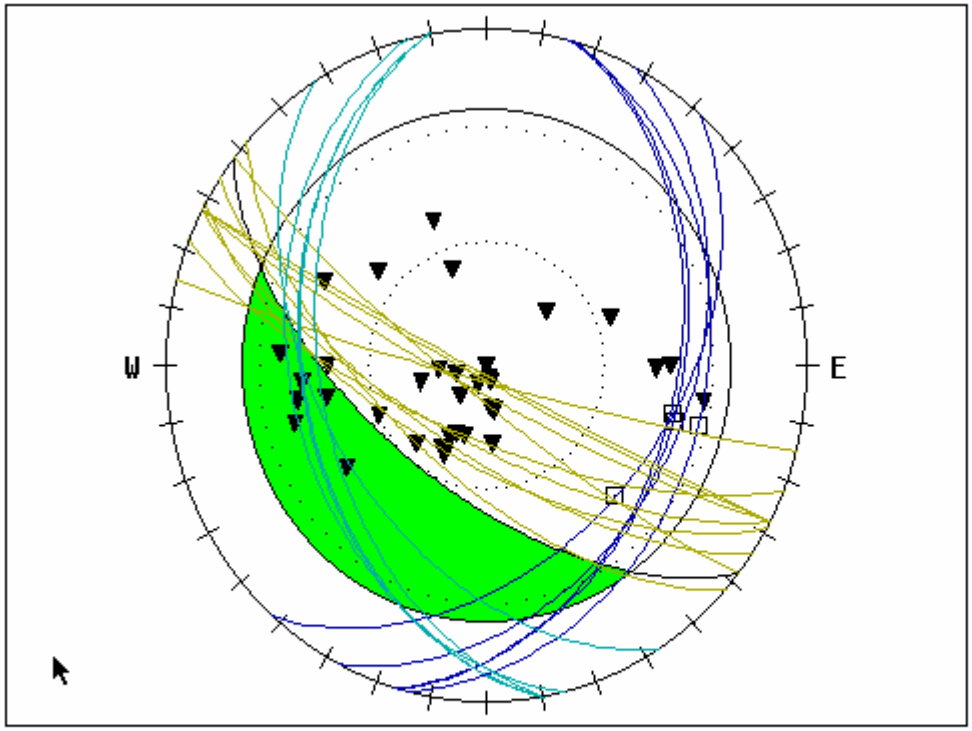
Number of Stations = 38

VDOT We Keep Virginia Moving



MARKLAND TEST PLOT: c:\rkpk2-04\data\a1&30
Friction Angle = 25 degrees
Slope dip direction = 218 degrees, Dip =
Number of Stations = 38



MARKLAND TEST PLOT: c:\rkpk2-04\data\a1&30714.DAT
Friction Angle = 25 degrees
Slope dip direction = 218 degrees, Dip = 60 degrees
Number of Stations = 38

Structural Rock Slope Stability Evaluation of Jefferson Rock Harpers Ferry National Historical Park

Daniel R. Gilliam Chester F. Watts William P. Anderson

November 1, 2002

Department of Geology, Radford University
Radford, Virginia 24142

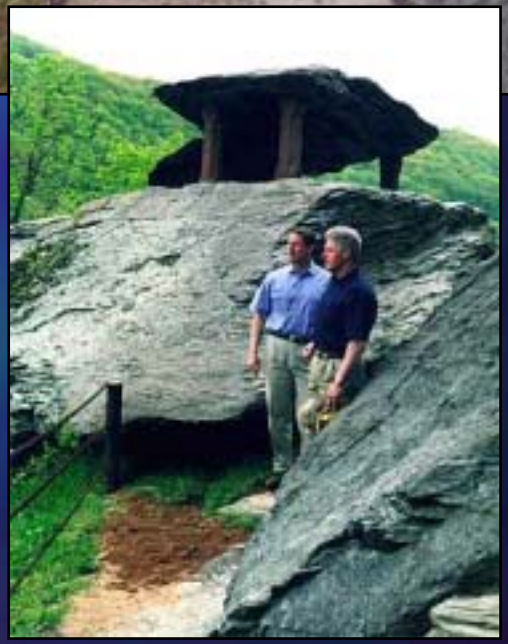
Circa 1810

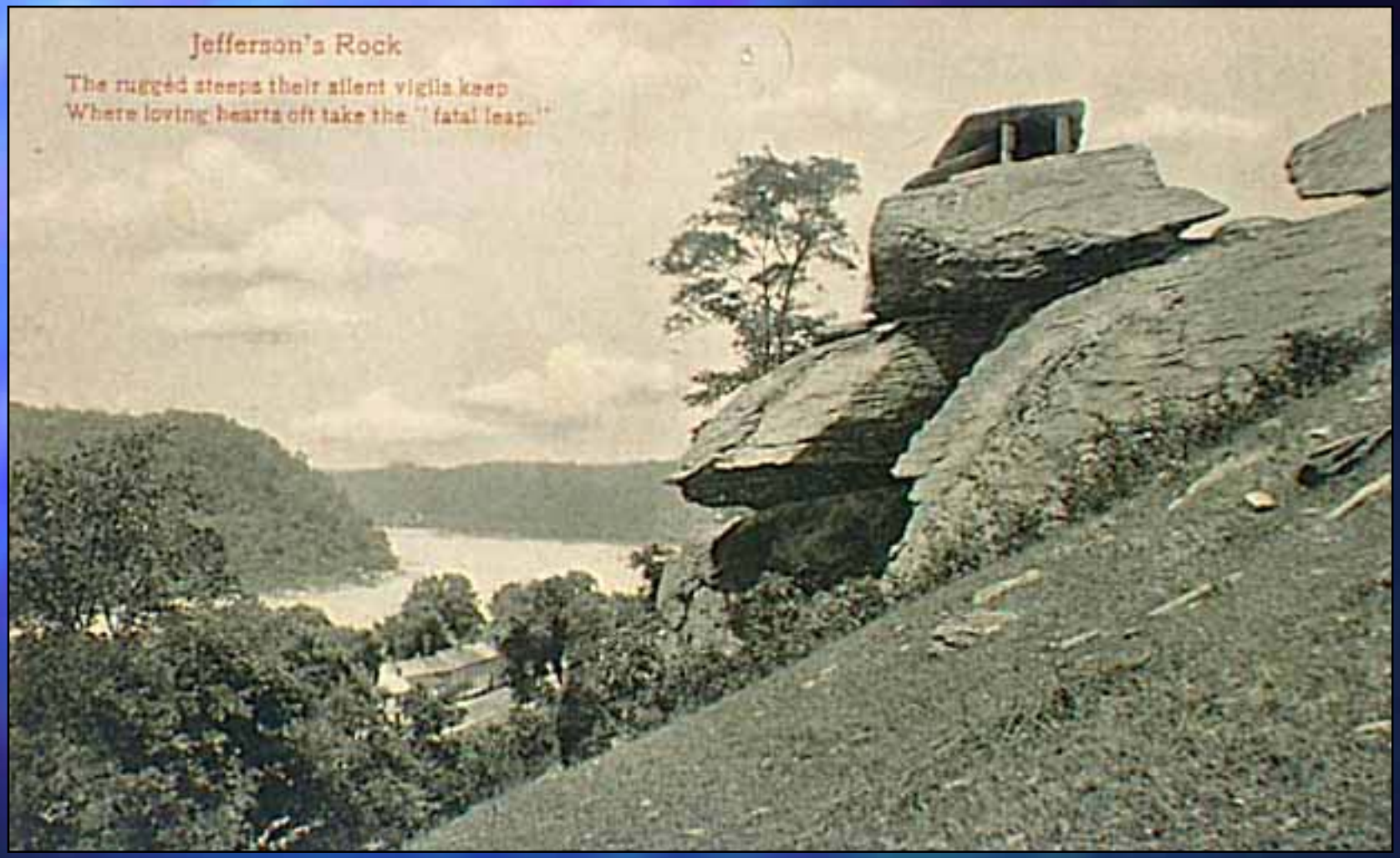
Circa 1890

Circa 1896 - 1902

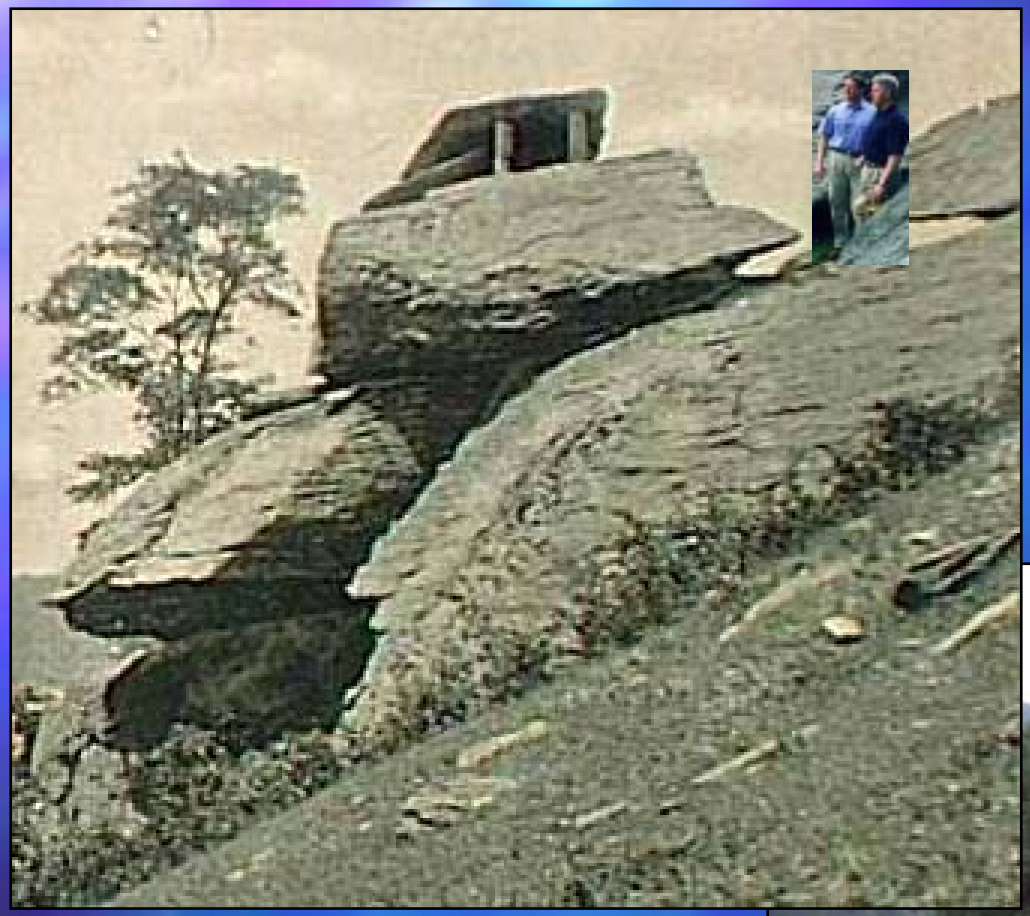
2002


9. 15. 2002



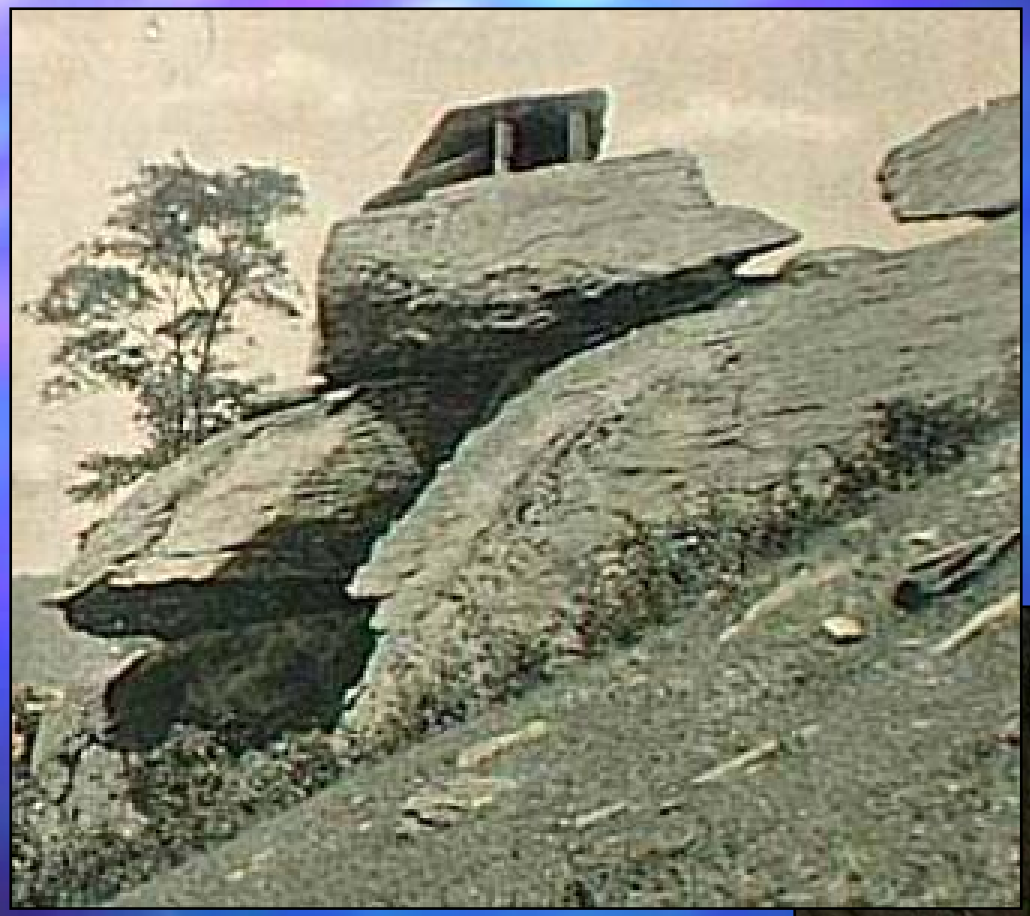

Jefferson's Rock
The rugged steeps their silent vigils keep
Where loving hearts oft take the "fatal leap."

Circa 1908



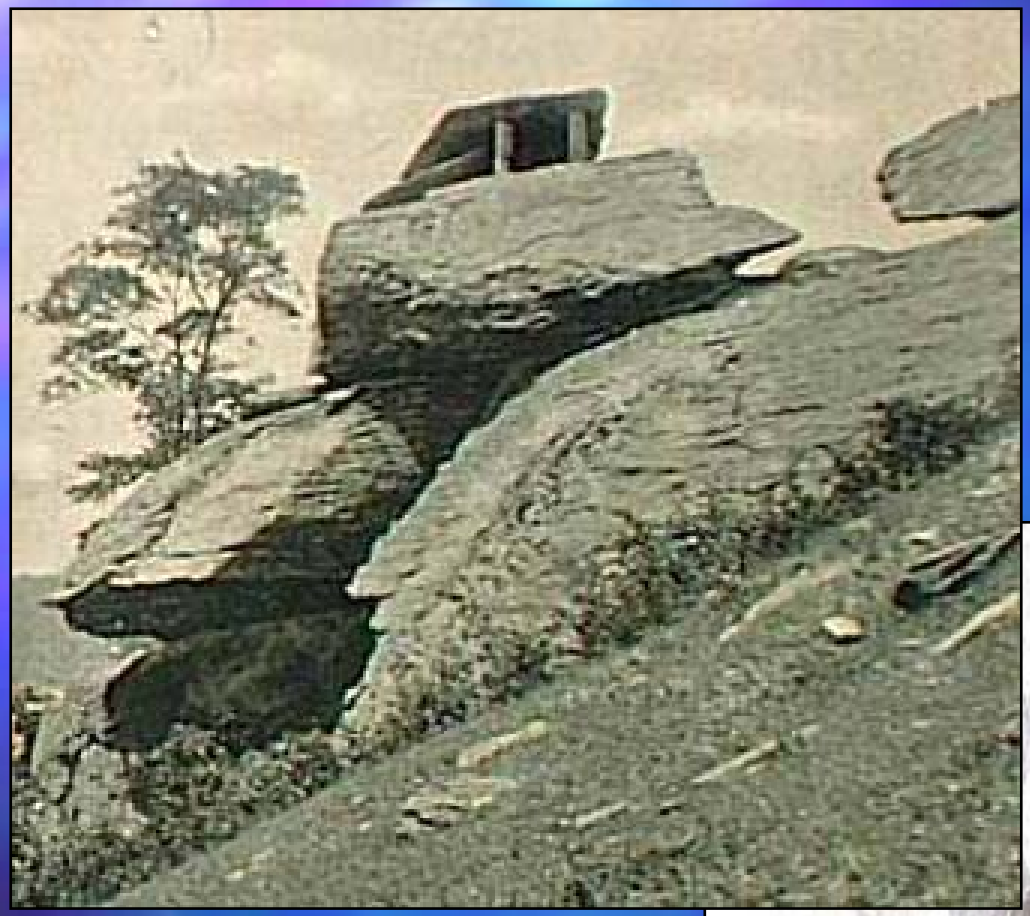
Circa 1908

Today



Circa 1908

Today



Circa 1908

Today

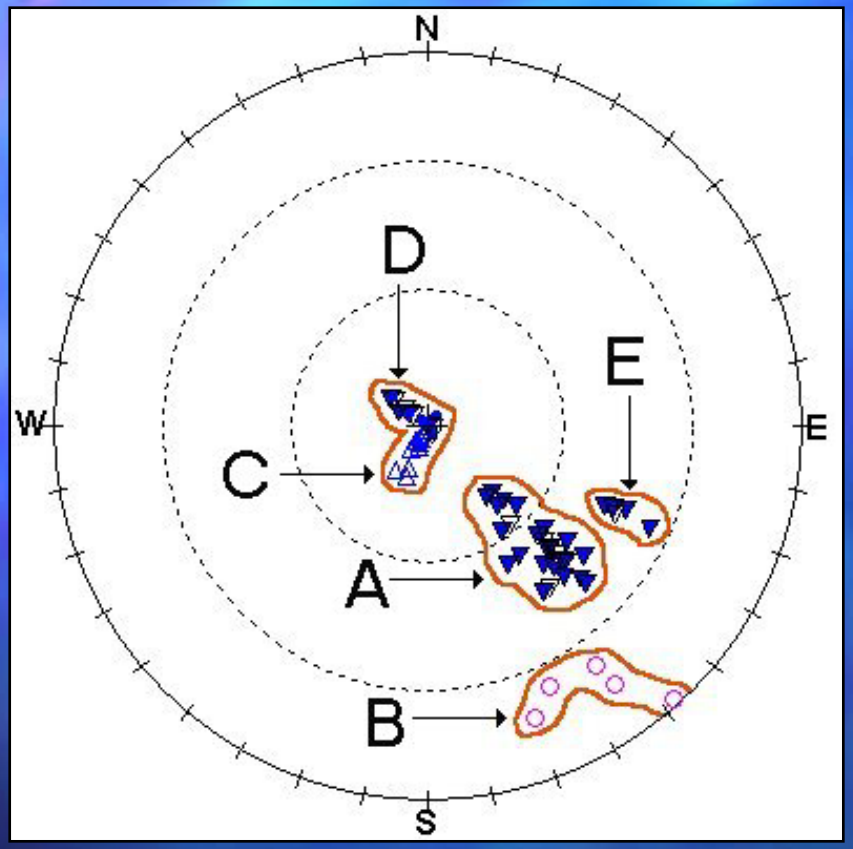
Geology

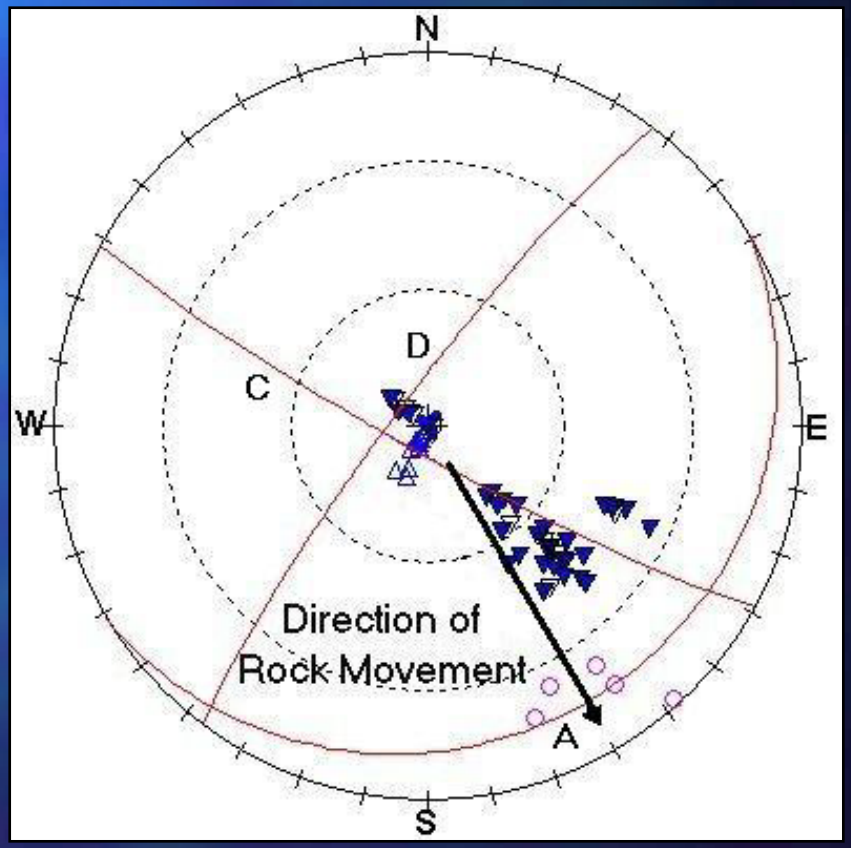
- Jefferson Rock is comprised of rock blocks of the Harpers Formation, a weak phyllitic shale.
  - Tectonic collisions created regional faulting and jointing (fracturing)
  - The fractures repeat in regular patterns and are regional and local.
  - The stability is controlled by these fractures and joints, as well as by the natural bedding planes and foliations.

Rock Block Designations

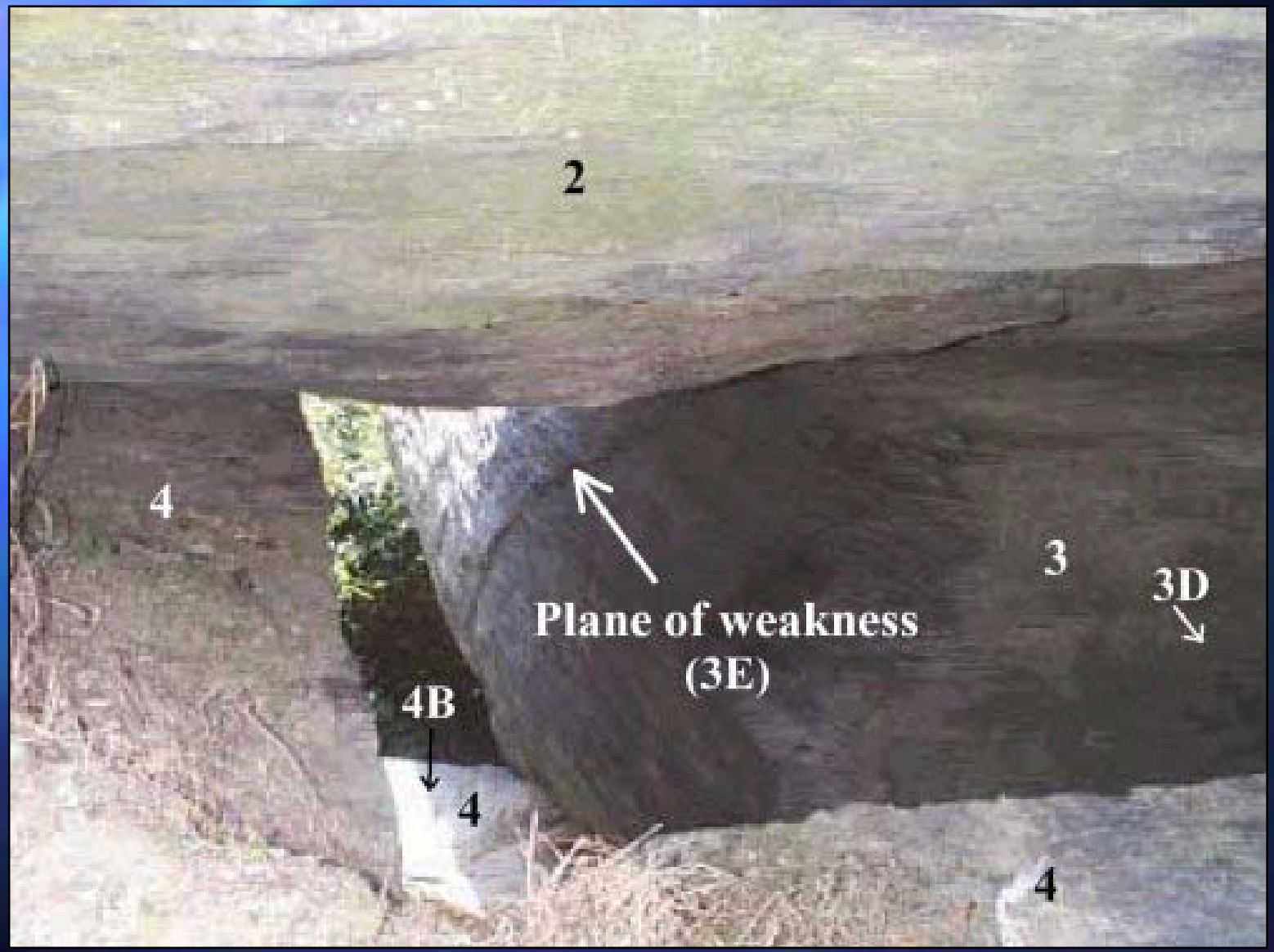
- The original numbering system used by Cloues and Ellis was retained.

Stereonet Analyses



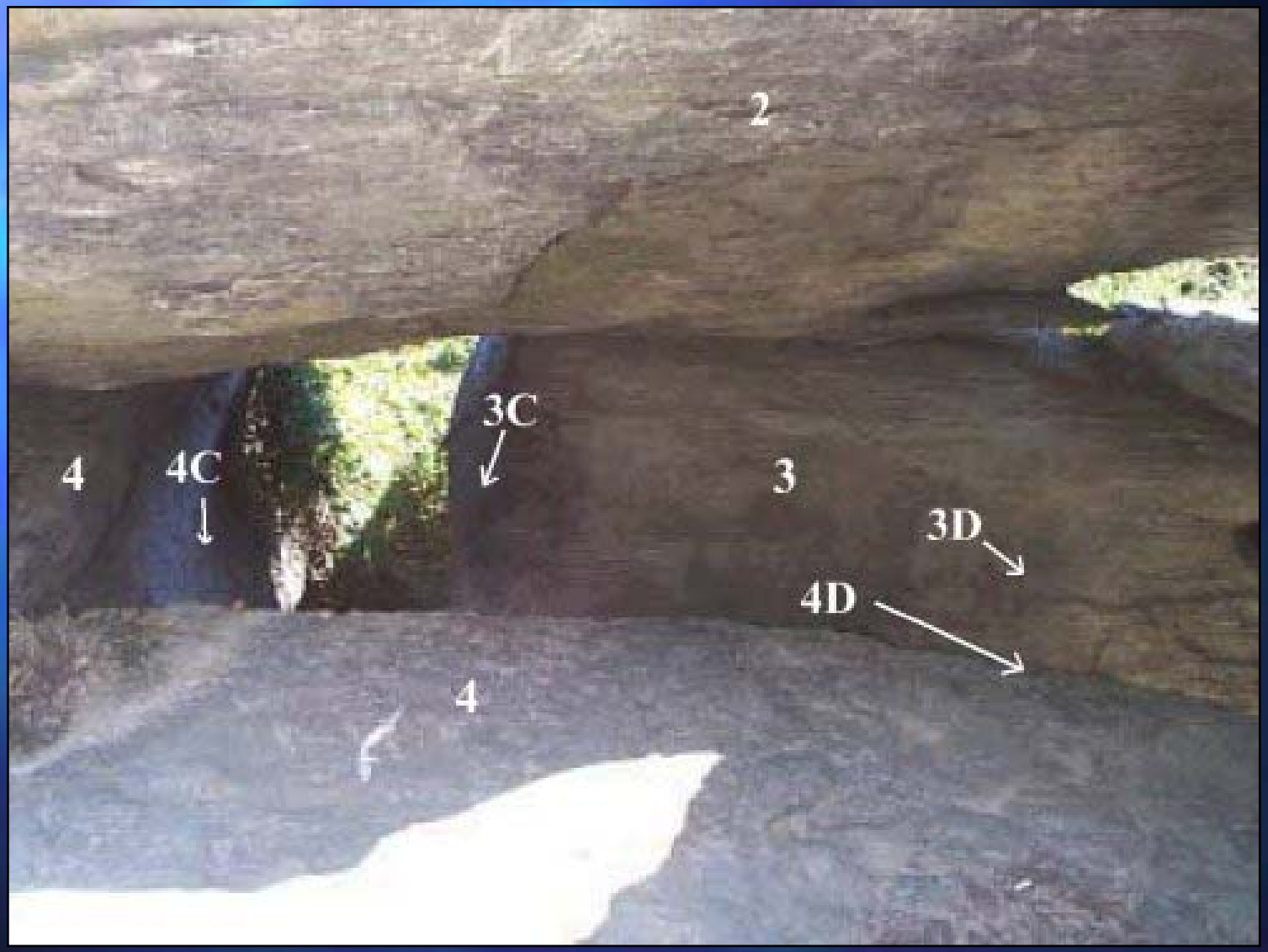


Discontinuities



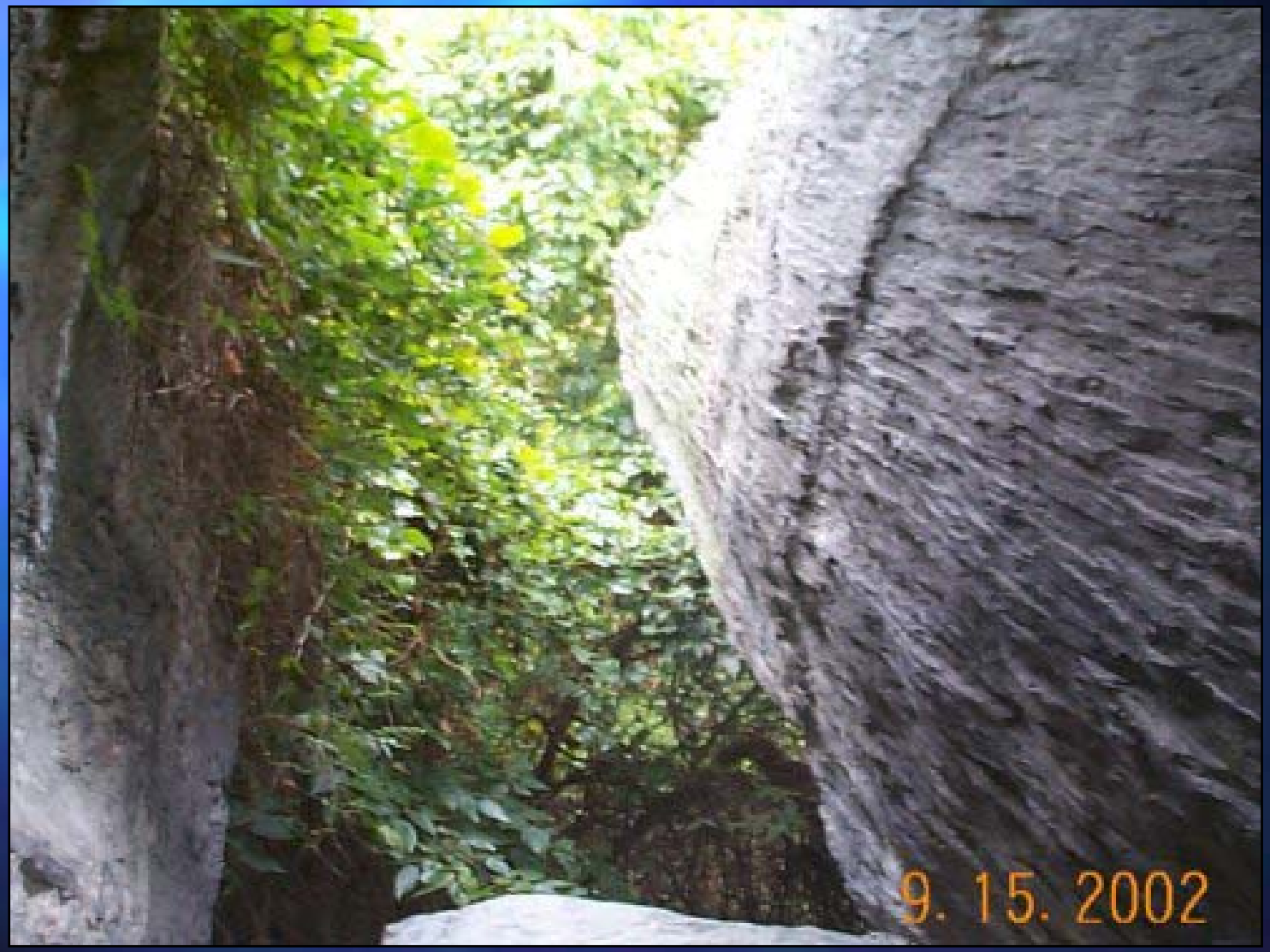
Discontinuities

Discontinuities



45° Potential Release Surface

Different View of 45° Surface



View of Rock with 45° Surface from Underneath

Direct Shear Test Analysis Results

Sample Number	***Description***	***Cohesion***	***Friction Angle***
Sample 1	Natural surface	-33.03 psf	33.42°
Sample 2	Natural surface	-22.49 psf	31.24°
Sample 3	Saw cut surface	-62.04 psf	29.74°

Factor of Safety Calculations

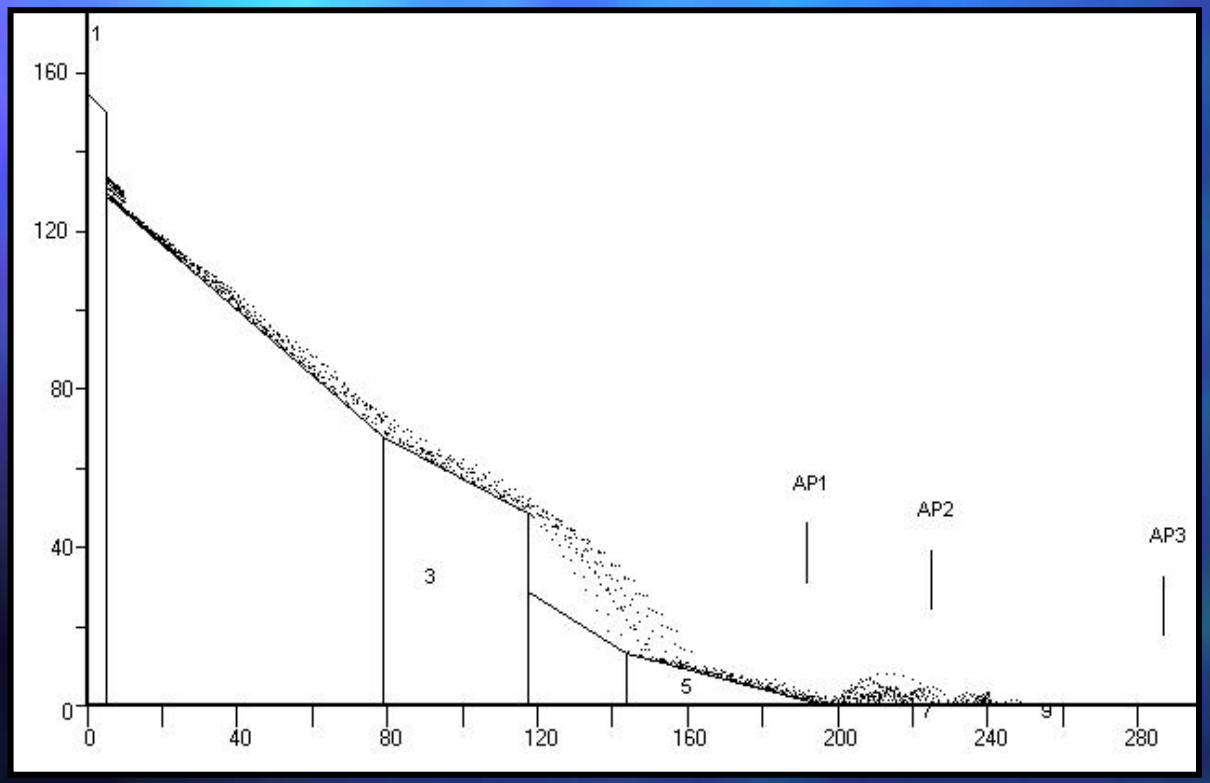
- Analysis for planar failure along discontinuity 3E indicates that the rock mass at the end of the rock block #3 has a factor of safety of 1.073

- This indicates that the rock piece is only marginally stable
  - As an example, general highway work considers 1.25 to 1.30 to be acceptable for public safety.

Area of rock fall simulation

(Pins indicate GPS readings taken during a rappelling traverse from Jefferson Rock directly to the roadway below.)

Colorado Rockfall Simulation Program Analysis



- A total of 18 different scenarios were developed, with 100 rocks being rolled in each run, for a total of 1,800 rocks
- Of greatest concern rock generated from the end of rock block #3 by discontinuity 3E
- A failure would result in a falling rock estimated to be about 15’ across
- According to the analysis, about 25% of rocks this size in the CRSP simulation reach the road, and some actually make

Issues

Stability at the site focuses on two issues

- potential slow creeping movement of rock block #3 along gently dipping discontinuity B.
  - long-term slow movement of rock block #3 could eventually lead to the collapse
  - That movement should be detectable by monitoring and is expected to give ample warning
- Of greater concern is a potential sudden rock fall that could occur from the overhang of rock block #3
  - it could pose a hazard below the site.
  - Computer modeling indicates that a rock from such a failure could roll to the road below and possibly make it to the walking path

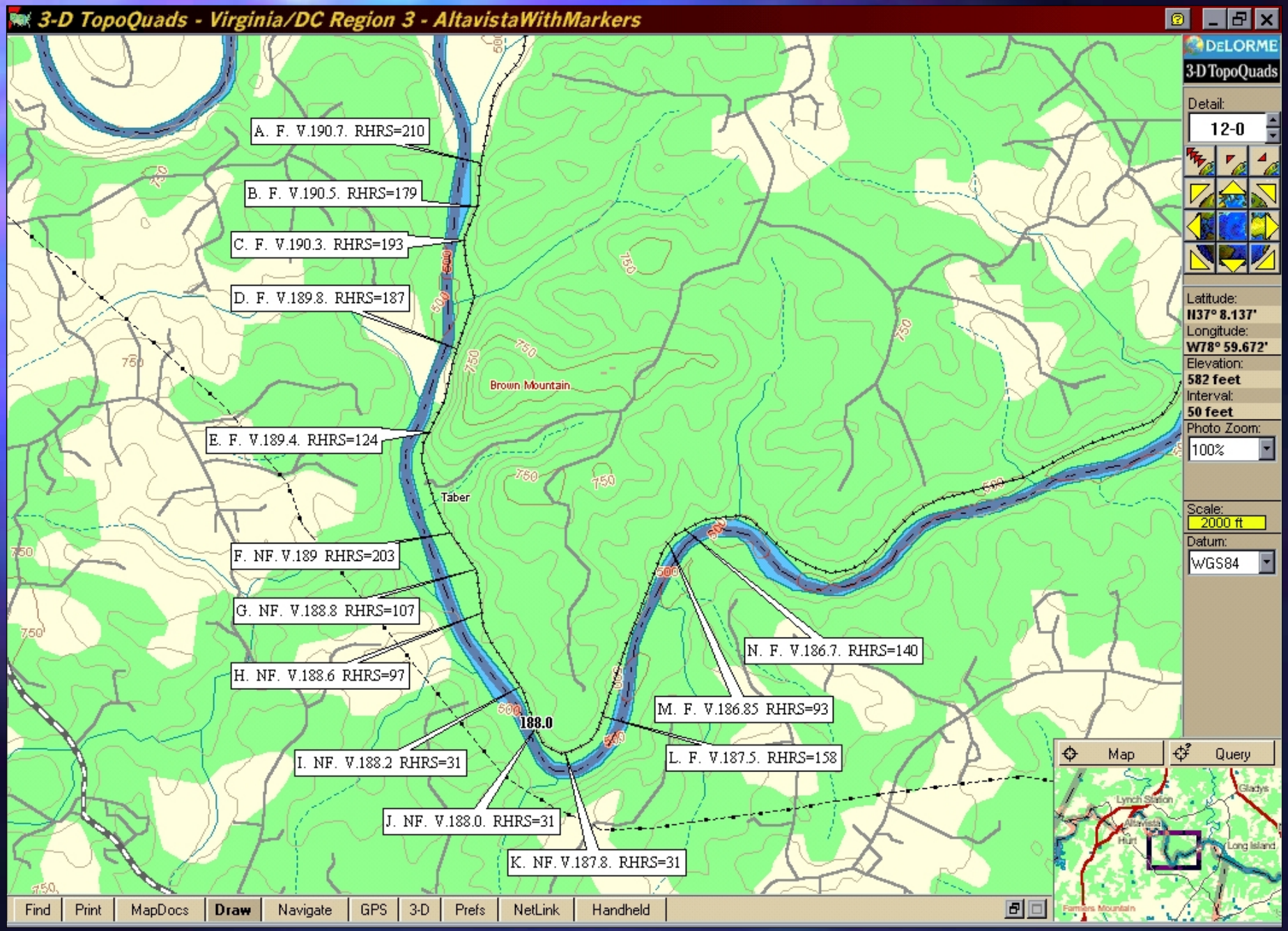
Recommendations

- Mitigating potential sudden failure along discontinuity 3E
  - Seal selected discontinuities in rock blocks #3 and #4 with an impermeable compound to prevent water infiltration
  - Install natural-looking rock fall barrier(s) at the base of slope to protect the road and walking path
  - Install rock bolts into rock block (#3) to provide artificial support and to secure the potential rock fall mass it contains

- Extensometer Monitoring
  - Monitoring of block #3 along discontinuity B should continue
  - This will allow any slow motion to be detected
  - Monitoring of discontinuity 3E is recommended by attaching crack gauges at key locations with epoxy

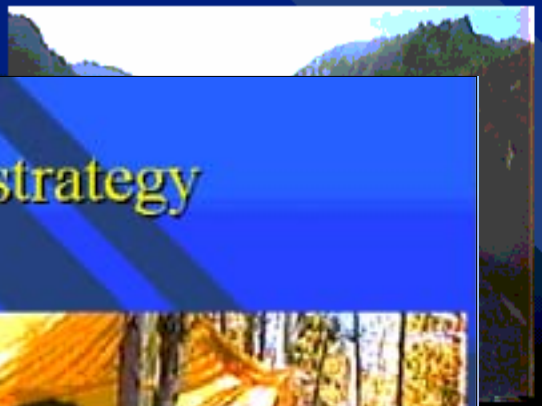
Special Thanks

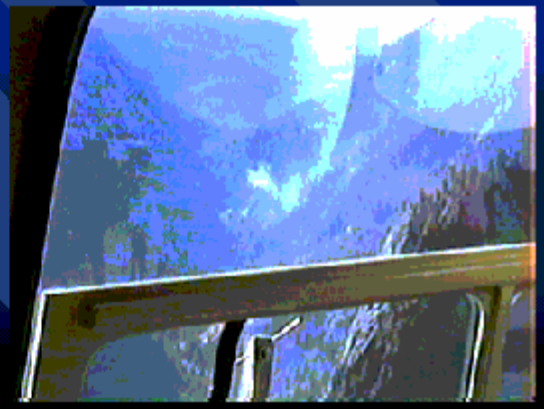
- Special thanks are extended to:
  - Bill Hebb, NPS, for overseeing this project, giving us the opportunity to do the study, and being patient with us as we completed it
  - Dale Nisbet, NPS, for assistance, taking digital pictures, and providing wonderful company
  - Jae Martin, NPS, for assistance, company, and being gutsy enough to learn to rappel so she could stay with us


3-D TopoQuads - Virginia/DC Region 3 - AltavistaWithMarkers
A. F. V.190.7. RHRS=210
B. F. V.190.5. RHRS=179
C. F. V.190.3. RHRS=193
D. F. V.189.8. RHRS=187
E. F. V.189.4. RHRS=124
F. NF. V.189 RHRS=203
G. NF. V.188.8 RHRS=107
H. NF. V.188.6 RHRS=97
I. NF. V.188.2 RHRS=31
J. NF. V.188.0. RHRS=31
K. NF. V.187.8. RHRS=31
L. F. V.187.5. RHRS=158
M. F. V.186.85 RHRS=93
N. F. V.186.7. RHRS=140
188.0
Brown Mountain
Taber
DeLORME
3-D TopoQuads
Detail:
12-0
Latitude:
N37° 8.137'
Longitude:
W78° 59.672'
Elevation:
582 feet
Interval:
50 feet
Photo Zoom:
100%
Scale:
2000 ft
Datum:
WGS84
Map
Query
Find
Print
MapDocs
Draw
Navigate
GPS
3-D
Prefs
NetLink
Handheld

Western Wildfires, summer of 1994

Lightning and sparks from chain saws have been blamed for causing the many wildfires that ravaged the west this summer.





Planning the strategy

After more than 200,000 acres of forest burned in the Wenatche Natl Forest, fire rehabilitation teams gathered to assess the damage.

Landslides are always one of the biggest concerns!

Installing rock bolts…

The End…