Rockslides!

Case Histories, Misconceptions & Public Policy
2003 AEG/GSA Jahns Distinguished Lecture Series

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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

Richard H. Jahns (1915-1983) was an engineering geologist who had a diverse and distinguished career in academia, consulting, and government.
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.
September 11, 2001: Defining moments for a year on the Hill
Capitol Hill
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...
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

Glacier Point, Yosemite National Park
(modified from 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.

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.

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

Read dip direction of plane. In this case, dip direction is
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<th>Data Set</th>
<th>Discontinuity</th>
<th>Traverse Trend</th>
<th>Distance</th>
<th>Dip Direction</th>
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<th>Rock Type</th>
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Examples of roughness profiles:

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

Stereonet analyses

Safety factor calculations

MARKLAND TEST PLOT: c:\rpc2-04\data\problem.DAT
Friction Angle = 20 degrees
Slope dip direction = 75 degrees, Dip = 85 degrees
Number of Stations = 40
STEREONET ANALYSES

Markland’s Test
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

Sample stereonet

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

The pink area is the critical zone for toppling failures.

Wedge & Plane failure analyses

Structure Key
- Bedding
- Small Joints
- Large Joints
- Sealed Joints
- Foliations
- Faults

Wedge failure analysis

Sample stereonet

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

The pink area is the critical zone for toppling failures.

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
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
### 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°
- **(CD)** Cohesive Strength of Failure Surface: 0 lb/ft
- **(PH)** Friction Angle of Failure Surface: 0°
- **(GR)** Density of Rock: 0 lb/ft³
- **(GW)** Density of Water: 0 lb/ft³

### Bolt Data

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

### Tension Crack Data

- **(AC)** Horizontal Acceleration: 0 g
- **(TZ)** Amount of Discontinuity: 0%
- **(VSUR)** Vertical Surchage: 0 lb
- **(HSUR)** Horizontal Surchage: 0 lb
- **(B)** Horizontal Distance of Tension Crack from Crest: 0 ft
- **(D2)** Relative Height of Water in Tension Crack: 0 decimal%

- **(Dry Slope)**
- **(Tension Crack Filled with Water)**

---

**Status:** READY
**Wedge Data**
- Include Tension Crack
- (TL) Distance of Tension Crack = 40 ft

**Cohesion and Friction Data**
- Plane 1: (C1) Cohesion = 500 lb/ft²
- (P1) Friction Angle = 20°

**Results**

**Factor of Safety = 1.14**

- Intersection of Planes 1 & 2:
  - Plunge = 31.2°
  - Trend = 157.73°
- Weight of Wedge = 28272195.3 lb
- Volume of Wedge = 176701.22 ft³
- Tension Crack Exists:
  - Maximum Free Draining Pressure on Both Planes = 0 lb/ft²
  - Water Pressure on Planes 1, 2, & 5 = 1082.53 lb/ft²
  - (V) Normal Force from Water on Tension Crack = 1998935.61 lb
  - (U1) Water Pressure on Plane 1 = 0 lb/ft²
  - (U2) Water Pressure on Plane 2 = 0 lb/ft²
  - (U5) Water Pressure on Plane 5 = 0 lb/ft²

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

- (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**

**Driving Forces = 15884016.43 lb**
SPECIFIC CASE HISTORIES

**The Salt Lake Tribune**

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

**By Christopher Smith**

**© 1996, 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 Geomorphics, 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 huge granite slabs sloughed off.

Watts also has presented the findings personally to the Park Service.
SPECIFIC CASE HISTORIES
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
Glacier Point, Computer-generated 3D View
(looking west)
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.
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

But then there were more...

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

BY CHRISTOPHER SMITH
and LEE SIEGEL

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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...
The Smart Road
The design dilemma:

- vertical slopes are **not** 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
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
**MARKLAND TEST PLOT: c:rkpk2-04\data\a1&30**

Friction Angle = 25 degrees
Slope dip direction = 218 degrees, Dip = 60 degrees
Number of Stations = 38
MARKLAND TEST PLOT: c:\rkpk2-04\data\a1\&30
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 1896 - 1902

2002
Circa 1908
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.
The original numbering system used by Cloues and Ellis was retained.
Stereonet Analyses

Direction of Rock Movement
Discontinuities

Plane of weakness (3E)

Discontinuities
Discontinuities

Plane of weakness
(4E)
Discontinuities
45° Potential Release Surface
Different View of 45° Surface
View of Rock with 45° Surface from Underneath
## Direct Shear Test Analysis Results

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<td>33.42°</td>
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<tr>
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<td>Sample 3</td>
<td>Saw cut surface</td>
<td>-62.04 psf</td>
<td>29.74°</td>
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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.
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...

Sunrise with dust from rockfall 7/11/96