Everyday Geospatial: New Technologies Anyone Can Afford for 3D Field Scanning, Point Cloud Processing, Rock Mass Characterization, Slope Stability (and monitoring)

John Kemeny

2024-25 Richard H. Jahns Distinguished Lectureship In Applied Geology

Professor Emeritus, University of Arizona

Honoring the Legacy of Richard H. Jahns

- Dr. Richard Jahns, professor of engineering geology, instrumental in the field as teacher, advisor, spokesman
- Lectureship was established in 1988 in sponsorship with AEG and the Engineering Geology Division of GSA.
- Lectureship provides funding for lectures at AEG chapters and academic institutions,
- Increase awareness about careers, professional organizations
- I am 37th Jahns Lecturer. Each lecturer different and brings a different perspective. **What perspective do I bring?**

Dick Jahns
1915-1983

What I can bring to the Jahns lectures

- Most of my career in rock mechanics, rock engineering
- I have been employed in consulting, government lab, academia, small business startup, total 45 years
- 35 yrs at University of Arizona, teaching/research in geomechanics, geospatial, rock fractures, design
- Successful spin-off company from UofA research, 22 years, sold to Hexagon Mining Division
- Since University retirement, focused on AI in Applied Geology to help combat climate change worldwide

Statue in Reykjavik Iceland

Connections Between My Five Jahns Talks

Rock Mechanics
What's it all about?

Entrepreneurship and
Careers in Applied Geo

Everyday Geospatial
for Rock Engineering

Innovative Monitoring
and Characterization
(with the help of AI)

Why is that Unstable
Rock Still Standing?
Rock Fracture Mechanics

Where Did I Go In 2025?

- Talks in Jan, Feb, Mar, Apr, May, Aug, Sept, Oct, Nov 2025
- About 50 talks so far (only a few more left)
- Mostly gave these 3 talks:
  - Everyday geospatial (talk 2)
  - Unstable looking rocks (talk 3)
  - Innovative monitoring AI (talk 4)

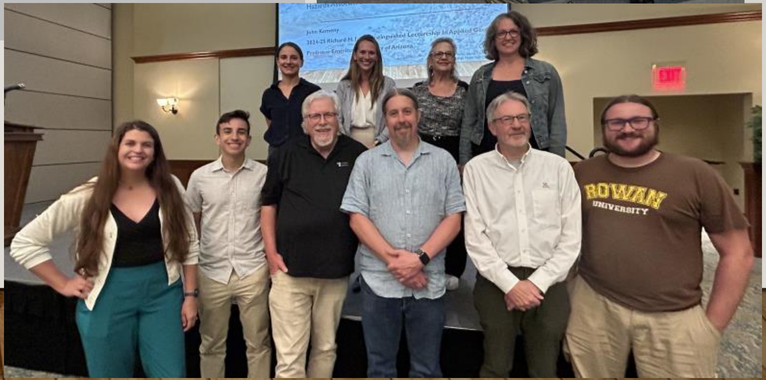
Talk 1	2
Talk 2	14
Talk 3	12
Talk 4	18
Talk 5	2

Schools Visited

CSM Geological Engineering
University Nevada Las Vegas (UNLV)
University Nevada Reno (UNR)
Western Washington University (WWU)
Portland State University
Missouri S&T
University Missouri Columbia
Univ. Missouri Kansas City (UMKC)
Florida State University
University of Florida
University of South Florida
Florida Atlantic University
Florida International University
UNC - Charlotte
Wake Tech
East Carolina University
NC State
UNC- Chapel Hill
UC Davis
UC Berkeley
California State University, Fresno
Illinois State University
University of IL Urbana
Northern IL University
Wheaton College
Purdue University
Lafayette College
Stockton University
Rowan University
Univ IL Chicago
University of Kansas

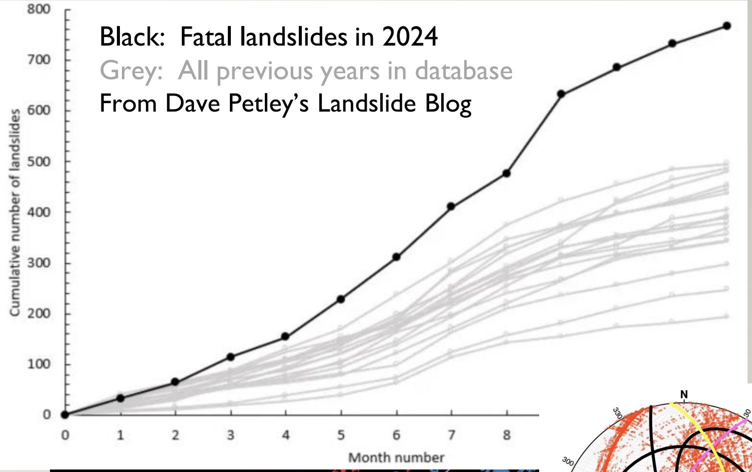
AEG Chapters Visited

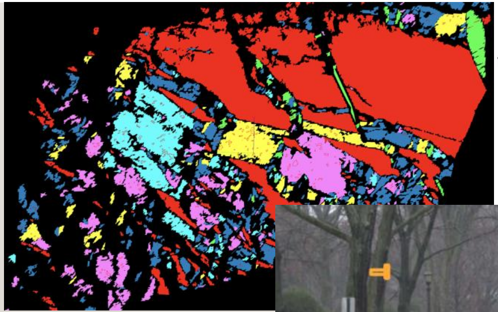
Denver AEG
Las Vegas AEG
Great Basin AEG
Nasqually AEG
Shannon & Wilson
Puget Sound AEG
Oregon AEG
St Louis AEG
Kansas City/Omaha AEG
NC AEG Chapter
Sacramento AEG
SF AEG
San Joaquin Valley AEG
Nashville AEG
AEG Chicago Chapter

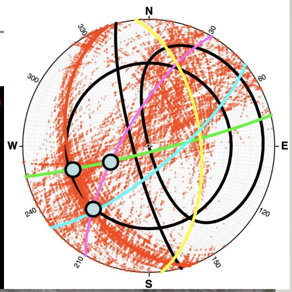


Theme of all Five Talks: Applied Geology More Important Than Ever

- Applied Geology needed to combat increased natural hazards due to Global Warming and Climate Change
- Fires, draught, flooding, tornadoes, debris flows, landslides, sinkholes, rockfall, <u>all on the rise</u>
- **Topics for Today:**
- The Geospatial Explosion
- “Everyday” and “Democratized” geospatial
- Everyday workflow rock engineering
- Predicting rock instability using EdgeAI





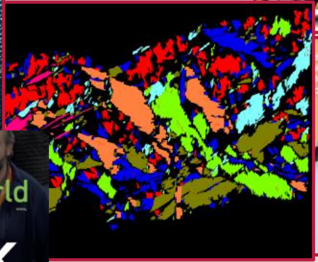


The Explosion of Geospatial Technologies for Rock Engineering

- New geospatial technologies include hand-held and drone lidar and photogrammetry, Earth Observation (EO), multi-sensor (thermal, radar, spectral), pt. cloud processing software, 3D GIS
- Overall new monitoring and geospatial technologies **transforming field of applied geology.**
- Example: GeoWeek Geospacial Conference, 200 exhibitors, 3000 attendees, 50 countries
- **Excellent entrepreneurship opportunities**





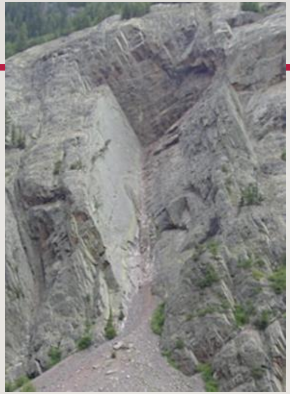
The Need for "Everyday" and "Democratized" Geospatial

- Geospatial technologies are limited by spatial/temporal resolution, cost, personnel for learn/use/analyze/maintain
- **Everyday Geospatial:** the subset of technologies that are Easy, Affordable, Automatable, Accurate Enough
- Smartphones, inexpensive drones, edgeAI sensors, publicly available satellite (EO), open-source software
- Users include students, schools, hobbyists, companies
- **Democratized Geospatial**: bringing advanced geospatial to under-resourced communities. Combine w/ crowdsourcing, DIY kits, geo education

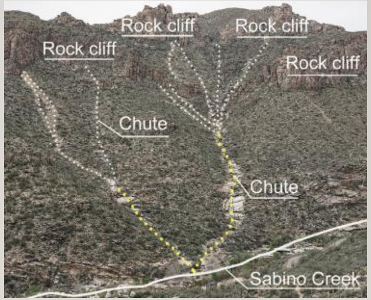
Humanitarian OpenStreetMap Team (HOT) for Nepal road data

Focus on Geospatial in Rock Engineering

- Rock Slope Stability
- Underground Stability
- Rockfall occurrences
- Stability of foundations for dams, bridges, and buildings (including scour and dam overtopping)
- Rock stability triggering landslides and debris flows






Example of Traditional Slope Stability - Plane Failure

- Highway slope in Tennessee
- Road closed when rockfall started to occur, video camera set up
- Note daylighting fractures at steep angle
- Also recent rainfall

Example of Plane Failure in Tennessee

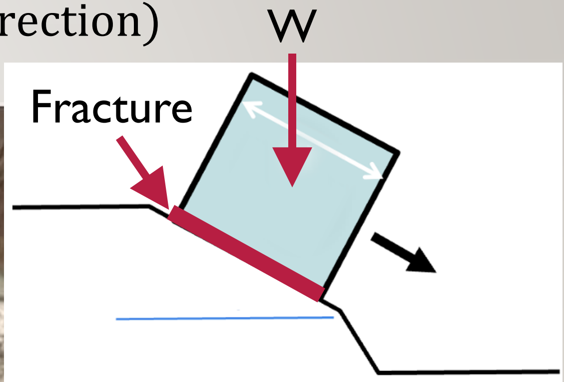
Example of Plane Failure in Tennessee

Example of Plane Failure in Tennessee

Factor of Safety (FS) for Plane Slope Failure

$$FS = \frac{\text{Strength (fracture cohesion + friction)}}{\text{Stress (block weight resolved into shear direction)}}$$

- Failure when FS ≤ 1
- Assume properties (dry)
  - FS = 1.31 => Stable
- Add pore pressure
  - $FS = \frac{C_0 + \left(\frac{W}{A}\cos\theta - p\right)\tan\phi_j}{\frac{W}{A}\sin\theta}$
  - FS reduces to 1.0 => Unstable



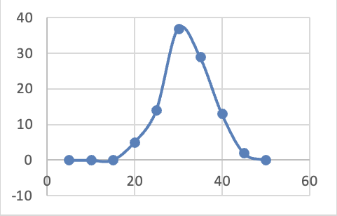
$$FS = \frac{C_0 + \frac{W}{A}\cos\theta\,\tan\phi}{\frac{W}{A}\sin\theta}$$

Probability of Failure (POF) for Plane Failure

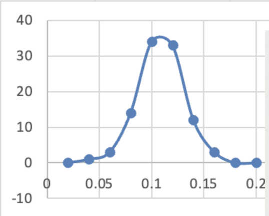
- Assume variation in properties
- Variations in ϕ, Co, θ
- POF = % that fail
- POF = 13% (no water), 30% with
- With modern geospatial, lots of data for POF

		Mean	SD
W	block weight (MN)	25	
A	joint surface area (m^2)	100	
theta	joint dip	40	5
Co	joint cohesion (MPa)	0.1	0.02
phij	joint friction angle	30	5
alpha	sesimic coeficient	0	
b	total bolt force (MN)		
p	water pressure (MPa)	0	
FS	FS from Mean values	1.3103488	
POF	Probability of Failure	13	

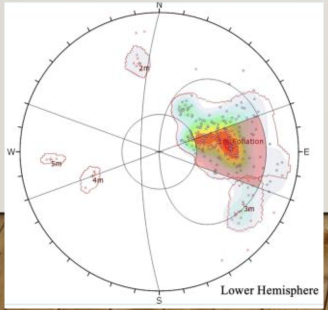
Joint Dip	Cohesion	Friction angle	Factor Safety	
θ	Co	ϕ	FS	1 for failure
39.104335	0.1074701	25.96554423	1.280701524	0
38.541333	0.0824438	38.8403428	1.540020114	0
42.87804	0.0591615	22.63993168	0.796957936	1
49.734357	0.1236047	29.1460789	1.120289898	0
43.103108	0.0881205	27.90885215	1.081799221	0
37.592817	0.0921003	28.6623935	1.313890305	0
42.818234	0.1285515	37.06867076	1.571822108	0
34.98459	0.0570623	27.65626402	1.146926115	0
44.507544	0.0909023	35.57578345	1.246391929	0
38.392545	0.1403837	31.93447676	1.690770221	0
39.412583	0.1199349	19.32105964	1.182260197	0
38.604145	0.078015	27.74356708	1.158936175	0
38.049445	0.093419	39.58983242	1.662877625	0
34.107261	0.1069486	30.49422362	1.632482675	0



Joint Friction Angle (ϕj)

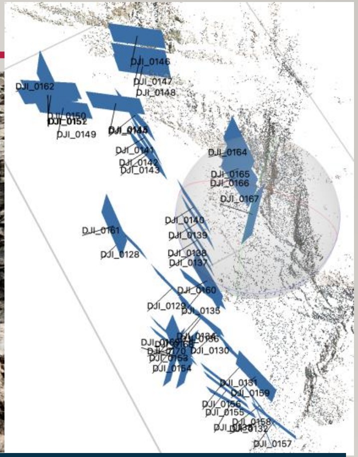


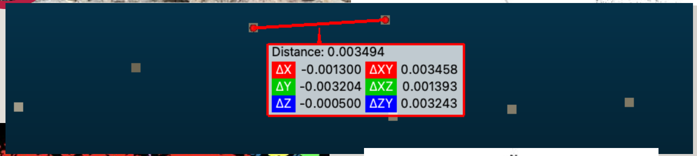
Joint Cohesion (Co

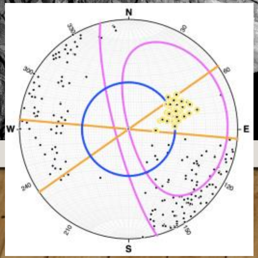


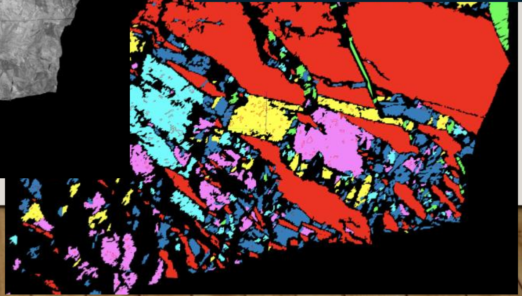
Everyday Geospatial Tools for Rock Engineering

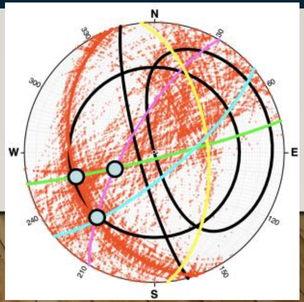
- **Field imaging**
  - iPhone Lidar
  - Smartphone Photogrammetry
  - Drone Lidar and Photogrammetry
- **Point cloud generation**
  - Smartphone and laptop apps
- **Point cloud processing**
  - CloudCompare and other apps
- **Stability Analysis**
  - Stereonet 11 and other apps





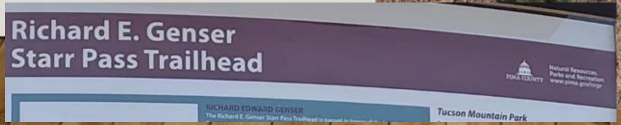






Everyday Field Imaging Example 1 (fun and fast): iPhone Lidar

- Example: Site 1 along Starr Pass Trailhead
- iPhone lidar works great for imaging a small slope or the lower portion of a large slope
- Need to be able to get close up (safely), iPhone lidar range 5 meters or less
- iPhone apps such as Scaniverse produce registered high-resolution point clouds (for free!)
- Portable: only notepad and iPhone needed

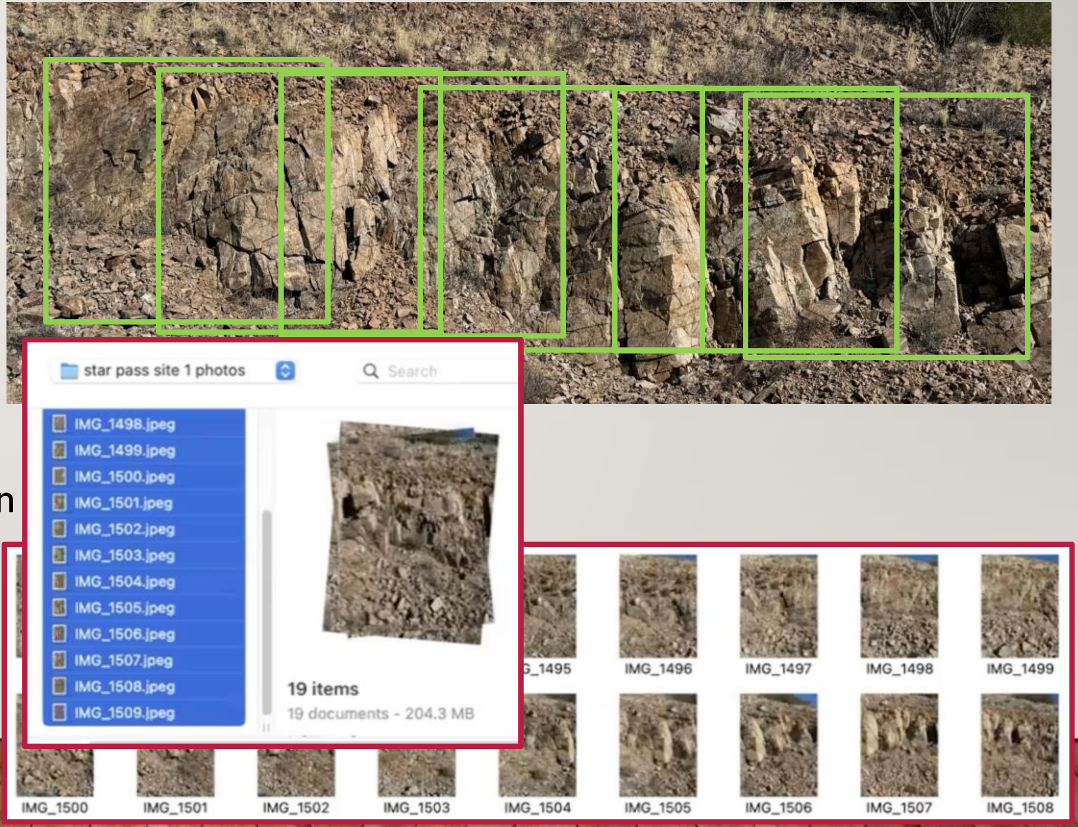


iPhone Lidar Imaging of Star Pass Site 1

- Example: small outcrop Starr Pass Trailhead
- First Steps: Step back, evaluate, then take some manual information to check registration and joint set orientations (use iPhone compass to find North), also key fracture features
- Next Step: Scaniverse scanning, get within 5 meters, scan over all fractures in outcrop
- Export a fully registered point cloud (.las)
- **Accuracy**: point cloud geometry accurate, cloud registration as good as iPhone gps

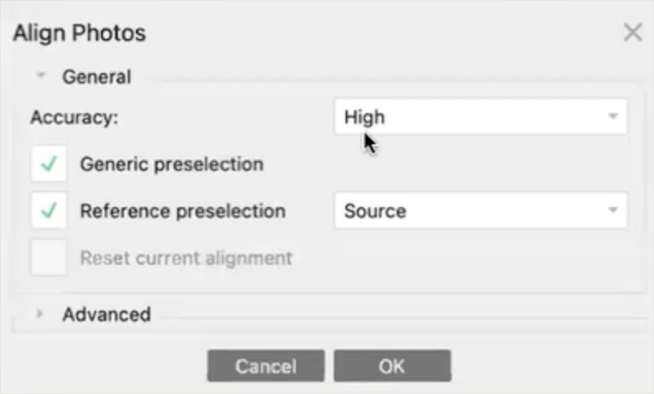
Field Imaging Example 2 (useful & accurate): Smartphone Photos

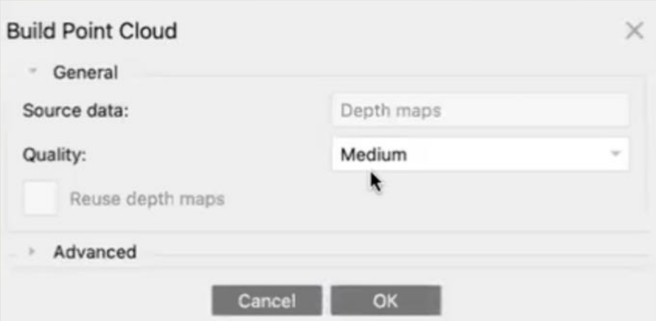
- Works great for small and large slopes
- Take photos with 50-60% overlap
- Distance away 1-2 times height of imaging
- Some apps will take the photos & produce fully registered high resolution point cloud (scaniverse, pix4Dcatch)
- Alternative is to export iphone photos to an app for processing, make sure photos have embedded gps in this case
- Shown here is Metashape Pro (19 photos)

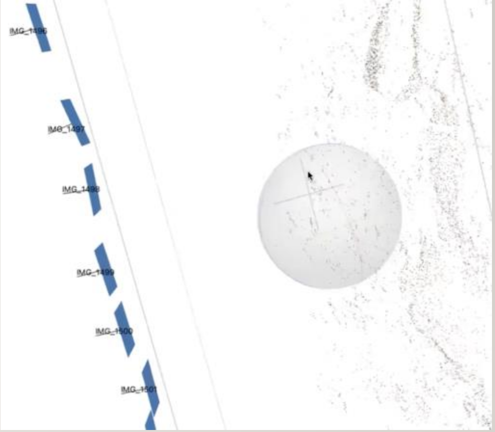


Smartphone Imaging of Star Pass Site 1

- Metashape Pro workflow:
- Align photos (I use High)
- Build point cloud (I use Medium)
- Export fully registered cloud (.las)
- Note Metashape Pro not free (except 30 day trial)

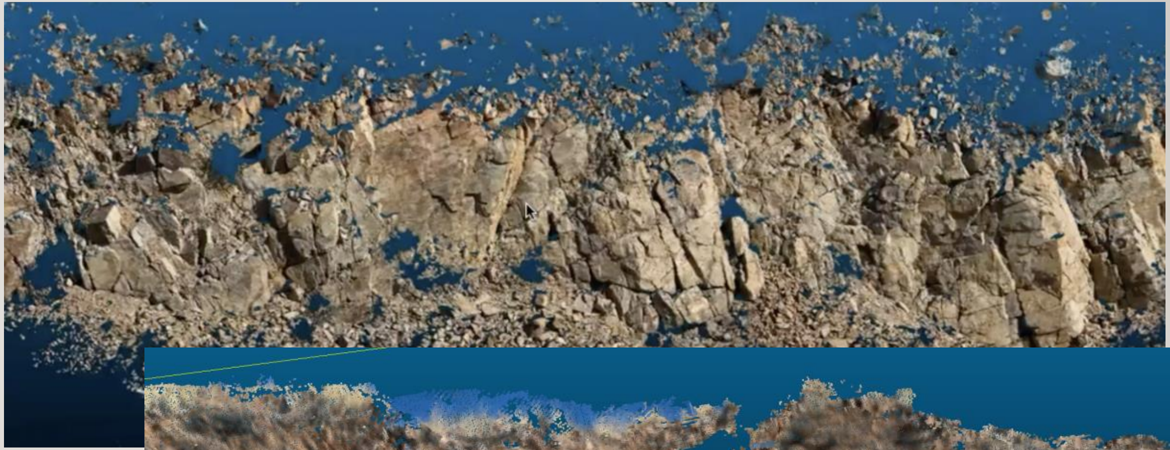


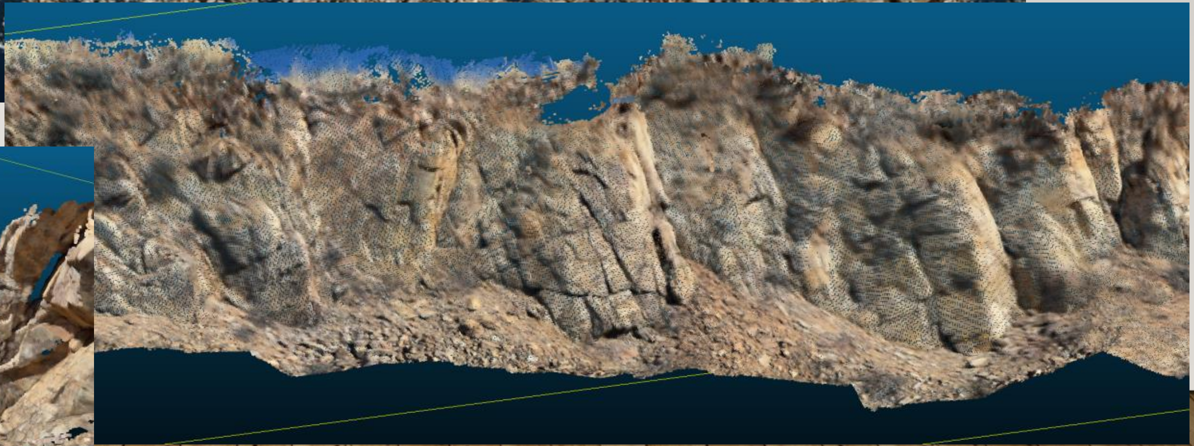


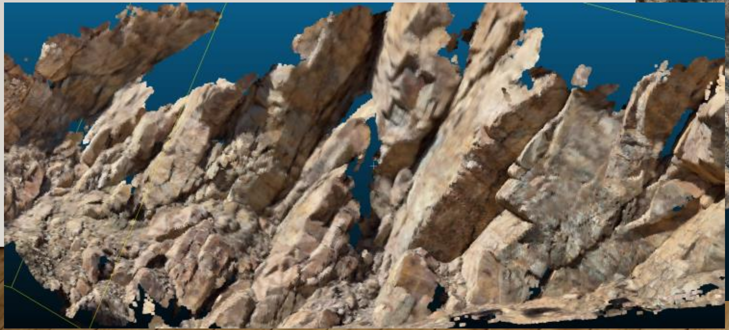


Compare iPhone Lidar vs Smartphone Photogrammetry

- iPhone photos produce better cloud in this case
- iPhone lidar shows some fuzziness, though other iPhone lidar uses are much clearer (example below from site 2)

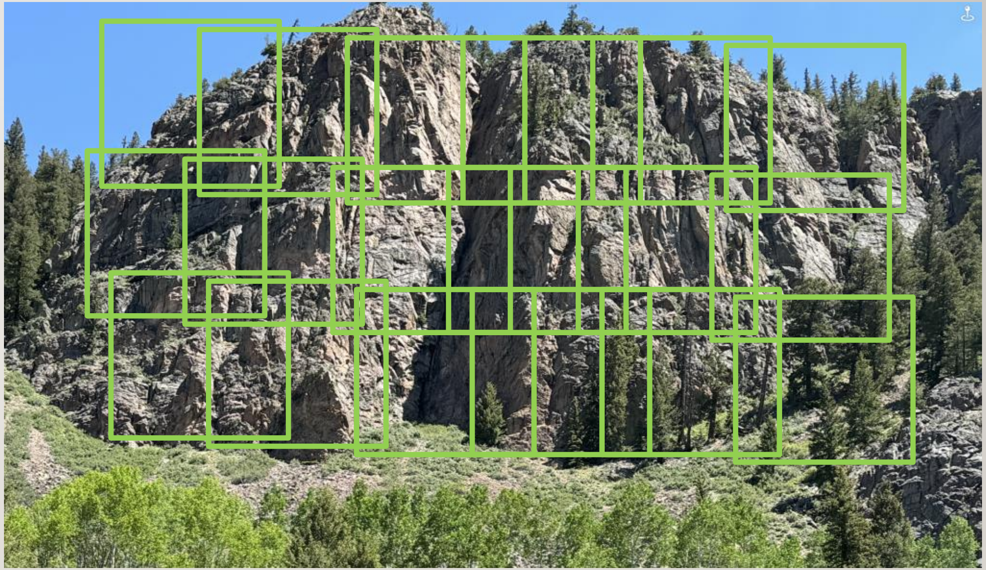






Field Imaging Example 3 (beautiful results): Drone Photos

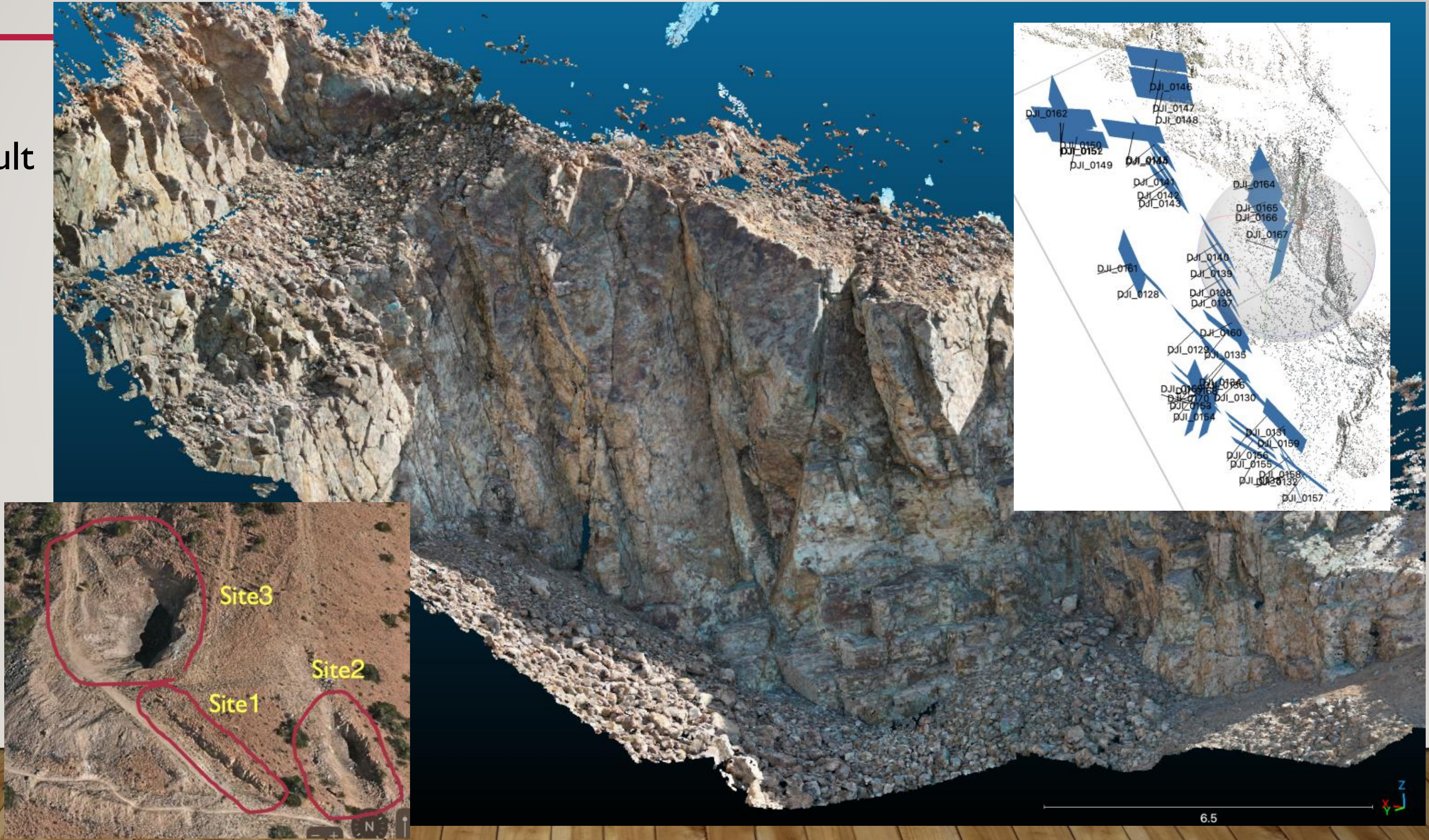
- Works great for large and very large slopes, sites with difficult access
- Many photos at different elevations, perpendicular to slope at each location
- Even low-cost drones have decent cameras (i.e., dji mini 3 pro <$800)
- Export drone photos to pix4D, metashape, dronedeploy, etc. Some options are low cost
- Very high-quality registered clouds in outcrops with only sparse vegetation



How do drone restrictions impact the use of drones for applied geo?

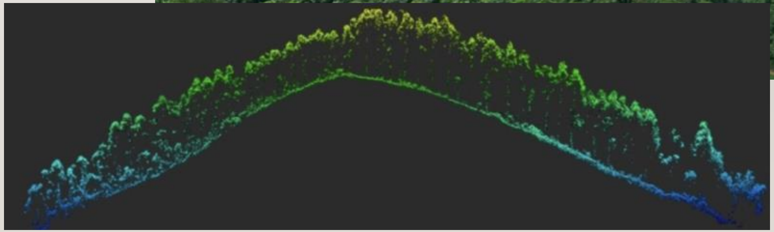
Smartphone Imaging of Star Pass Site 3

- Star Pass Site 3
- > 40 ft slope, difficult to access close up
- Photos from DJI Mini 3 Pro
- 42 photos taken perp. to slope
- Pt. Cloud from Metashape Pro
- Beautiful pt. cloud

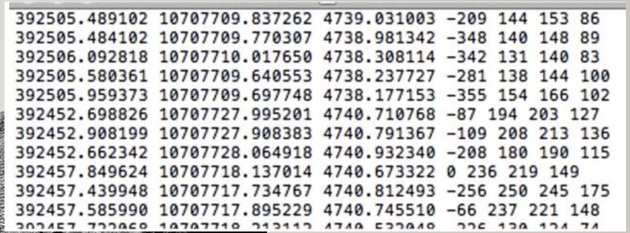


Field Imaging Example 4 (all-terrain but expensive): Drone Lidar

- Works for a wide range of slope conditions include highly vegetated
- Not really everyday: lidar unit expensive, needs more expensive drone for payload, replacement or repair expensive if drone lost or crashed
- Multiple lidar returns give tree tops & bare earth
- Shown here examples from DJI Matrice 350 drone (~$12k) + DJI Zenmuse L2 lidar (~$12k)
- A few of these (or similar) can form the basis for a geospatial startup (+ RTK & surveying skills)

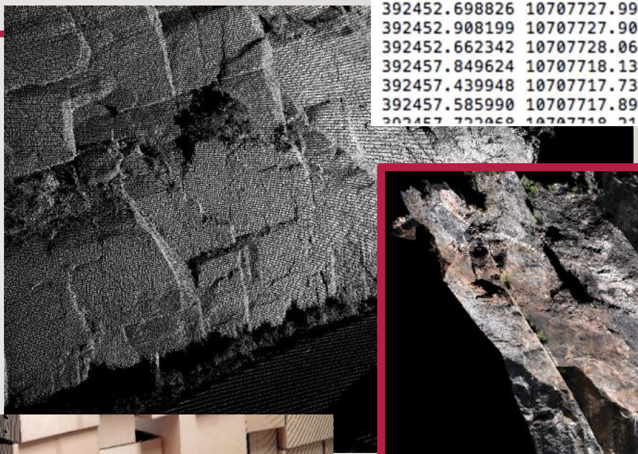


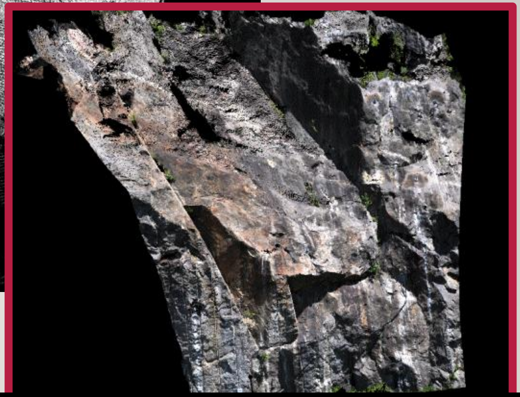
Next Step: Everyday Point Cloud Processing

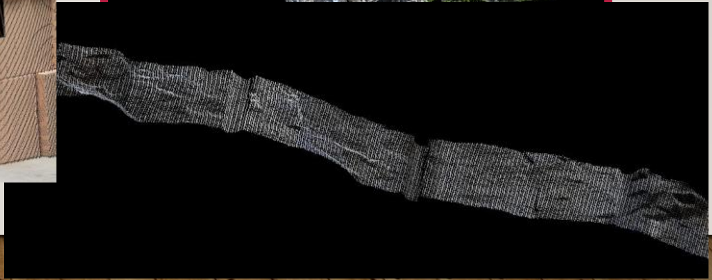


392505.489102 10707709.837262 4739.031003 -209 144 153 86
392505.484102 10707709.770307 4738.981342 -348 140 148 89
392506.092818 10707710.017650 4738.308114 -342 131 140 83
392505.580361 10707709.640553 4738.237727 -281 138 144 100
392505.959373 10707709.697748 4738.177153 -355 154 166 102
392452.698826 10707727.995201 4740.710768 -87 194 203 127
392452.908199 10707727.908383 4740.791367 -109 208 213 136
392452.662342 10707728.064918 4740.932340 -208 180 190 115
392457.849624 10707718.137014 4740.673322 0 236 219 149
392457.439948 10707717.734767 4740.812493 -256 250 245 175
392457.585990 10707717.895229 4740.745510 -66 237 221 148

- **What is a point cloud**: Millions of 3D xyz points that represent a topographic surface
- **Grayscale** point cloud (x,y,z + intensity), **Color** point cloud (xyz + rgb)
- Color point clouds have **sun shadows**, Lidar point clouds have **line of site shadows**
- Common **file types**: xyz, las, E57, ply
- Accuracy: **point spacing** < 2cm for geotech, flat wall scan to determine accuracy
- **Lidar vs Photogrammetry** (a long story)

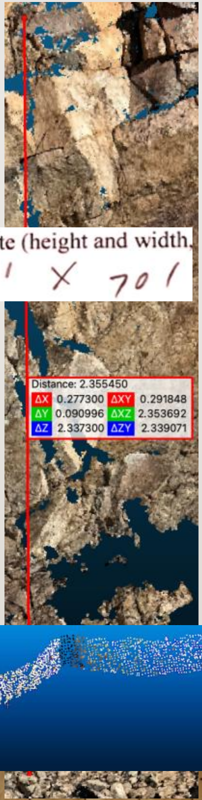


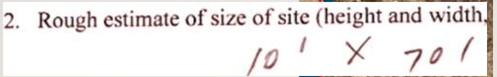


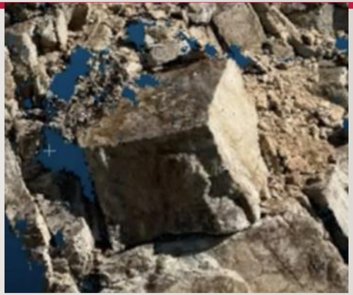


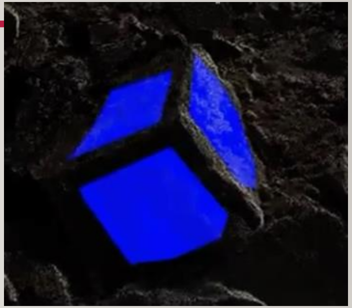
CloudCompare Point Cloud Processing Workflow Site 1

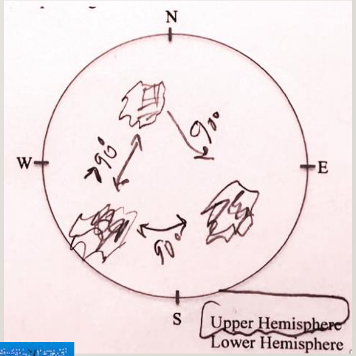
- **CloudCompare**: all purpose, open-source with plugins, free, windows and mac
- **1. Check registration, point spacing and accuracy**
- 2. Fracture characterization (orientation, size, sets, spacing, roughness, persisetence (rock bridges), etc.
- 3. Site characterization: height, width, slope dip and dip direction
- 4. Additional information

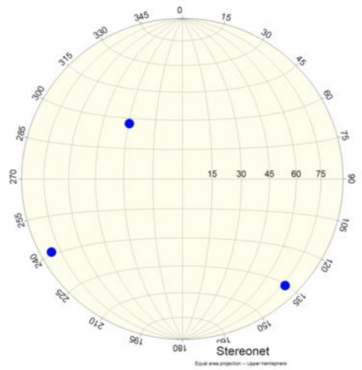


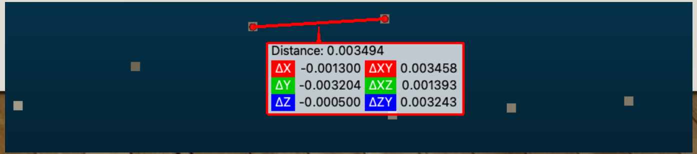






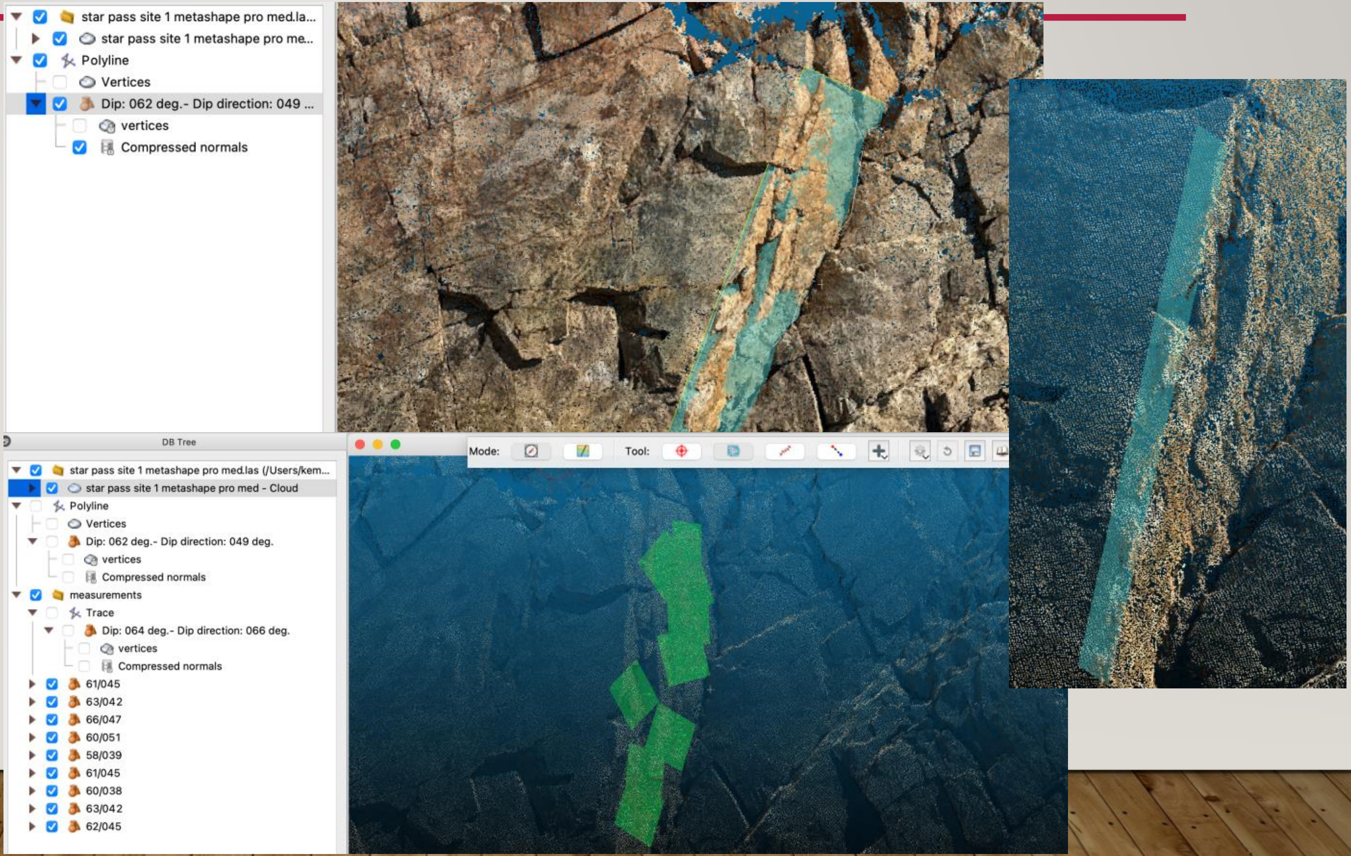






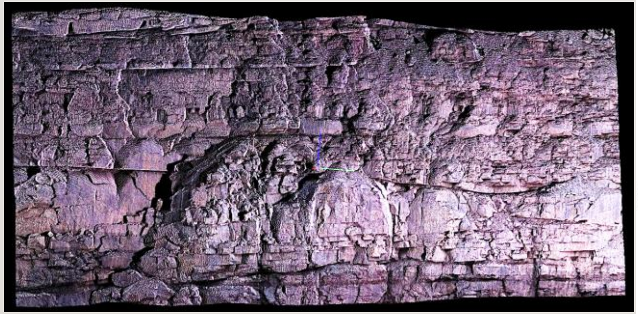
CloudCompare Point Cloud Processing Workflow Site 1

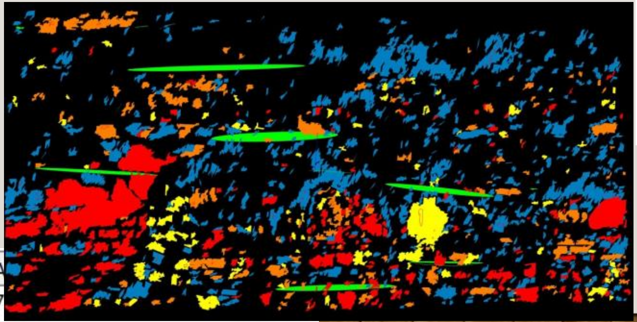
- **Four ways to get fracture orientation:**
  - **Outline fracture surface**
  - **Outline a fracture trace**
  - **Spot orientation data on a fracture** (compass plugin)
  - Auto fracture delineation
- Associated fracture info:
  - Roughness
  - Spacing

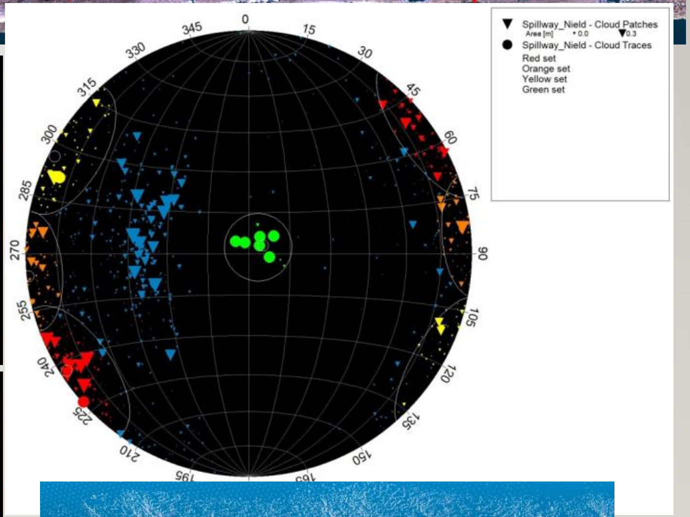


CloudCompare Point Cloud Processing Workflow Site 1

- **Four ways to get fracture orientation:**
  - Outline fracture surface
  - Outline a fracture trace
  - Spot data on a fracture
  - **Auto fracture delineation** (many many fractures, show size on plot, watch for errors & unwanted delineations, structure changes)



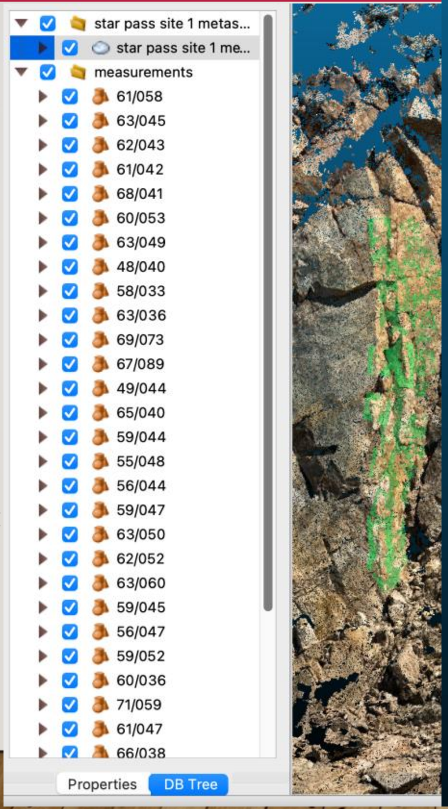


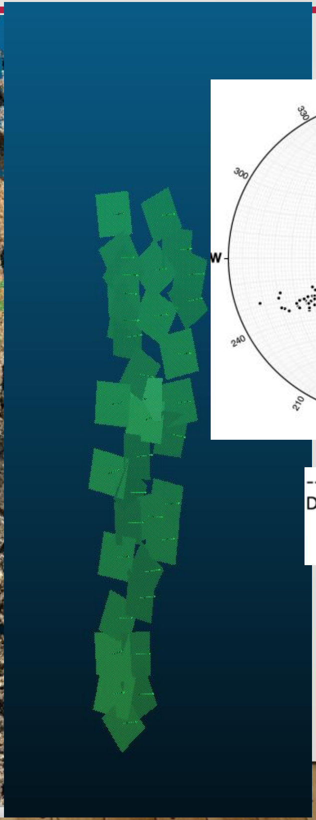


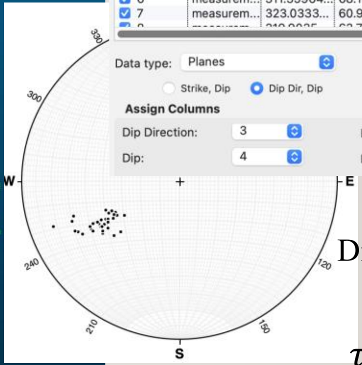
Set Name	Calculated	Orientation	Fisher K	A	
Green set	Yes	5.9, 239.7	117	7	
Yellow set	Yes	86.8, 116.5	41	12.71	0.99
Orange set	Yes	89.1, 84.1	59	10.55	0.97
Red set	Yes	86.6, 57.3	37	13.34	0.98

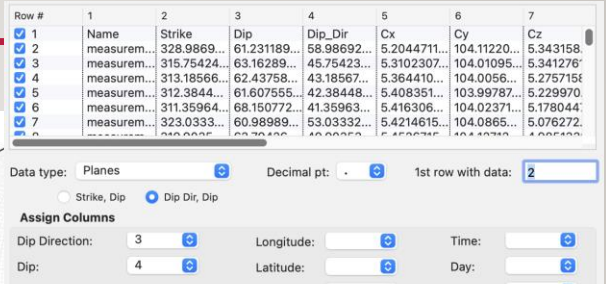
CloudCompare Point Cloud Processing Workflow Site 1

- Four ways to get fracture orientation:
  - Outline a fracture surface
  - Outline a fracture trace
  - Spot orientation on fracture
  - Facet plugin to auto delineate
- **Associated fracture info:**
  - **Roughness (dilation angle)**
  - Spacing









$$\tau = C_o + \sigma_n \tan(\phi_j + i)$$

----- Fisher Mean Vector | 12/11/24 at 1:50 PM-----
Data set: Poles to Imported Planes

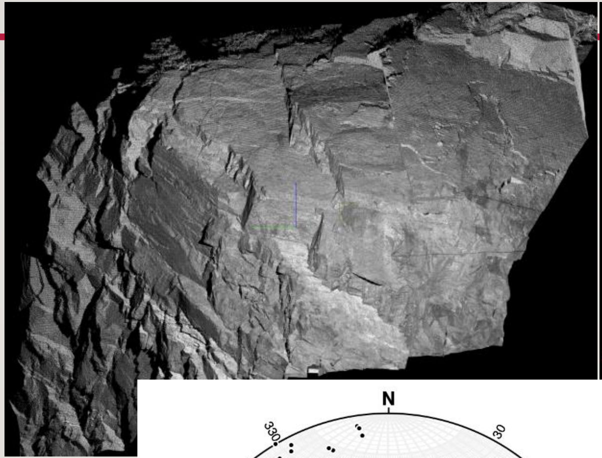
	N	Trend	Plunge	a95	a99	kappa	mean length
all	34	241.8	42.4	2.9	3.6	73.8	0.9868

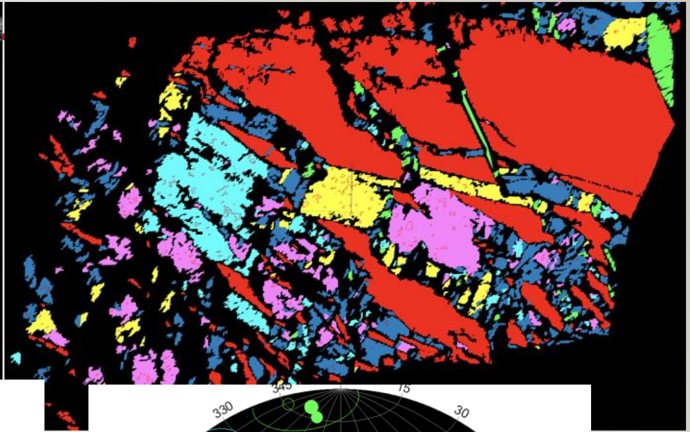
Average Dilation Angle

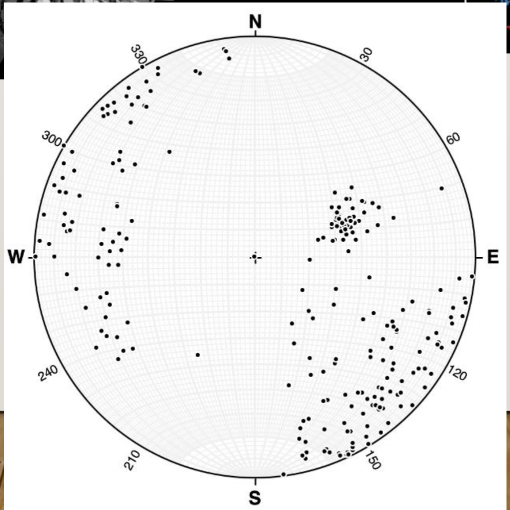
$$i_{50} = \frac{67.5}{\sqrt{k}} = \frac{67.7}{\sqrt{73.8}} = 7.9$$

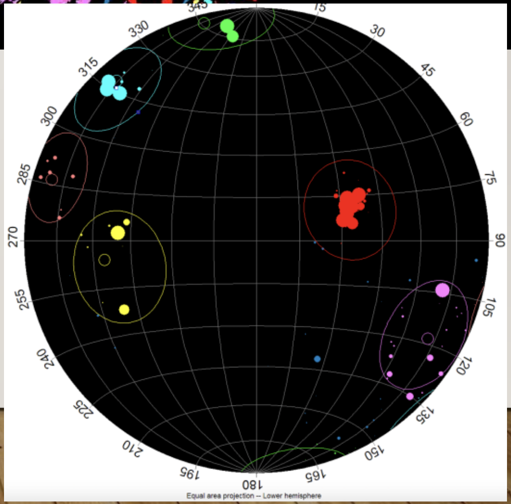
Modern Slope Stability (many many orientation measurements)

- Make sure automated fracture delineation accurate
- Example road cut along Million Dollar Highway CO
- Visualize delineated fractures on point cloud
- Show larger fractures with larger icon
- More Data => much better Probability of Failure calcs



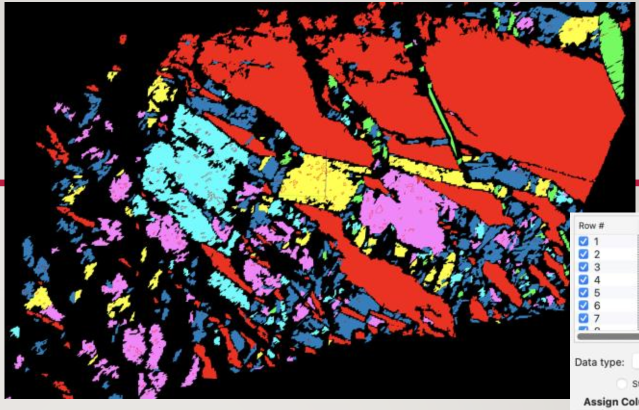


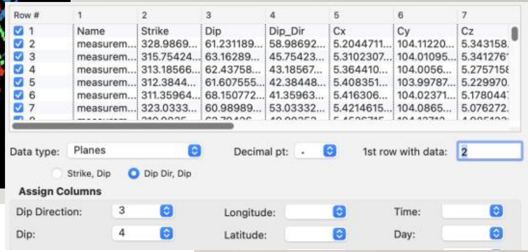




Plane Sliding

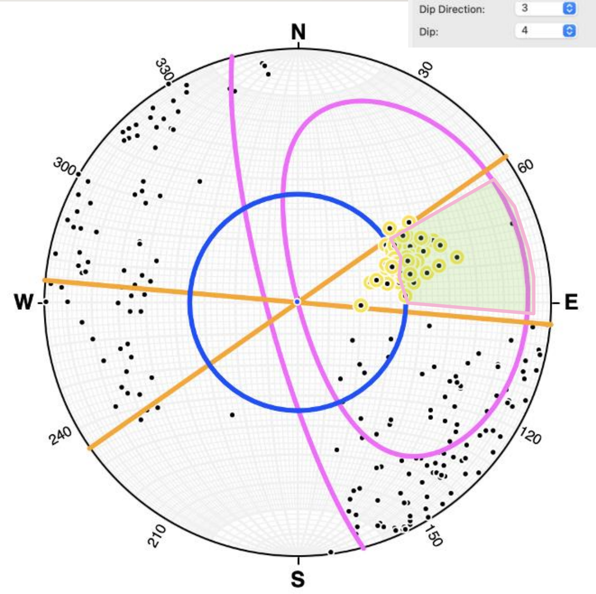
- Example analyze plane failure along Million Dollar Highway in Colorado
- Stereonet 11 by Dr. Almendinger (free)
- Import CloudCompare data, plot poles with plane sliding overlay (friction circle, daylighting envelope, dip direction limits)
- Zone outside friction, inside daylighting, within limits can slide (gravity only)
- POF of given set or all fractures



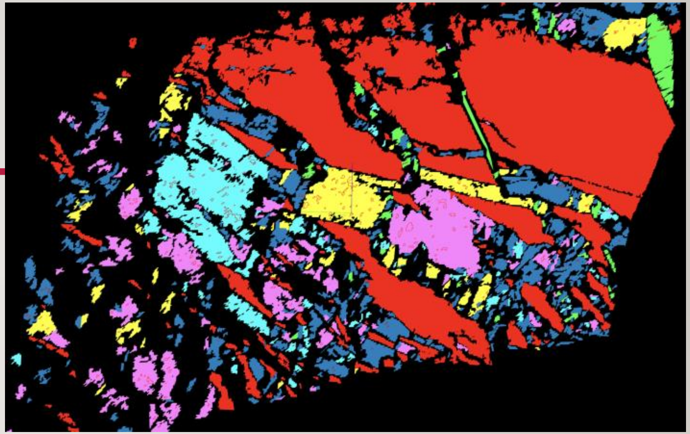


Row #	1	2	3	4	5	6	7
1	Name	Strike	Dip	Dip_Dir	Cx	Cy	Cz
2	measurem...	328.9869...	61.231189...	58.98692...	5.2044711...	104.11220...	5.343158.
3	measurem...	315.75424...	63.16289...	45.75423...	5.3102307...	104.01095...	5.341276
4	measurem...	313.18566...	62.43758...	43.18567...	5.364410...	104.0056...	5.275715
5	measurem...	312.3844...	61.607555...	42.38448...	5.408351...	103.99787...	5.229970.
6	measurem...	311.35964...	68.150772...	41.35963...	5.416306...	104.02371...	5.178044
7	measurem...	323.0333...	60.98989...	53.03332...	5.4214615...	104.0865...	5.076272.

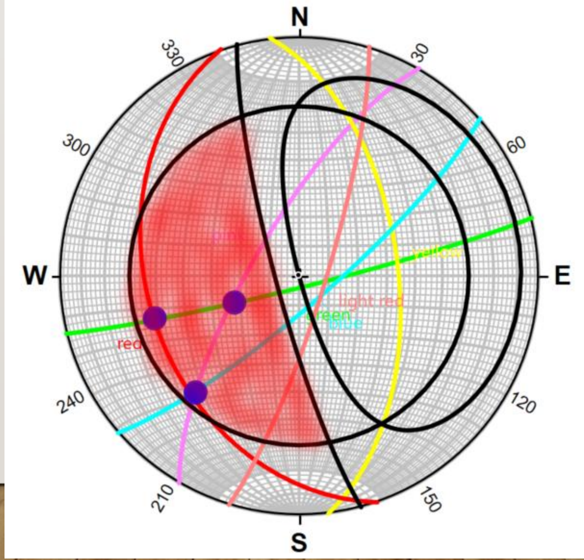
Data type: Planes
Decimal pt: .
1st row with data: 2
Strike, Dip
Dip Dir, Dip
Assign Columns
Dip Direction: 3
Longitude:
Time:
Dip: 4
Latitude:
Day:

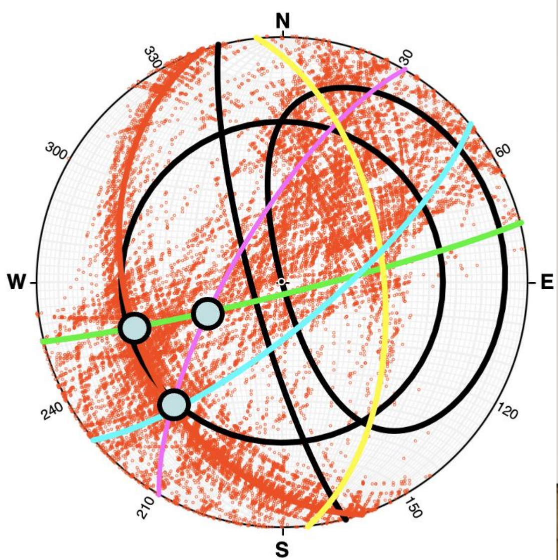


Wedge Sliding (many many intersections)



- Plot great circles for mean orientation of each set
- Any intersection inside friction circle, outside excavation surface can slide
- Plot every fracture intersection, lower hemisphere (28,920 inter.)
- Two intersection clusters associated w/ red set, plane sliding
- Only true wedge (pink/green) doesn't appear much in outcrop

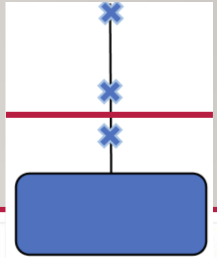


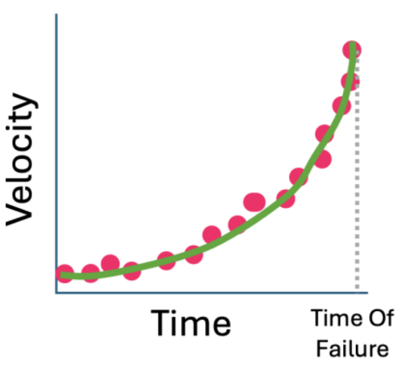


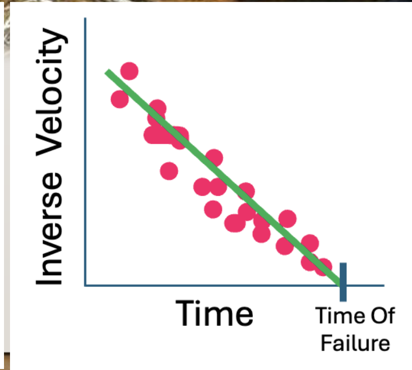
Monitoring and Predicting Natural Hazards

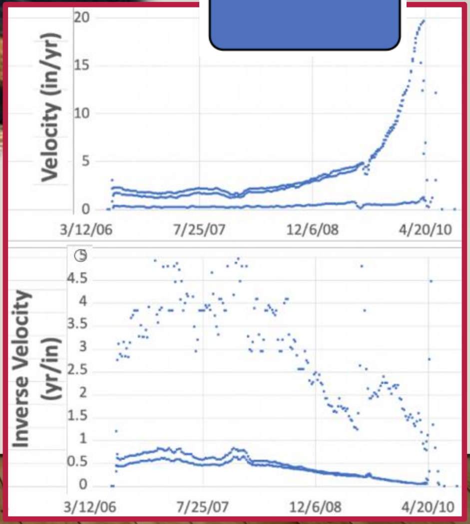
(In some cases we are very good)

- 2013 Kennecott failure predicted down to the day with help of slope radar & inverse velocity
- Underground example, linear trend in inverse velocity starts 7 months before failure
- Overall new monitoring and geospatial tech transforming ability to monitor/predict hazards









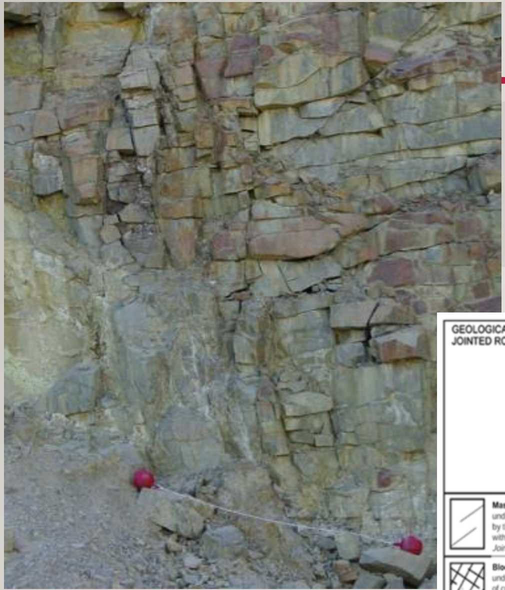
Monitoring and Predicting Natural Hazards
(But there are many difficulties where innovation needed)

- For "everyday" natural hazards, difficult to predict exactly when and exactly where they will occur
- Innovations needed (with the help of AI):
  - **Useful Sensing**: On-ground sensors are compact, easy install/maintain, long battery life, accurate enough
  - **On-Board Analysis**: from individual and sensor groups, report/predict/alarm, low power connectivity
  - **Monitor things other than deformation**: but still utilize the concept of inverse "rate of something"
  - **Periodic Complete Rock Mass Inventory**: Semi-continuous imaging/characterization drones, satellite

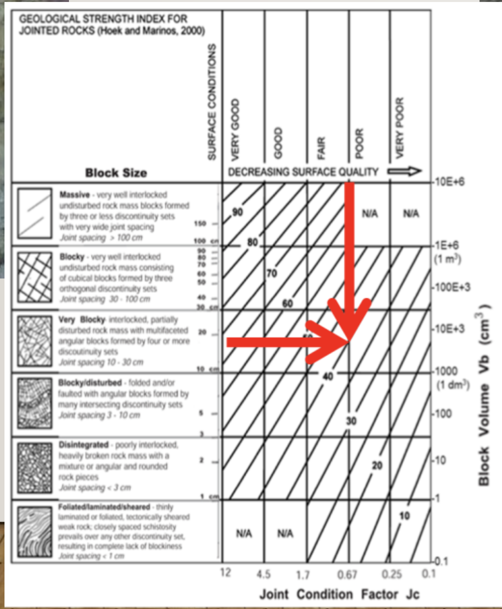
J. Pfeifer, Davidson College News
September 25, 2024

J. Gaffney, New York Times
Oct. 21, 2024

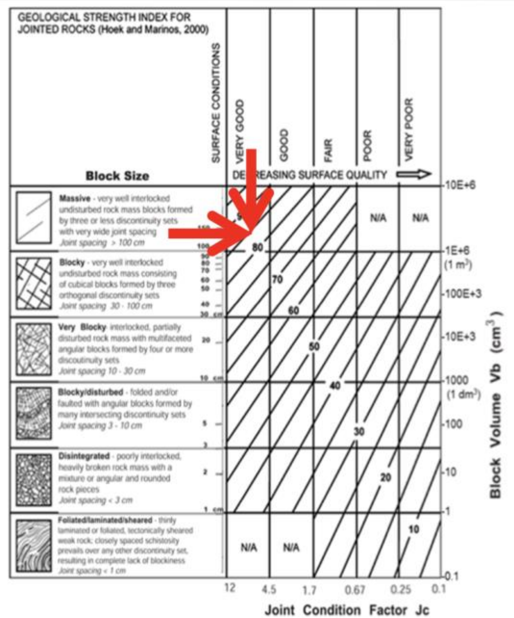
Example of Simple Rock Characterization: GSI



Geologic Strength Index (GSI)

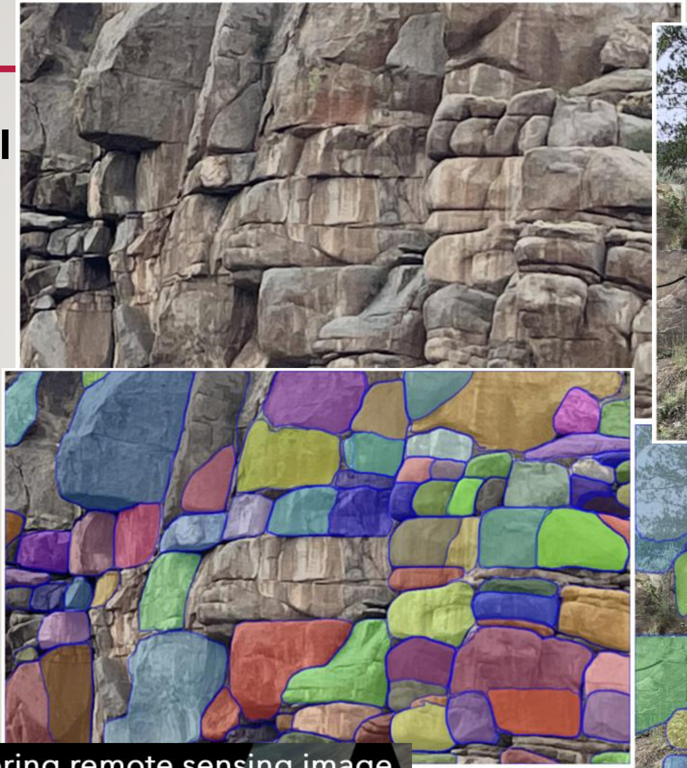


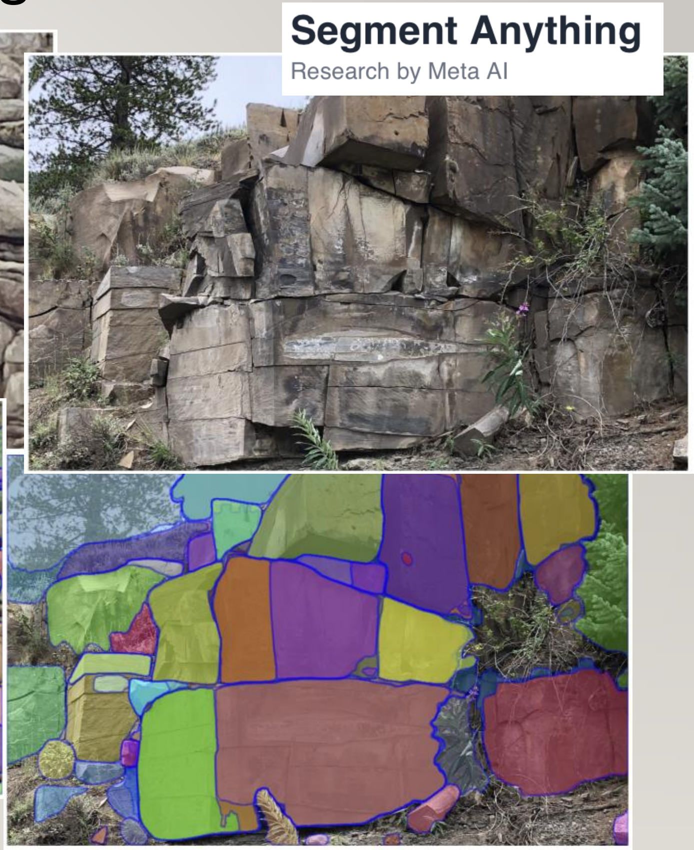
Limited usefulness when comparing sites



However, if 1) Automate using an AI Tool

- **Segmant Anything Model (SAM) from Meta AI**
- Distilled version called "NanoSAM" specifically optimized for real-time performance on the Orin Nano platform
- Additional training for rock fractures possible using transfer learning



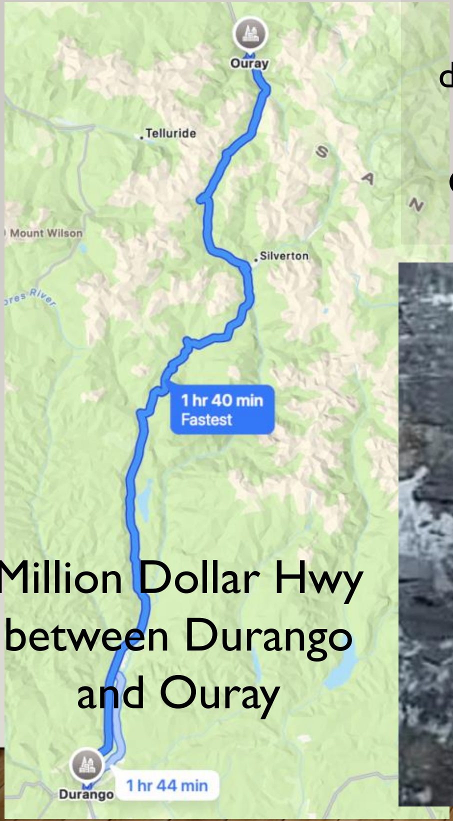


Mastering remote sensing image segmentation with AI: A hands-on workshop with the Segment Anything Model

AI for Good

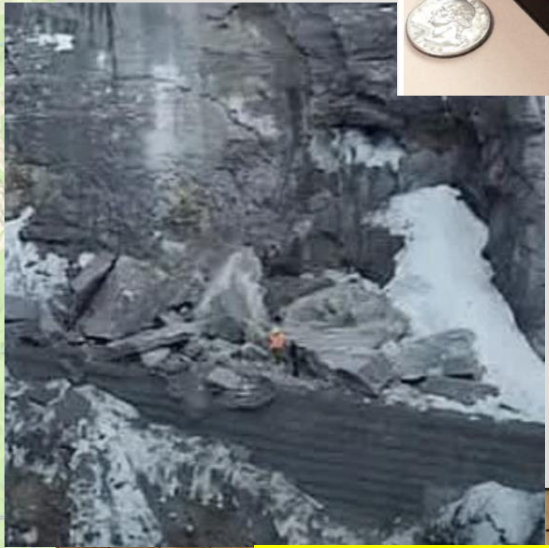
And 2) Continuous Characterization: A Future Monitoring Strategy (2D)

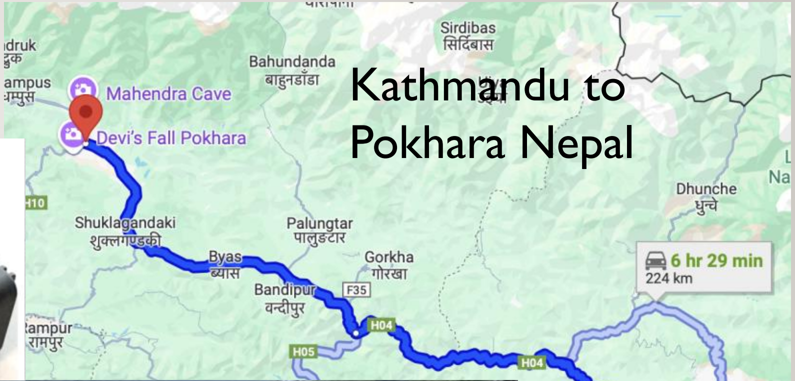
- Monitoring 1000s of Miles of Mountain Highways for GSI change



Million Dollar Hwy between Durango and Ouray

Possible drone & dashcam application for EdgeAI with Stereo Camera (Oak-D Lite)

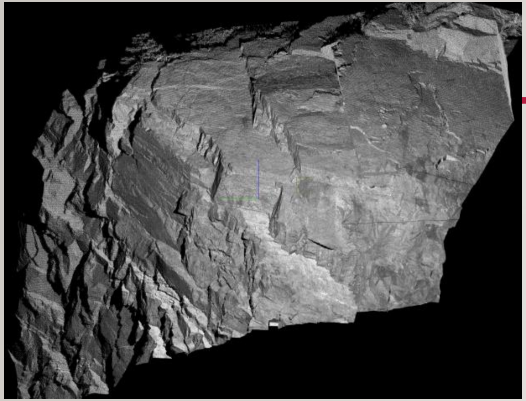




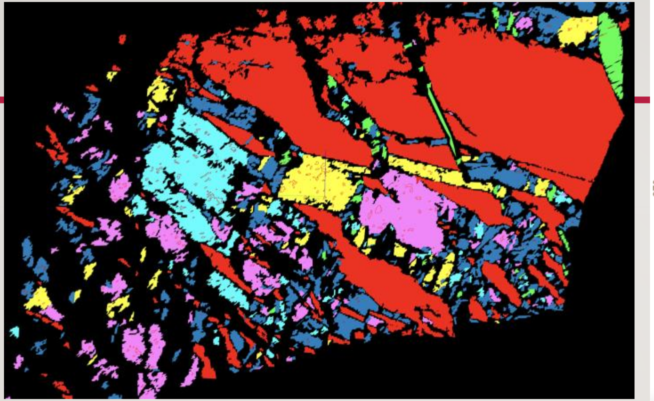
Kathmandu to Pokhara Nepal

Simple, Affordable, Automatable, Accurate Enough

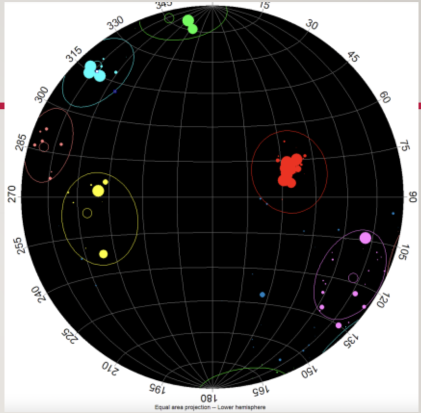
Continuous Slope Stability: A Future Monitoring Strategy (3D)



Registered Point Cloud

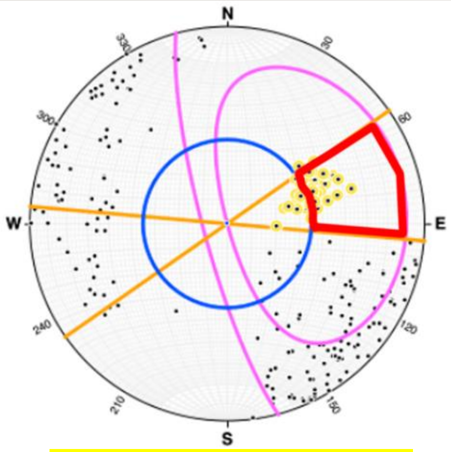


Automated Fracture Delineation

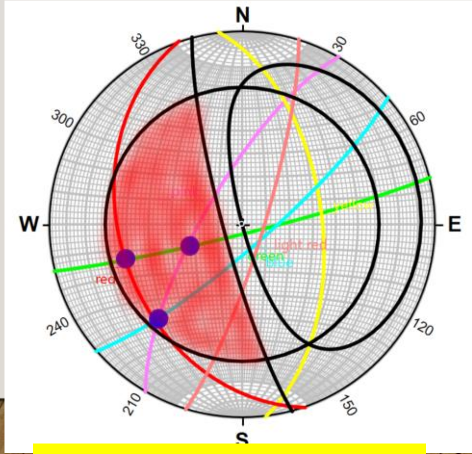


Pole Plot with Sets

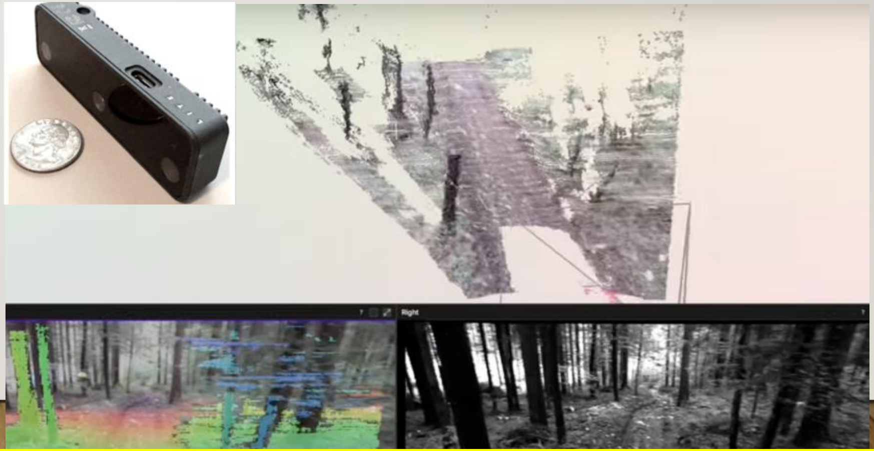
Repeat drone application: Look for failure modes, block rotation/sliding



Plane Failure Analysis



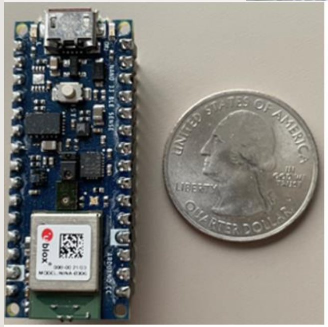
Wedge Failure Analysis



Example of Real Time Point Clouds from OakD Camera

The Potential for EdgeAI and TinyML in Applied Geology

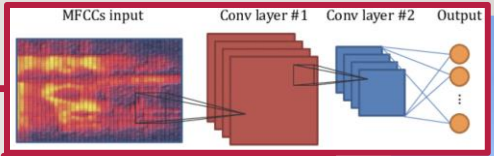
- **EdgeAI**: trained AI routines in edge devices such as Raspberry Pi. Fast, portable, compact
- **TinyML**: AI routines in the smallest micro-controllers. Low energy, compact, easy install
- <u>Edge-AI and TinyML can be transformational</u> and bring more on-ground sensors, low cost, low energy, timely warnings
- **EdgeAI/TinyML for** micro-climate, micro-soil moisture/pore pressure, micro-rock and soil characterization, movement, **predict** hazards

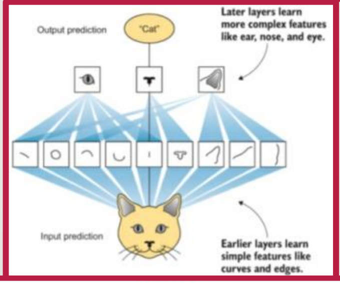


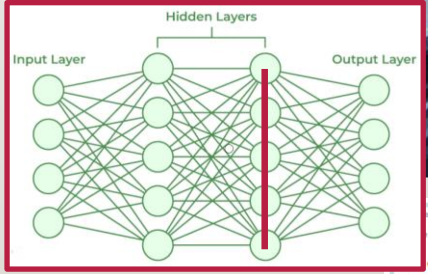
Microcontroller for TinyML. Orange sensors to monitor flooding

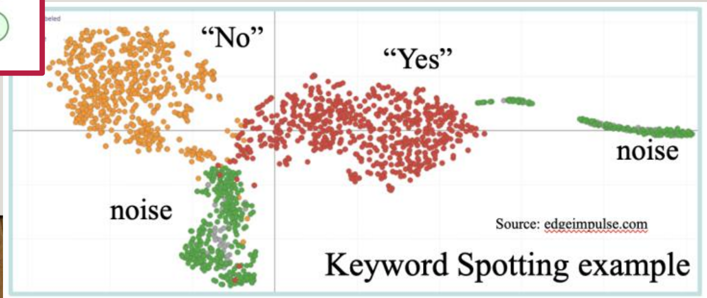
Monitoring Everyday Geologic Hazards with Sound (microphone)

- Microphone very low energy sensor, makes inexpensive sensor
- Embedding AI means data analyzed on board, low data transfer, privacy
- Example: model recognizes yes no
- Sound to image (spectrogram), CNN model to classify
- Embedded vector plot to assess accuracy



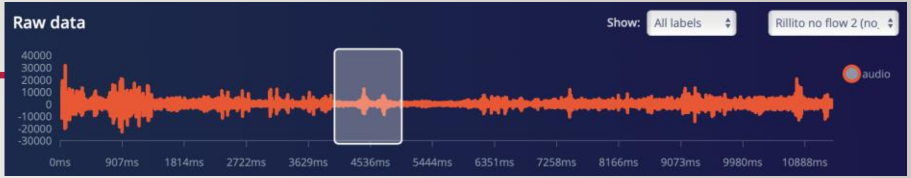




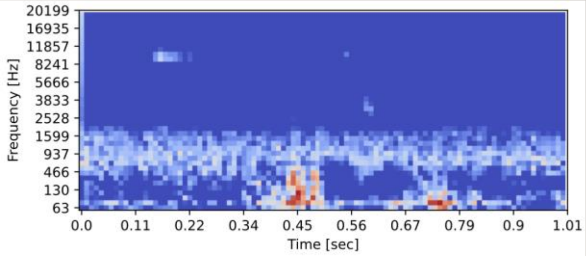


Monitoring Water Flow w/ Sound

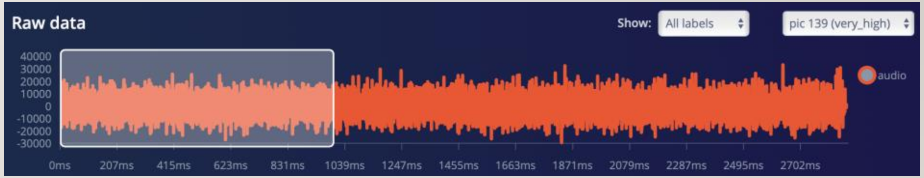
- **Location:** Campbell Bridge which crosses the Rillito River in Tucson, AZ
- **Initial Data**: Hundreds of labeled sound samples collected (iPhone) underneath the bridge along the south side bike path during rainfall events between Sept '22 & Jan '23
- **Approach**: label each sound file based on ground truth data from USGS flow sensors located two miles upstream. Classify flow into 4 or 5 levels

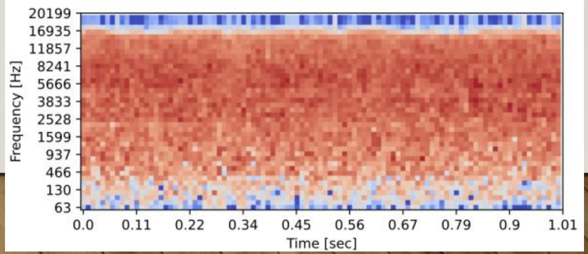


No Flow (mostly cars)



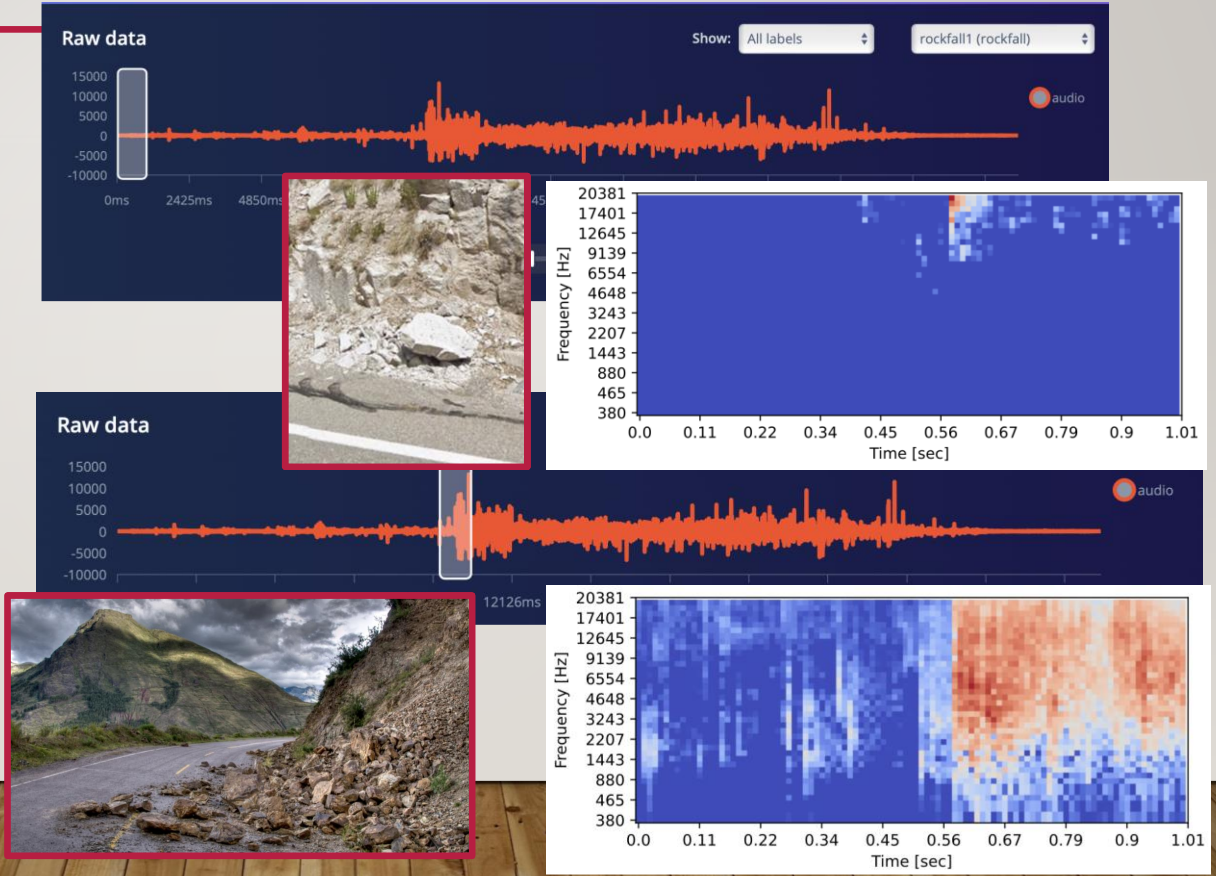
Very High Flow





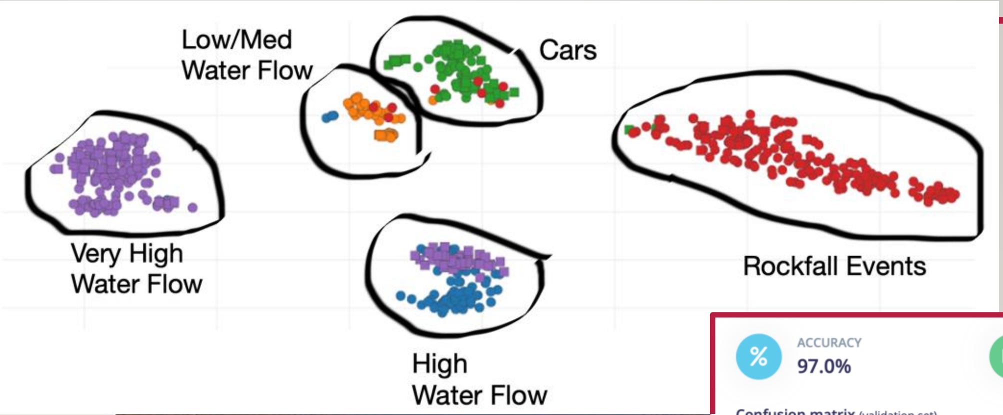
Monitoring Rockfall and Landslides w/ Sound

- Tested this idea with some rockfall sound clips from freesound.org
- Used the four-level flow model and added rockfall sounds
- Shown here are some waveforms and associated spectrograms (rocks high freq. compared with low freq. cars)
- Data split 77% training, 23% testing



Combining Water Flow, Cars, Rockfall and Landslides

- Training performed well, main error was rockfall (red) being labeled as no flow (green)
- **Can we use sound to predict "everyday" rockfall and landslides?**
- Linear trending inverse rockfall rate vs time to indicate possible large event



ACCURACY 97.0%

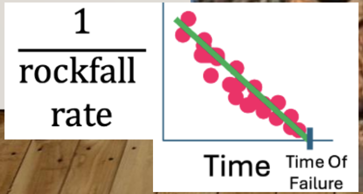
LOSS 0.07

Confusion matrix (validation set)

	HIGHFLOW	LOWMEDFLC	NOFLOW	ROCKFALL	VH
HIGHFLOW	92.3%	0%	0%	0%	7.7%
LOWMEDFLOW	0%	100%	0%	0%	0%
NOFLOW	0%	0%	100%	0%	0%
ROCKFALL	0%	4.3%	0%	95.7%	0%
VH	0%	0%	0%	0%	100%
F1 SCORE	0.96	0.80	1.00	0.98	0.98

Metrics (validation set)

METRIC	VALUE
Area under ROC Curve	1.00
Weighted average Precision	0.98
Weighted average Recall	0.97
Weighted average F1 score	0.97



Vision Language Models – VLM

- **Vision Language Models (VLM),** including LLaVA, Phi 3.5-Vision, Gemini 1.5 **compatible with Raspberry Pi & Jetson Orin Nano** (suitable for EdgeAI)
- Provide **text interpretation from a scene** in real time from ground sensors, drones, dashcams
- **GPT 5.0** a vision language model, not suitable EdgeAI
- Vision models can **monitor rockfall, aperture, GSI** and other indicators of slope degredation

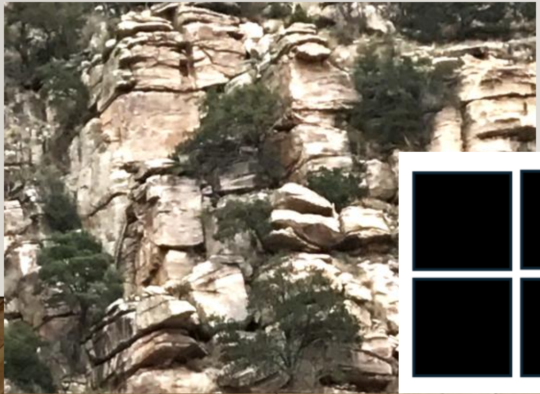
The image depicts a mountainous road with a section that has fallen rocks onto the roadway. The rocks vary in size, with some large boulders scattered across the road, making it potentially hazardous for vehicles. The road itself appears to be a two-lane road with no visible lane markings, and it curves to the left in the distance. The surrounding landscape is rocky and barren, with sparse vegetation. The sky is overcast, suggesting that the weather might be unpredictable. The size of the rocks on the road ranges from small pebbles to large boulders, with some of the larger rocks being several feet in diameter.

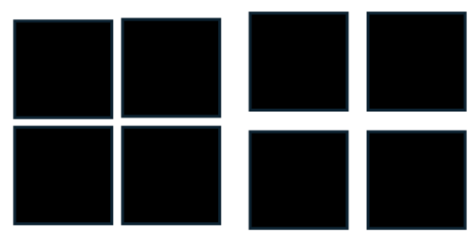
The **roadway lane width** gives us a natural scale reference — a single lane of asphalt road is typically **3.0–3.5 meters (10–12 feet)** wide.

The fallen rocks appear scattered across perhaps **half a lane width** in places, suggesting individual block sizes can be visually compared against that scale.

Many of the smaller fragments look to be in the **20–40 cm range** (basketball to large backpack size).
Some of the larger blocks toward the middle of the road appear closer to **0.5–0.7 m across** (roughly the size of a suitcase or small boulder).
I don't see blocks larger than ~1 m in diameter in this photo.

Top example from **Phi 3.5-Vision**, bottom is **GPT 5.0**



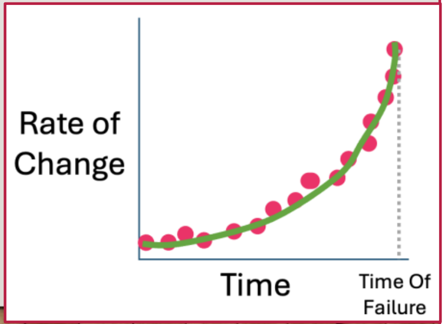


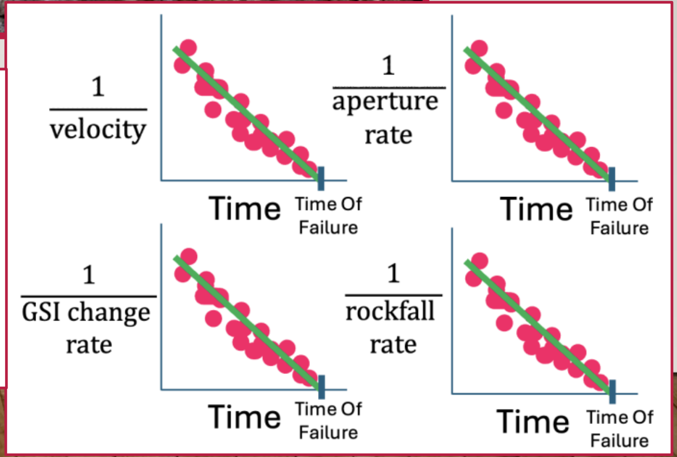
From Phi 3.5: "the right group of boxes has a larger aperture compared to the left group of boxes"

Summary of Using AI to Monitor and Predict Everyday Slope Failure

- **Innovation to monitor change** using sound, vision, EdgeAI, GenAI
- Traditional **point cloud change detection** is complex, requires aligned clouds, need accurately registered clouds + fine alignment
- Alternative is to monitor **slope degradation**, (aperture, rockfall, GSI)
- **Inverse "Rate of Change"** to point to the time of failure, only need two points

Photo from J. Pfeifer, North Carolina, Davidson College News Sept 25, 2024





Thanks

- Thanks to the AEG and GSA Foundations for supporting the Jahns Lectureship
- Thanks to the generous support of the AEG chapters and the universities and colleges involved
- Thanks to the working professionals and educators for inviting, organizing and hosting the Jahns lecturers
- Thanks to the audiences of working and retired professionals, students, faculty and others that attend the Jahns lectures

Thanks, and Please Contact Me for Additional Discussion

- John Kemeny
  kemeny@arizona.edu (email me!)
  (520) 326-7161 (text me!)

- www.rockswriter.com